The Semiconductor Data Book

One of the major problems facing workers in the electronics field is the identification and selection of semiconductor devices. Type numbers themselves are of little value since they indicate neither device parameters nor applications. Because it is difficult even to identify the many thousands of device type numbers, let alone evaluate their merits for a particular application, engineers often limit their designs to a few well-known device types — despite the fact that newer or more suitable devices may be available.

This book identifies and characterizes all semiconductor devices with 1N---, 2N---, and 3N--- numbers registered with the Electronics Industries Association at the close of the production date for the book, as well as a broad line of devices with special in-house type numbers. (It provides complete data-sheet specifications for a wide range of semiconductors, and short-form specifications for integrated circuits.) And in addition, to simplify the selection of the most useful semiconductor type numbers, it contains carefully prepared selector guides with recommended devices for specific applications. Properly used, it can be a valuable aid for the design engineer, the component engineer and the purchasing agent in narrowing the broad categories of potentially useable components to those best suited for a specific project.

The information in this book has been carefully checked and is believed to be reliable; however, no responsibility is assumed for inaccuracies. Furthermore, this information does not convey to the purchaser of semiconductor devices any license under the patent rights of any manufacturer.

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4th Edition, June 1969

DATA BOOK UPDATING SERVICE

Because of large numbers of new semiconductor devices introduced each year, provisions have been made to update the Semiconductor Data Book through the publication of Supplements. At least two supplements will be published during the year.

The Data Book Supplements will contain not only complete data sheets for newly added Motorola devices, but will list short-form specifications of all devices registered with the EIA since the publication of the Data Book or previous Supplement.

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CONTENTS

Page No.

Section 1 Introduction

How To Use This Data Book viii

Section 2 1N---Index

1N Numbers, Numerical Index and Short-Form Specifications 2
Varactor Diodes, Short-Form Specifications 92
Tunnel Diodes, Short-Form Specifications 98
4-Layer Diodes, Short-Form Specifications 102

Section 3 2N---Index

2N and 3N Numbers, Numerical Index and Short-Form Specifications 104
Thyristors, Short-Form Specifications 164
Field-Effect Transistors, Short-Form Specifications 176
Reference Amplifiers, Short-Form Specifications 182
Unijunction Transistors, Short-Form Specifications 184

Section 4 Alpha-Numerical Index and Product Identification 188

Section 5 Selector Guides

Glossary 198
Zener Diodes 202
  Regulator Diodes/Reference Diodes/Transient Suppressors/Current Regulators/Precision Reference/Reference Amplifiers
Silicon Rectifiers 210
Silicon Power Rectifier Assemblies 214
Thyristors and Triggers 216
  Silicon Controlled Rectifiers/Trigger Diodes/Triacs/4-Layer Diodes/Unijunction Transistors
Plastic Encapsulated Small-Signal Transistors 220
Silicon Power Transistors 226
Germanium Power Transistors 231
Silicon Small-Signal Hermetic Annular Transistors 234
Field-Effect Transistors 242
Micro-T Transistors and Diodes 246
Optoelectronics 248
RF Semiconductors and Power Varactors 250
EPICAP Tuning Diodes 256

Section 6 1N———JEDEC Registered Device Specifications

- Diodes/Reference, Zener, Signal
- Rectifiers/Fast Recovery/Assemblies
- Power Varactors/Tuning Diodes

Section 7 2N———and 3N———JEDEC Registered Device Specifications

- Transistors/Amplifier, Chopper, Light Sensitive, Multiple Device, Power, Switching, Unijunction
- Thyristors and Triggers

Section 8 House Numbered Device Specifications

- Diodes
- Power Varactors
- Rectifiers
- Rectifier Assemblies
- Thyristors and Triggers
- Transistors

Section 9 Hardware

Section 10 Integrated Circuits

- Digital
  - Selector Guide IC-6
  - MECL MC300/350 Series IC-9
  - MECL II MC1000/1200 Series IC-13
  - MECL III MC1600 Series IC-20
  - MHTL MC660 Series IC-23
  - MTTL MC5400/7400 Series IC-27
  - MTTL I MC400/500 Series IC-31
  - MTTL II MC2000/2100 Series IC-37
  - MTTL III MC3000 Series IC-40
  - MTTL MC4000 Series Complex Functions IC-45
  - MDTL MC830/930 Series IC-49
  - DTL MC200/250 Series IC-56
  - MRTL MC700/800/900 Series IC-59
  - mW MRTL MC708/808/908 Series IC-65
  - MOS MC1120 Series IC-69
  - Special Logic Products for Custom Applications IC-73
- Linear
  - Selector Guide IC-77
  - Operational Amplifiers IC-79
  - High-Frequency Amplifiers IC-87
  - Power Amplifiers IC-92
  - Differential Amplifiers IC-94
  - Sense Amplifiers IC-96
  - Stereo Preamplifiers IC-101
  - Chroma Demodulators IC-102
  - Voltage Regulators IC-103

Section 11 Dimensioned Device Outlines

Page No.

Section 12 Application Notes

Understanding Transistor Response Parameters AN-3
RF Small-Signal Design Using 2-Port Parameters AN-8
Selecting Commercial Power Transistor Heat Sinks AN-16
Mounting Procedure For, And Thermal Aspects of, Thermopad Plastic Power Devices AN-22
A Method of Predicting Thermal Stability AN-25
Avoiding Second Breakdown AN-30
Thermal Response of Semiconductors AN-37
Field-Effect Transistors in Theory and Practice AN-47
Field-Effect Transistors in Chopper and Analog Switching Circuits AN-58
FET Current Regulators – Circuits and Diodes AN-65
Selecting Varactor Diodes AN-75
High-Power Varactor Diodes: Theory and Application AN-80
EPICAP VVC Tuning of Resonant Circuits AN-87
SCR Power Control Fundamentals AN-91
Characterization of SCR's as Switches for Line Type Modulators AN-96
Theory and Characteristics of the Unijunction Transistor AN-103
Unijunction Transistor Timers and Oscillators AN-113
Theory and Characteristics of Phototransistors AN-124

HOW TO USE THE SEMICONDUCTOR DATA BOOK

This book is designed to serve three specific functions:

1. To permit quick identification of any semiconductor device bearing an EIA registered 1N, 2N, and 3N number, as well as special in-house numbers.
2. To permit quick selection of preferred devices for specific circuit applications.
3. To permit quick selection of preferred devices that best meet a desired set of electrical specifications.

The following examples illustrate how the book can be used to quickly solve these device identification and preselection problems.

EXAMPLE I

Known: EIA-registered type number or special house number.
Needed Information: Identification, short-form specifications.
Procedure: If the device type number begins with 1N, turn to the table on page 2 entitled

1N Type Numbers – Complete Index, and Short-Form Device Specifications

This table lists all 1N type numbers in numerical sequence and provides short-form specifications for these devices.

If the device type number begins with 2N or 3N, turn to the table on page 1-100 entitled

2N and 3N Type Numbers – Complete Index and Bi-Polar Transistor
Short-Form Specifications

This table serves two functions. It lists all 2N and 3N type numbers in numerical sequence, and it provides short-form specifications for all bi-polar transistor types. Those 2N type numbers representing semiconductor devices other than bi-polar transistors (i.e. SCRs, FETs, etc.) are identified in blocks (i.e. 2N–through 2N–) and are referenced to a subsequent table where they are individually tabulated and characterized.

If the device type number is non-registered, turn to the index on page 188 which refers you to a page number in the book where complete data sheet specifications for the device are given.

EXAMPLE 2

Known: Desired Application or desired device parameters.
Needed Information: Specific type numbers of devices to fit known applications or device parameters.
Procedure: To find the recommended devices, refer to the Selector Guide Index (page 197) and consult the desired guide for device selection. Then turn to the specific data sheet (these are arranged in alpha-numerical sequence) for more detailed specifications.

NUMERICAL INDEX

NUMERICAL INDEX

1N--- TYPE NUMBERS — COMPLETE INDEX and SHORT-FORM DEVICE SPECIFICATIONS

The following table lists, in numberical sequence, all EIA-registered devices with 1N---- type numbers. This also provides major electrical specifications for rectifier diodes, signal diodes, zener diodes, and reference diodes. The "key" to proper interpretation of these specifications is given below.

Other types of devices with 1N----numbers, including varactor diodes, tunnel diodes, and 4-layer diodes, are identified in the table but, due to the differences in major specifications, they are "specified" separately in succeeding tables.

KEY

RECTIFIERS

V_R = DC Blocking Voltage
V_F = Average Forward Voltage Drop
I_O = Average Rectifier Forward Current
I_R = Average Reverse Current
I_{surge} = Peak Surge Current

ZENER DIODES

V_Z (min) = Minimum Zener Breakdown Voltage (Volts)
V_Z (max) = Maximum Zener Breakdown Voltage (used only when a corresponding **V_Z (min)** is specified. Otherwise, this column refers to **V_Z (nom)*** Nominal Zener Breakdown Voltage.)

Tol = Tolerance, for specified Nominal Breakdown Voltage

P_D = Maximum Power Dissipation. **M** = milliwatts. **W** = watts

TYPE	MATERIAL	REPLACE-MENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom)* V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μS)	TC %/°C	V_Z	T (min) °C	T (max) °C

Numerical Listing of Registered Type Numbers

S = Silicon
G = Germanium
SE = Selenium

Type number of recommended replacement or of nearest electrical equivalent fully characterized in this book.

Reference device number indicates specific Data Sheet on which device is characterized.

SHADING INDICATES SIGNAL DIODES

PRV = Peak Reverse Voltage
V_F @ I_F = Maximum Forward Voltage at Indicated Forward Current — M = milliamps, A = amps
I_R = Reverse Current — M = milliamps, * = microamps N = nanoamps
t_{rr} = Reverse Recovery Time

SHADING INDICATES REFERENCE DIODES

TC = Temperature Coefficient
V_Z = Zener Breakdown Voltage
T (min) } T (max) } Temperature Range over which indicated temperature coefficient is applicable.

The codes listed below define the listed device and indicates the appropriate specification column heading.

R* — Rectifiers
DR — Diode, Reference
DZ — Diode, Zener
DS — Diode, Signal

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z(min)	V_Z(nom) * V_Z(max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N34	G			DS	60	1.0	8.5M	15*					
1N34A	G			DS	60	1.0	5.0M	30*					
1N35	G			DS	50			2.0M					
1N38	G			DS	100	1.0	7.5M	25*					
1N38A	G			DS	100	1.0	4.0M	6.0*					
1N38B	G			DS	100	1.0	4.0M	6.0*					
1N39	G			DS	200	1.0	5.0M	40*					
1N39A	G			DS	200	1.0	5.0M	40*					
1N39B	G			DS	200	1.0	4.0M	650*					
1N40	G			DS	25								
1N41	G			DS	25								
1N42	G			DS	50								
1N43	G			DS	60	1.0	5.0M	20*					
1N44	G			DS	115	1.0	3.0M	410*					
1N45	G			DS	75	1.0	3.0M	410*					
1N46	G			DS	50	1.0	3.0M	1.5M					
1N47	G			DS		1.0	5.0M	400*					
1N48	G			DS	85	1.0	4.0M	833*					
1N49	G			DS	50	1.0	4.0M						
1N50	G			DS	50	1.0	4.0M						
1N51	G			DS	50	1.0	2.5M						
1N52	G			DS	85	1.0	4.0M	150*					
1N52A	G			DS	50	1.0	5.0M	100*					
1N53	S	Microwave Ka-band Mixer: f = 34,860 MHz; NF = 13.1 to 9.0 dB											
1N53A	S	Microwave Ka-band Mixer: f = 34,860 MHz; NF = 13.1 to 9.0 dB											
1N53B	S	Microwave Ka-band Mixer: f = 34,860 MHz; NF = 13.1 to 9.0 dB											
1N53C	S	Microwave Ka-band Mixer: f = 34,860 MHz; NF = 13.1 to 9.0 dB											
1N53D	S	Microwave Ka-band Mixer: f = 34,860 MHz; NF = 13.1 to 9.0 dB											
1N54	G			DS	35	1.0	5.0M	10*					
1N54A	G			DS	50	1.0	5.0M	7.0*					
1N55	G			DS	150	1.0	3.0M	0.3M					
1N55A	G			DS	150	1.0	4.0M	500*					
1N55B	G			DS	190	1.0	5.0M	500*					
1N56	G			DS	30	1.0	15M	300*					
1N56A	G			DS	40	1.0	15M	300*					
1N57	G			DS	80	1.0	3.6M	300*					
1N58	G			DS	100	1.0	5.0M	800*					
1N58A	G			DS	100	1.0	4.0M	600*					
1N59	G			DS	250	1.0	3.0M	800*					
1N60	G			DS	50	1.0	5.0M	40*					
1N60A	G			DS	40								
1N61	G			DS	130	1.0	5.0M	300*					
1N62	G			DS	110	1.0	5.0M	700*					
1N63	G			DS	125	1.0	4.0M	50*					
1N63A	G			DS	100	1.0	4.0M	50*					
1N64	G			DS	20								
1N65	G			DS	85	1.0	2.5M	200*					
1N66	G			DS	60	1.0	5.0M	50*					
1N66A	G			DS	60	1.0	5.0M	50*					
1N67	G			DS	80	1.0	4.0M	5.0*					
1N67A	G			DS	100	1.0	4.0M	5.0*					
1N68	G			DS	100	1.0	3.0M	625*					
1N68A	G			DS	130	1.0	3.0M	625*					
1N69	G			DS	75	1.0	5.0M	50*					
1N69A	G			DS	60	1.0	5.0M	30*					
1N70	G			DS	125	1.0	3.0M	25*					
1N70A	G			DS	100	1.0	3.0M	25*					
1N71	G			DS	40	1.0	15M	0.3M					
1N73	G			DS		1.7	15M	0.05M					
1N74	G			DS		1.8	15M	0.05M					
1N75	G			DS	125	1.0	2.5M	50*					
1N76	S	Microwave X-band Detector f = 9,375 MHz, V_O = 5.0 mV to 16 mV											
1N76A	S	Microwave X-band Detector f = 9,375 MHz, V_O = 5.0 mV to 16 mV											
1N77A		Photosensitive Device; V_F = 10 V @ 10 mA, $I_{R(dark)}$ = 30 μA @ 50 V											
1N77B		Photosensitive Device; V_F = 10 V @ 10 mA, $I_{R(dark)}$ = 30 μA @ 50 V											
1N78	S	Microwave Ku-band Mixer: f = 16,000 MHz; NF = 12 to 7.5 dB											
1N78A	S	Microwave Ku-band Mixer: f = 16,000 MHz; NF = 12 to 7.5 dB											
1N78B	S	Microwave Ku-band Mixer: f = 16,000 MHz; NF = 12 to 7.5 dB											
1N78C	S	Microwave Ku-band Mixer: f = 16,000 MHz; NF = 12 to 7.5 dB											
1N78D	S	Microwave Ku-band Mixer: f = 16,000 MHz; NF = 12 to 7.5 dB											
1N78E	S	Microwave Ku-band Mixer: f = 16,000 MHz; NF = 12 to 7.5 dB											
1N78F	S	Microwave Ku-band Mixer: f = 16,000 MHz; NF = 12 to 7.5 dB											
1N79		Meter Rectifier - to 3,000 MHz											
1N81	G			DS	50	1.0	3.0M	10*					
1N81A	G			DS	40	1.0	3.0M	10*					
1N82	S	Microwave Mixer - to 1,000 MHz; NF = 16 to 14 dB											
1N82A	S	Microwave Mixer - to 1,000 MHz; NF = 16 to 14 dB											
1N82AG	S	Microwave Mixer - to 1,000 MHz; NF = 16 to 14 dB											
1N82G	S	Microwave Mixer - to 1,000 MHz; NF = 16 to 14 dB											
1N83	G			DS	225	1.0	5.0M	30*					
1N84	G			DS	12	1.0	60M	0.1M					
1N85		Photosensitive Device; $I_{R(dark)}$ = 20 μA @ 90 V, Sensitivity = 0.35 μA/mW @ 90 V											

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N86	G			DS	70	1.0	4.0M	50*					
1N87	S			DS	23	0.25	0.1M	30*					
1N87A	S			DS	23	0.25	0.1M	10*					
1N88	G			DS	85	1.0	2.5M	0.1M					
1N89	G			DS	100	1.0	3.5M	8.0*					
1N90	G			DS	75	1.0	5.0M	800*					
1N91	G		1N91	R*	100	0.5	0.15	4.0	25				
1N92	G		1N91	R*	200	0.5	0.1	2.0	25				
1N93	G		1N91	R*	300	0.5	0.075	1.3	25				
1N94	G			R*	380	0.7	0.5	0.8	25				
1N95	G			DS	75	1.0	10M	800*					
1N96	G			DS	75	1.0	20M	800*					
1N96A	G			DS	60	1.0	40M	500*					
1N97	G			DS	100	1.0	10M	100*					
1N98	G			DS	100	1.0	20M	100*					
1N98A	G			DS	250	1.0	40M	100*					
1N99	G			DS	100	1.0	10M	50*					
1N100	G			DS	100	1.0	20M	50*					
1N100A	G			DS	80	1.0	40M	0.05M					
1N101	G			DS	150	1.0	10M	10*					
1N102	G			DS	75	1.0	15M	3.0*					
1N103	G			DS	12	1.0	30M	0.1M					
1N104	G			DS	12	1.0	30M	0.1M					
1N105	S	Microwave Switch: BV = 500 V, P_D = 8.0 W											
1N106	G			DS	300	1.0	20M	70*					
1N107	G			DS	10	1.0	150M	200*					
1N108	G			DS	50	1.0	50M	200*					
1N109	G			DS	15	1.0	1.0M	0.1M					
1N110	G	Microwave Mixer - to 1,000 MHz, NF = 10 dB											
1N111	G			DS	70	1.0	5.0M	25*					
1N112	G			DS	70	1.0	5.0M	50*					
1N113	G			DS	70	1.0	2.5M	25*					
1N114	G			DS	70	1.0	2.5M	50*					
1N115	G			DS	70	1.0	2.5M	100*					
1N116	G			DS	75	1.0	5.0M	100*					
1N117	G			DS	75	1.0	10M	100*					
1N118	G			DS	75	1.0	20M	100*					
1N118A	G			DS	60	1.0	40M	0.1M					
1N119	G			DS	60	1.0	5.0M		0.5				
1N120	G			DS	60	1.0	5.0M		0.5				
1N124	G	Microwave Mixer - to 1,000 MHz, NF = 10 to 8.0 dB											
1N124A	G	Microwave Mixer - to 1,000 MHz, NF = 10 to 8.0 dB											
1N126	G			DS	75	1.0	5.0M	50*					
1N126A	G			DS	75	1.0	25M	50*					
1N127	G			DS	125	1.0	3.0M	25*					
1N127A	G			DS	125	1.0	25M	25*					
1N128	G			DS	50	1.0	3.0M	10*					
1N128A	G			DS	40	1.0	3.0M	10*					
1N132	G			DS	25								
1N133	G			DS	5.0	0.5	3.0M	300*					
1N134		UHF Detector: f = 400 MHz											
1N137A	S			DS	36	1.0	3.0M	0.03*					
1N137B	S			DS	36	1.0	20M	0.03*					
1N138A	S			DS	18	1.0	5.0M	0.01*					
1N138B	S			DS	18	1.0	40M	0.01*					
1N139	G			DS	40	1.0	20M	1.5M					
1N140	G			DS	70	1.0	40M	300*					
1N141	G			DS	70	1.0	20M	50*					
1N142	G			DS	100	1.0	5.0M	100*					
1N143	G			DS	100	1.0	40M	100*					
1N144	G			DS	30	1.0	100M	200*					
1N145	G			DS	30	1.0	40M	100*					
1N147	G	UHF Mixer: f = 900 MHz; NF = 10 to 9.0 dB											
1N147A	G	UHF Mixer: f = 900 MHz; NF = 10 to 9.0 dB											
1N149	S	Microwave X-band Mixer: f = 9,375 MHz; NF = 8.3 dB											
1N150	S	Microwave C-band Mixer: f = 6,750 MHz; NF = 9.8 dB											
1N151	G			R*	100	0.7	0.5	2.4	25				
1N152	G			R*	200	0.7	0.5	1.9	25				
1N153	G			R*	300	0.7	0.5	1.2	25				
1N155	S	Microwave Detector: f = 9,000 MHz											
1N155A	S	Microwave Detector: f = 9,000 MHz											
1N156	S	Microwave X-band Mixer: f = 9,375 MHz											
1N158	G			R*	380	1.4	0.5	0.8	25				
1N160	S	Microwave C-band Mixer: f = 6,750 MHz; NF = 11.4 dB											
1N173A	S	UHF Mixer - to 1,000 MHz; NF = 13 dB											
1N188		Photosensitive Device; I_R(dark) = 20 μA @ 40 V, Sensitivity = 10 μA/mW											
1N189		Photosensitive Device; R_D = 4,000 ohm, Sensitivity = 0.083%/fc											
1N190	G			DS	3.0	0.75	10M	0.8M					
1N191	G			DS	90	1.0	5.0M		0.5				
1N192	G			DS	70	1.0	5.0M		0.5				
1N193	S			DS	40	2.0	1.0M	40*	0.5				
1N194	S			DS	40	2.0	1.5M	10*	0.2				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N194A	S			DS	40	1.0	1.0M	10*	0.2				
1N195	S			DS	40	2.0	2.0M	10*	0.3				
1N196	S			DS	40	2.0	1.0M	10*	0.1				
1N198	G			DS	80	1.0	4.0M	10*					
1N198A	G			DS	80	1.0	4.0M	10*					
1N198B	G			DS	80	1.0	4.0M	10*	0.3				
1N200	S			DZ						7.5			150M
1N201	S			DZ						9.0			150M
1N202	S			DZ						11			150M
1N203	S			DZ						13.5			150M
1N204	S			DZ						17			150M
1N205	S			DZ						20			150M
1N206	S			DZ						25			150M
1N207	S			DZ						30			150M
1N208	S			DZ						37			150M
1N209	S			DZ						43			150M
1N210	S			DZ						52			150M
1N211	S			DZ						62			150M
1N212	S			DZ						75			150M
1N213	S			DZ						90			150M
1N214	S			DZ						110			150M
1N215	S			DZ						135			150M
1N216	S			DZ						170			150M
1N217	S			DZ						200			150M
1N218	S			DZ						250			150M
1N219	S			DZ						300			150M
1N220	S			DZ						370			150M
1N221	S			DZ						430			150M
1N222	S			DZ						520			150M
1N225	S	.5M8.7ZZS10		DZ						7.5	10		150M
1N225A	S	.5M9.1ZZS5		DZ							9.1*	5.0	150M
1N226	S	.5M10.5ZZS10		DZ						9.0	12		150M
1N226A	S	.5M10ZZS5		DZ							10*	5.0	150M
1N227	S	.5M12.7ZZS10		DZ						11	14.5		150M
1N227A	S	.5M12ZZS5		DZ							12*	5.0	150M
1N228	S	.5M15.7ZZS10		DZ						13.5	18		150M
1N228A	S	.5M15ZZS5		DZ							15*	5.0	150M
1N229	S	.5M19ZZS10		DZ						17	21		150M
1N229A	S	.5M18ZZS5		DZ							18*	5.0	150M
1N230	S	.5M23.5ZZS5		DZ						20	27		150M
1N231	S	.5M28.5ZZS10		DZ						25	32		150M
1N232	S	.5M34.5ZZS10		DZ						0.30	39		150M
1N233	S	.5M41ZZS10		DZ						37	45		150M
1N234	S	.5M48.5ZZS10		DZ						43	54		150M
1N235	S	.5M58ZZS10		DZ						52	64		150M
1N236	S	.5M71ZZS10		DZ						62	80		150M
1N237	S	.5M87.5ZZS10		DZ						75	100		150M
1N238	S	.5M105ZZS10		DZ						90	120		150M
1N239	S	.5M127.5ZZS5		DZ						110	145		150M
1N248	S	1N248A		R*	50	1.5	10	5.0	200				
1N248A	S	1N248B	1N248B	R*	50	1.5	20	5.0	250				
1N248B	S		1N248B	R*	50	1.5	20	5.0	250				
1N248C	S		1N248B	R*	39	1.2	20	3.8	350				
1N249	S	1N249A		R*	100	1.5	10	5.0	200				
1N249A	S	1N249B	1N248B	R*	100	1.5	20	5.0	250				
1N249B	S		1N248B	R*	100	1.5	20	5.0	250				
1N249C	S		1N248B	R*	77	1.2	20	3.6	350				
1N250	S	1N250A		R*	200	1.5	10	5.0	200				
1N250A	S	1N250B	1N248B	R*	200	1.5	20	5.0	250				
1N250B	S		1N248B	R*	200	1.5	20	5.0	250				
1N250C	S		1N248B	R*	154	1.2	20	3.4	350				
1N251	S			DS	30	1.0	5.0M	0.1*	0.15				
1N252	S			DS	20	1.0	10M	0.1*	0.15				
1N253	S	MR1121	MR1120	R*	95	1.5	1.0	0.1	4.0				
1N254	S	MR1122	MR1120	R*	190	1.5	0.4		1.5				
1N255	S	MR1124	MR1120	R*	380	1.5	0.4		1.5				
1N256	S	MR1126	MR1120	R*	570	1.5	0.2		1.0				
1N259	S	Microwave Mixer pair - to 9,000 MHz											
1N263	G	Microwave X-band Mixer: f = 9,375 MHz; NF = 7.5 dB											
1N264	S	Microwave Mixer pair: f = 3,000 MHz											
1N265	G			DS	90	1.0	3.2M	100*					
1N266	G			DS	60	1.0	4.0M	75*					
1N267	G			DS	25	1.0	3.5M	12*					
1N268	G			DS	30	1.0	2.5M	20*					
1N269	G	Microwave S-band Mixer: NF = 7.5 dB											
1N270	G			DS	80	1.0	200M	100*					
1N273	G			DS	30	1.0	100M	20*					
1N276	G			DS	50	1.0	40M	100*	0.3				
1N277	G			DS	100	1.0	100M	75*					
1N278	G			DS	50	1.0	20M	125*					
1N279	G			DS	30	1.0	100M	200*					
1N281	G			DS	60	1.0	100M	30*					

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * / V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N282	G			DS		1.0	40M	20M					
1N283	G			DS	20	1.0	200M	20*					
1N285		UHF Mixer; NF = 12.5 dB											
1N286	S	Microwave X-K band Mixer; NF = 11.3 dB											
1N286A	S	Microwave X-K band Mixer; NF = 11.3 dB											
1N287	G			DS	60	1.0	20M	1.5M					
1N288	G			DS	85	1.0	40M	350*					
1N289	G			DS	85	1.0	20M	50*					
1N290	G			DS	120	1.0	5.0M	100*					
1N291	G			DS	120	1.0	40M	100*					
1N292	G			DS	75	1.0	100M	200*					
1N294	G			DS	60	1.0	5.0M	10*					
1N294A	G			DS	60	1.0	5.0M	10*					
1N295	G			DS	40			200*					
1N295A	G			DS	40			200*					
1N296	G			DS	40			200M					
1N297	G			DS	80	1.0	3.5M	10*					
1N297A	G			DS	80	1.0	3.5M	10*					
1N298	G			DS	70	2.0	30M						
1N298A	G			DS	30	2.0	30M	250*					
1N299	G			DS		0.5	3.0M	200M					
1N300	S			DS	15	1.0	15M	0.001*					
1N300A	S			DS	15	1.0	30M	0.001*					
1N300B	S			DS	15	1.0	50M	0.001*					
1N301	S			DS	70	1.0	5.0M	0.05*					
1N301A	S			DS	70	1.0	18M	0.05*					
1N301B	S			DS	70	1.0	50M	0.01*					
1N302	S			DS	225	1.0	1.0M	0.2*					
1N302A	S			DS	225	1.0	5.0M	0.2*					
1N303	S			DS	125	1.0	3.0M	0.1*					
1N303A	S			DS	125	1.0	12M	0.1*					
1N303B	S			DS	125	1.0	50M	0.1*					
1N304	S			DS	55	1.5	2.0M	2.0*					
1N305	G			DS	60	0.8	100M	20*					
1N306	G			DS	15	0.8	100M	2.0*					
1N307	G			DS	125	1.0	100M	5.0*					
1N308	G			DS	8.0	1.0	300M	500*					
1N309	G			DS	40	1.0	100M	100*					
1N310	G			DS	125	1.0	40M	20*					
1N311	S	Microwave Mixer - to 12,000 MHz; NF = 10.5 dB											
1N312	G			DS	60	1.0	70M	50*					
1N313	G			DS	125	1.0	40M	10*					
1N314	G			DS				0.05M					
1N315	G			R*	300	0.48	0.075	0.3	25				
1N315A	G			R*	200	0.48	0.1	0.16	25				
1N316	S	1N4001	1N4001	R*	50	2.0	0.2		2.0				
1N317	S	1N4002	1N4001	R*	100	2.0	0.2		2.0				
1N318	S	1N4003	1N4001	R*	200	2.0	0.2		2.0				
1N319	S	1N4004	1N4001	R*	350	2.0	0.2		2.0				
1N320	S	1N4005	1N4001	R*	500	2.0	0.2		2.0				
1N321	S	1N4007	1N4001	R*	850	1.2	0.25	1.0	10				
1N322	S			R*	850	1.2	0.25	1.0	10				
1N323	S			R*	50	2.0	0.4		2.0				
1N324	S			R*	100	2.0	0.4		2.0				
1N325	S			R*	200	2.0	0.4		2.0				
1N326	S			R*	350	2.0	0.4		2.0				
1N327	S			R*	500	2.0	0.4		2.0				
1N328	S			R*	850	1.2	0.4	0.06	10				
1N329	S			R*	1000	1.2	0.4	0.06	10				
1N330	S			DS	32	1.0	3.0M	0.03*					
1N331	S			DS	16	1.0	5.0M	0.01*					
1N332	S	MR1124	MR1120	R*	400	2.0	0.4	0.2	10				
1N333	S	MR1124	MR1120	R*	400	2.0	0.2	0.2	5.0				
1N334	S	MR1123	MR1120	R*	300	2.0	0.4	0.2	10				
1N335	S	MR1123	MR1120	R*	300	2.0	0.2	0.2	5.0				
1N336	S	MR1122	MR1120	R*	200	2.0	0.4	0.1	10				
1N337	S	MR1122	MR1120	R*	200	2.0	0.2	0.1	5.0				
1N338	S	MR1121	MR1120	R*	100	2.0	1.0	0.2	20				
1N339	S	MR1121	MR1120	R*	100	2.0	0.4	0.1	10				
1N340	S	MR1121	MR1120	R*	100	2.0	0.2	0.1	5.0				
1N341	S	MR1124	MR1120	R*	400	2.0	0.4	0.5	10				
1N342	S	MR1124	MR1120	R*	400	2.0	0.2	0.5	5.0				
1N343	S	MR1123	MR1120	R*	300	2.0	0.4	0.5	10				
1N344	S	MR1123	MR1120	R*	300	2.0	0.2	0.5	5.0				
1N345	S	MR1122	MR1120	R*	200	2.0	0.4	0.5	10				
1N346	S	MR1122	MR1120	R*	200	2.0	0.2	0.5	5.0				
1N347	S	MR1121	MR1120	R*	100	2.0	1.0	0.5	20				
1N348	S	MR1121	MR1120	R*	100	2.0	0.4	0.5	10				
1N349	S	MR1121	MR1120	R*	100	2.0	0.2	0.5	5.0				
1N350	S			DS	70	1.0	20M	0.03*					
1N351	S			DS	120	1.0	20M	0.03*					
1N352	S			DS	170	1.0	20M	0.05*					

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N353	S			DS	225	1.0	20M	0.1*					
1N354	S			DS	325	1.0	20M	0.1*					
1N355	G			DS	100	1.0	4.0M	50*					
1N358	S	Microwave L-X-band Detector											
1N358A	S	Microwave L-X-band Detector											
1N359	S	1N4001	1N4001	R*	50	2.0	0.1		2.0				
1N360	S	1N4002	1N4001	R*	100	2.0	0.1		2.0				
1N361	S	1N4003	1N4001	R*	200	2.0	0.1		2.0				
1N362	S	1N4004	1N4001	R*	350	2.0	0.1		2.0				
1N363	S	1N4005	1N4001	R*	500	2.0	0.1		2.0				
1N364	S	1N4007	1N4001	R*	850	1.2	0.1	0.06	10				
1N365	S	1N4007	1N4001	R*	1000	1.2	0.1	0.06	10				
1N367	G			DS	15								
1N368	G			R*	200	0.5	0.1	0.3	25				
1N368A	G			R*	200	0.5	0.1	0.16	25				
1N369	S	Microwave S-X-band Detector											
1N369A	S	Microwave L-X-band Detector											
1N370	S	1N5221B	1N5221	DZ						1.5	2.2		200M
1N371	S	1N5221A	1N5221	DZ						2.0	2.7		200M
1N372	S	1N5225A	1N5221	DZ						2.5	3.3		200M
1N373	S	1N5227A	1N5221	DZ						3.1	3.9		200M
1N374	S	1N5229A	1N5221	DZ						3.7	4.5		200M
1N375	S	1N5230A	1N5221	DZ						4.3	5.4		200M
1N376	S	1N5233A	1N5221	DZ						5.2	6.4		200M
1N377	S	1N5236A	1N5221	DZ						6.2	8.0		200M
1N378	S	1N5238A	1N5221	DZ						7.5	10		200M
1N379	S	1N5240A	1N5221	DZ						9.0	12		200M
1N380	S	1N5243A	1N5221	DZ						11	14.5		200M
1N381	S	1N5246A	1N5221	DZ						13.5	18		200M
1N382	S	1N5249A	1N5221	DZ						17	21		200M
1N383	S	1N5252A	1N5221	DZ						20	27		200M
1N384	S	1N5255A	1N5221	DZ						25	32		200M
1N385	S	1N5258A	1N5221	DZ						30	39		200M
1N386	S	1N5260A	1N5221	DZ						37	45		200M
1N387	S	1N5261A	1N5221	DZ						43	54		200M
1N388	S	1N5264A	1N5221	DZ						52	64		200M
1N389	S	1N5266A	1N5221	DZ						62	80		200M
1N390	S	1N5269A	1N5221	DZ						75	100		200M
1N391	S	1N5271A	1N5221	DZ						90	120		200M
1N392	S	1N5274A	1N5221	DZ						110	145		200M
1N393	S	1N5277A	1N5221	DZ						135	180		200M
1N394	S	1N5280A	1N5221	DZ						170	210		200M
1N395	S	.5M115ZSB10		DZ						200	270		200M
1N396	S	.5M140ZSB10		DZ						250	320		200M
1N397	S	.5M170ZSB10		DZ						300	390		200M
1N398	S	.5M205ZSB10		DZ						370	450		200M
1N399	S	.5M160ZSC10		DZ						430	540		200M
1N400	S	.5M195ZSC10		DZ						520	640		200M
1N401	S			DS	1.5								
1N402	S			DS	2.0								
1N403	S			DS	2.5								
1N404	S			DS	3.1								
1N405	S			DS	3.7	1.0	225M						
1N406	S			DS	4.3	1.0	200M						
1N407	S			DS	5.2	1.0	170M						
1N408	S			DS	6.2	1.0	130M						
1N411B	S	MR1810 SB		R*	50	1.5	50	25	525				
1N412B	S	MR1811 SB		R*	100	1.5	50	25	525				
1N413B	S	MR1813 SB		R*	200	1.5	50	25	525				
1N415B	S	Microwave X-band Mixer; NF = 11.4 to 6.5 dB											
1N415C	S	Microwave X-band Mixer; NF = 11.4 to 6.5 dB											
1N415D	S	Microwave X-band Mixer; NF = 11.4 to 6.5 dB											
1N415E	S	Microwave X-band Mixer; NF = 11.4 to 6.5 dB											
1N415F	S	Microwave X-band Mixer; NF = 11.4 to 6.5 dB											
1N415G	S	Microwave X-band Mixer; NF = 11.4 to 6.5 dB											
1N416B	S	Microwave S-band Mixer; NF = 10.3 to 5.5 dB											
1N416C	S	Microwave S-band Mixer; NF = 10.3 to 5.5 dB											
1N416D	S	Microwave S-band Mixer; NF = 10.3 to 5.5 dB											
1N416E	S	Microwave S-band Mixer; NF = 10.3 to 5.5 dB											
1N416F	S	Microwave S-band Mixer; NF = 10.3 to 5.5 dB											
1N416G	S	Microwave S-band Mixer; NF = 10.3 to 5.5 dB											
1N417	G			DS	60				0.3				
1N418	G			DS	60	1.0	7.0M		0.3				
1N419	G			DS	80	1.0	125M		0.3				
1N429	S		1N429	DR							6.2		
1N430	S	1N3156	1N3154	DR						0.002	8.4	-55	100
1N430A	S	1N3157	1N3154	DR						0.001	8.4	-55	100
1N430B	S	1N3157A	1N3154	DR						0.001	8.4	-55	150
1N431	S			DS	68	0.55	15M						
1N432	S			DS	40	1.0	10M	5.0N					
1N432A	S			DS	40	1.0	20M	5.0N					
1N433	S			DS	145	1.0	3.0M	0.1*					

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N433A	S			DS	145	1.0	10M	0.1*					
1N434	S			DS	180	1.0	2.0M	0.1*					
1N434A	S			DS	180	1.0	7.0M	0.1*					
1N435	G			DS	40			0.3M					
1N440	S	1N4002	1N4001	R*	100	1.5	0.3	0.3					
1N440B	S	1N4002	1N4001	R*	100	1.5		0.3	15				
1N441	S	1N4003	1N4001	R*	200	1.5	0.3	0.75					
1N441B	S	1N4003	1N4001	R*	200	1.5			15				
1N442	S	1N4004	1N4001	R*	300	1.5	0.3	1.0					
1N442B	S	1N4004	1N4001	R*	300	1.5		0.001	15				
1N443	S	1N4004	1N4001	R*	400	1.5	0.3	1.5					
1N443B	S	1N4004	1N4001	R*	400	1.5			15				
1N444	S	1N4005	1N4001	R*	500	1.5	0.3	1.75					
1N444B	S	1N4005	1N4001	R*	500	1.5			15				
1N445	S	1N4005	1N4001	R*	600	1.5	0.3	2.0					
1N445B	S	1N4005	1N4001	R*	600	1.5		0.002	15				
1N446	S	Microwave K-Ka-band Detector											
1N447	G			DS	30	1.0	25M	20*					
1N448	G			DS	100	1.0	25M	30*					
1N449	G			DS	30	1.0	50M	10*					
1N450	G			DS	100	1.0	50M	30*					
1N451	G			DS	150	1.0	50M	150*					
1N452	G			DS	30	1.0	100M	30*					
1N453	G			DS	100	1.0	100M	30*					
1N454	G			DS	50	1.0	200M	50*					
1N455	G			DS	30	1.0	300M	30*					
1N456	S			DS	25	1.0	40M	25N					
1N456A	S			DS	25	1.0	100M	25N					
1N457	S			DS	60	1.0	20M	25N					
1N457A	S			DS	60	1.0	100M	25N					
1N458	S			DS	125	1.0	2.0M	25N					
1N458A	S			DS	125	1.0	100M	25N					
1N459	S			DS	175	1.0	3.0M	25N					
1N459A	S			DS	175	1.0	100M	25N					
1N460	S			DS	90	1.0	5.0M	0.1*					
1N460A	S			DS	90	1.0	15M	0.1*					
1N461	S			DS	25	1.0	15M	0.5*					
1N461A	S			DS	25	1.0	100M	0.5*					
1N462	S			DS	60	1.0	5.0M	0.5*					
1N462A	S			DS	60	1.0	100M	0.5*					
1N463	S			DS	175	1.0	1.0M	0.5*					
1N463A	S			DS	175	1.0	100M	0.5*					
1N464	S			DS	125	1.0	3.0M	0.5*					
1N464A	S			DS	125	1.0	100M	0.5*					
1N465	S	1N5223A	1N5221	DZ						2.0	3.2		200M
1N465A	S	1N5223B	1N5221	DZ							2.7*	5.0	200M
1N465B	S	.5M2.7ZS1		DZ							2.7*	1.0	200M
1N466	S	1N5226A	1N5221	DZ						3.0	3.9		200M
1N466A	S	1N5226B	1N5221	DZ							3.3*	5.0	200M
1N466B	S	.5M3.3ZS1		DZ							3.3*	1.0	200M
1N467	S	1N5228B	1N5221	DZ						3.7	4.5		200M
1N467A	S	1N5228B	1N5221	DZ							3.9*	5.0	200M
1N467B	S	.5M3.9ZS1		DZ							3.9*	1.0	200M
1N468	S	1N5230A	1N5221	DZ						4.3	5.4		200M
1N468A	S	1N5230B	1N5221	DZ							4.7*	5.0	200M
1N468B	S	.5M4.7ZS1		DZ							4.7*	1.0	200M
1N469	S	1N5232B	1N5221	DZ						5.2	6.4		200M
1N469A	S	1N5232B	1N5221	DZ							5.6*	5.0	200M
1N469B	S	.5M5.6ZS1		DZ							5.6*	1.0	200M
1N470	S	1N5235B	1N5221	DZ						6.2	8.0		200M
1N470A	S	1N5235B	1N5221	DZ							6.8*	5.0	200M
1N470B	S	.5M6.8ZS1		DZ							6.8*	1.0	200M
1N471	S	.5M3.4ZZS10		DZ						3.0	3.9		200M
1N471A	S	.5M3.3ZZS5		DZ							3.3*	5.0	200M
1N472	S	.5M4.1ZZS10		DZ						3.7	4.5		200M
1N472A	S	.5M3.9ZZS5		DZ							3.9*	5.0	200M
1N473	S	.5M4.8ZZS10		DZ						4.3	5.4		200M
1N473A	S	.5M4.7ZZS5		DZ							4.7*	5.0	200M
1N474	S	.5M5.8ZZS10		DZ						5.2	6.4		200M
1N474A	S	.5M5.6ZZS5		DZ							5.6*	5.0	200M
1N475	S	.5M7.1ZZS10		DZ						6.2	8.0		150M
1N475A	S	.5M6.8ZZS5		DZ							6.8*	5.0	200M
1N476	G			DS	90	1.0	2.5M	11*					
1N477	G			DS	90	1.0	2.5M	11*					
1N478	G			DS	90	1.0	5.0M	7.0*					
1N479	G			DS	90	1.0	5.0M	7.0*					
1N480	G			DS	60	1.0	5.0M		0.5				
1N481	G			R*	200	0.5	0.1	1.9	25				
1N482	S			DS	36	1.1	100M	0.25*					
1N482A	S			DS	36	1.0	100M	25N					
1N482B	S			DS	36	1.0	100M	25N					
1N483	S			DS	70	1.0	100M	25N					

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N483A	S			DS	70	1.0	100M	25N					
1N483B	S			DS	70	1.0	100M	25N					
1N484	S			DS	130	1.1	100M	0.25*					
1N484A	S			DS	130	1.0	100M	25N					
1N484B	S			DS	130	1.0	100M	25N					
1N485	S			DS	180	1.1	100M	0.25*					
1N485A	S			DS	180	1.0	100M	25N					
1N485B	S			DS	180	1.0	100M	25N					
1N486	S			DS	225	1.1	100M	0.25*					
1N486A	S			DS	225	1.0	100M	0.05*					
1N486B	S			DS	225	1.0	100M	0.05*					
1N487	S			DS	300	1.1	100M	0.25*					
1N487A	S			DS	300	1.0	100M	0.1*					
1N487B	S			DS	300	1.0	100M	0.1*					
1N488	S			DS	380	1.1	100M	0.25*					
1N488A	S			DS	380	1.0	100M	0.1*					
1N488B	S			DS	380	1.0	100M	0.1*					
1N490	G			DS	90	1.0	5.0M		0.5				
1N497	G			DS	30	1.0	100M	20*					
1N498	G			DS	60	1.0	100M	25*					
1N499	G			DS	75	1.0	100M	30*					
1N500	G			DS	80	1.0	100M	40*					
1N501	G			DS	100	1.0	100M	40*					
1N502	G			DS	120	1.0	100M	50*					
1N503	S			R*	50	1.2	0.33	0.5					
1N504	S			R*	100	1.2	0.33	0.5					
1N505	S			R*	200	1.2	0.33	0.5					
1N506	S			R*	300	1.2	0.33	0.5					
1N507	S			R*	400	1.2	0.33	0.25					
1N508	S			R*	600	1.2	0.33	0.25					
1N509	S			R*	800	1.2	0.33	0.25					
1N510	S			R*	1000	1.2	0.33	0.25					
1N511	S			R*	50	1.2	1.0	0.5					
1N512	S			R*	100	1.2	1.0	0.5					
1N513	S			R*	200	1.2	1.0	0.5					
1N514	S			R*	300	1.2	1.0	0.5					
1N515	S			R*	400	1.2	1.0	0.25					
1N516	S			R*	600	1.2	1.0	0.25					
1N517	S			R*	800	1.2	1.0	0.25					
1N518	S			R*	1000	1.2	1.0	0.25					
1N519	S			R*	50	1.2	1.25	0.5					
1N520	S			R*	100	1.2	1.25	0.5					
1N521	S			R*	200	1.2	1.25	0.5					
1N522	S			R*	300	1.2	1.25	0.5					
1N523	S			R*	400	1.2	1.25	0.25					
1N524	S			R*	600	1.2	1.25	0.25					
1N525	S			R*	800	1.2	1.25	0.25					
1N526	S			R*	1000	1.2	1.25	0.25					
1N527	G			DS	10	0.3	1.0M	50*					
1N530	S	1N4002	1N4001	R*	100	2.0	0.3	0.003	3.0				
1N531	S	1N4003	1N4001	R*	200	2.0	0.3		3.0				
1N532	S	1N4004	1N4001	R*	300	2.0	0.3	0.01	3.0				
1N533	S			R*	400	2.0	0.3	0.015	3.0				
1N534	S	1N4005	1N4001	R*	500	2.0	0.3		3.0				
1N535	S	1N4005	1N4001	R*	600	2.0	0.3	0.02	3.0				
1N536	S	1N4001	1N4001	R*	50	0.5	0.25	0.4	15				
1N537	S	1N4002	1N4001	R*	100	0.4	0.25	0.5	15				
1N538	S	1N4003	1N4001	R*	200	0.3	0.25	0.5	15				
1N539	S	1N4004	1N4001	R*	300	0.5	0.25	0.3	15				
1N540	S	1N4004	1N4001	R*	400	0.5	0.25	0.3	15				
1N541	G			DS	45	2.2	10M	18*					
1N542	G			DS									
1N543	S			R*	1000	10	0.005	0.1					
1N543A	S			R*	1000	8.0	0.025	0.1					
1N544	S			R*	1000	10	0.015	0.1					
1N544A	S			R*	1000	10	0.075	0.1					
1N547	S	1N4005	1N4001	R*	600	1.1	0.25	0.35	15				
1N548	S			R*	900	1.1	0.3	0.35	15				
1N549	S			R*	1200	1.1	0.3	0.35	15				
1N550	S	MR1121	MR1120	R*	100	1.5	0.5		4.0				
1N551	S	MR1122	MR1120	R*	200	1.5	0.5	0.001	4.0				
1N552	S	MR1123	MR1120	R*	300	1.5	0.5		4.0				
1N553	S	MR1124	MR1120	R*	400	1.5	0.5		4.0				
1N554	S	MR1125	MR1120	R*	500	1.5	0.5		4.0				
1N555	S			R*	600	1.5	0.5	0.005	4.0				
1N560	S	1N4006	1N4001	R*	800	1.75	0.25	0.015	2.0				
1N561	S	1N4007	1N4001	R*	1000	1.75	0.25	0.02	2.0				
1N562	S	MR1128	MR1120	R*	800	1.75	0.4	0.015	3.0				
1N563	S	MR1130	MR1120	R*	1000	1.75	0.4	0.02	3.0				
1N566	G			DS	220	1.0	20M	0.2M					
1N567	G			DS	100	1.0	150M	0.15M	0.3				
1N568	G			DS	7.0	0.32	5.0M	0.1M	0.08				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	ZENER DIODES V_Z (min)	V_Z (nom) * / V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (µs)	REFERENCE DIODES TC %/°C	V_Z	T (min) °C	T (max) °C
1N569	G			DS	12	0.5	250M	0.05M					
1N570	S			R*	1250	10	37.5	0.1					
1N571	G			DS		1.0	200M	100*	4.0				
1N573	G			R*	380	0.15	0.25						
1N574	G			R*	380	0.15	0.3						
1N575	G			R*	380	0.3	0.35						
1N575A	G			R*	380	0.15	0.35						
1N576A	G			R*	380	0.15	0.4						
1N581	G			R*	380	0.15	0.25						
1N582	G			R*	380	0.15	0.3						
1N583	G			R*	380	0.15	0.35						
1N584	G			R*	380	0.15	0.4						
1N588	S			R*	1500	1.75	0.1	0.1	5.0				
1N589	S	MR991A	MR990A	R*	1500	1.75	0.25	0.1	10				
1N590	S			R*	1500	8.0	0.075	0.1					
1N591	S			R*	1500	8.0	0.075	0.1					
1N596	S	1N4005	1N4001	R*	600	3.0	0.125	0.025	1.0				
1N597	S	1N4006	1N4001	R*	800	3.0	0.125	0.025	1.0				
1N598	S	1N4007	1N4001	R*	1000	3.0	0.125	0.025	1.0				
1N599	S	1N4001	1N4001	R*	50	1.5	0.3	0.025	2.0				
1N599A	S	1N4001	1N4001	R*	50	1.5	0.3	0.001	2.0				
1N600	S	1N4002	1N4001	R*	100	1.5	0.3	0.025	2.0				
1N600A	S	1N4002	1N4001	R*	100	1.5	0.3	0.001	2.0				
1N601	S	1N4003	1N4001	R*	150	1.5	0.3	0.025	2.0				
1N601A	S	1N4003	1N4001	R*	150	1.5	0.3	0.001	2.0				
1N602	S	1N4003	1N4001	R*	200	1.5	0.3	0.025	2.0				
1N602A	S	1N4003	1N4001	R*	200	1.5	0.3	0.001	2.0				
1N603	S	1N4004	1N4001	R*	300	1.5	0.3	0.025	2.0				
1N603A	S	1N4004	1N4001	R*	300	1.5	0.3	0.001	2.0				
1N604	S	1N4004	1N4001	R*	400	1.5	0.3	0.025	2.0				
1N604A	S	1N4004	1N4001	R*	400	1.5	0.3		2.0				
1N605	S	1N4005	1N4001	R*	500	1.5	0.3	0.025	2.0				
1N605A	S	1N4005	1N4001	R*	500	1.5	0.3	0.002	2.0				
1N606	S	1N4005	1N4001	R*	600	1.5	0.3	0.025	2.0				
1N606A	S	1N4005	1N4001	R*	600	1.5	0.3		2.0				
1N607	S			R*	50	1.5	0.8	0.025	3.0				
1N607A	S	MR1120	MR1120	R*	50	1.5	0.8	0.001	3.0				
1N608	S			R*	100	1.5	0.8	0.025	3.0				
1N608A	S	MR1121	MR1120	R*	100	1.5	0.8	0.001	3.0				
1N609	S			R*	150	1.5	0.8	0.025	3.0				
1N609A	S	MR1122	MR1120	R*	150	1.5	0.8	0.001	3.0				
1N610	S			R*	200	1.5	0.8	0.025	3.0				
1N610A	S	MR1122	MR1120	R*	200	1.5	0.8	0.001	3.0				
1N611	S			R*	300	1.5	0.8	0.025	3.0				
1N611A	S	MR1123	MR1120	R*	300	1.5	0.8	0.001	3.0				
1N612	S			R*	400	1.5	0.8	0.025	3.0				
1N612A	S	MR1124	MR1120	R*	400	1.5	0.8	1.5	3.0				
1N613	S			R*	500	1.5	0.8	0.025	3.0				
1N613A	S	MR1125	MR1120	R*	500	1.5	0.8	0.002	3.0				
1N614	S			R*	600	1.5	0.8	0.025	3.0				
1N614A	S	MR1126	MR1120	R*	600	1.5	0.8	2.5	3.0				
1N615	G			R*	300		0.075	1.2	25				
1N616	G			DS	20	1.0	8.0M	0.4M					
1N617	G			DS	115	1.0	3.0M	11*					
1N618	G			DS	115	1.0	5.0M	7.0*					
1N619	S			DS	30	1.0	3.0M	0.08*					
1N622	S			DS	150	1.0	7.0M	0.16*					
1N625	S			DS		1.5	4.0M	1.0*	1.0				
1N626	S			DS		1.5	4.0M	1.0*	1.0				
1N627	S			DS		1.5	4.0M	1.0*	1.0				
1N628	S			DS		1.5	4.0M	1.0*	1.0				
1N629	S			DS		1.5	4.0M	1.0*	1.0				
1N630	S	Microwave L-X-band Detector											
1N631	G			DS	60				0.3				
1N632	G			DS	60	1.0	7.0M		0.3				
1N633	G			DS	80	1.0	125M		0.3				
1N634	G			DS	100	1.0	50M	45*					
1N635	G			DS	150	1.0	50M	175*					
1N636	G			DS	60	1.0	2.5M	10*					
1N643	S			DS	175	1.0	10M	1.0*	0.3				
1N643A	S			DS	175	1.0	100M	1.0*	0.3				
1N645	S	1N4003	1N4001	DS	225	1.0	400M	0.2*					
1N645A	S	1N4003	1N4001	DS	225	1.0	400M	0.05*					
1N646	S	1N4004	1N4001	DS	300	1.0	400M	0.2*					
1N647	S	1N4004	1N4001	DS	400	1.0	400M	0.2*					
1N648	S	1N4005	1N4001	DS	500	1.0	400M	0.2*					
1N649	S	1N4005	1N4001	DS	600	1.0	400M	0.2*					
1N658	S			DS	100	1.0	100M	0.05*	0.3				
1N658A	S			DS	120	1.0	100M	25N	0.3				
1N659	S			DS	50	1.0	6.0M	5.0*	0.3				
1N659A	S			DS	60	1.0	10M	25N	0.3				
1N660	S			DS	100	1.0	6.0M	5.0*	0.3				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N660A	S			DS	120	1.0	10M	25N	0.3				
1N661	S			DS	200	1.0	6.0M	10*	0.3				
1N661A	S			DS	240	1.0	10M	25N	0.3				
1N662	S			DS	80	1.0	10M	1.0*	0.5				
1N662A	S			DS	80	1.0	100M	1.0*	0.3				
1N663	S			DS	80	1.0	100M	5.0*	0.5				
1N663A	S			DS	80	1.0	100M	0.1*	0.3				
1N664	S	1N5237A	1N5221	DZ							8.2*	10	250M
1N665	S	1N5242A	1N5221	DZ						10.8	13.2		0.25W
1N666	S	1N5245B	1N5221	DZ						14.2	15.8		0.25W
1N667	S	1N5248A	1N5221	DZ						16.2	19.8		0.25W
1N668	S	1N5251A	1N5221	DZ						19.8	24.2		0.25W
1N669	S	1N5254A	1N5221	DZ						24.3	29.7		0.25W
1N670	S	1N5266B	1N5221	DZ							68*	5.0	250M
1N671	S	1N5271A	1N5221	DZ						90	110		0.25W
1N672	S	1N5276A	1N5221	DZ						135	165		0.25W
1N673	S		1N5221	DS	350	1.0	250M	1.0*					
1N674	S	1N5230A	1N5221	DZ							4.7*	10	250M
1N675	S	1N5234B	1N5221	DZ							6.2*	5.0	250M
1N676	S	1N4002	1N4001	R*	100	1.0	0.075	0.2	3.0				
1N677	S	1N4002	1N4001	R*	100	1.0	0.15	0.2	5.0				
1N678	S	1N4003	1N4001	R*	200	1.0	0.075	0.2	3.0				
1N679	S	1N4003	1N4001	R*	200	1.0	0.15	0.2	5.0				
1N681	S	1N4004	1N4001	R*	300	1.0	0.075	0.2	3.0				
1N682	S	1N4004	1N4001	R*	300	1.0	0.15	0.2	5.0				
1N683	S	1N4004	1N4001	R*	400	1.0	0.075	0.2	3.0				
1N684	S	1N4004	1N4001	R*	400	1.0	0.15	0.2	5.0				
1N685	S	1N4005	1N4001	R*	500	1.0	0.075	0.2	3.0				
1N686	S	1N4005	1N4001	R*	500	1.0	0.15	0.2	5.0				
1N687	S	1N4005	1N4001	R*	600	1.0	0.075	0.2	3.0				
1N689	S	1N4005	1N4001	R*	600	1.0	0.15	0.2	5.0				
1N690	S			DS	36	1.0	400M	0.25*	0.8				
1N691	S			DS	70	1.0	400M	0.25*	0.8				
1N692	S			DS	100	1.0	400M	0.25*	0.8				
1N693	S			DS	130	1.0	400M	0.25*	0.8				
1N695	G			DS	20	1.0	100M	2.0*	0.3				
1N695A	G			DS	25	0.5	10M	2.0*	0.3				
1N696	S			DS	30	1.0	10M	15N	5.0				
1N697	S			DS		1.0	0.25A	1.0*					
1N698	G			DS	25	0.65	30M	160*	0.5				
1N699	G			DS	80	1.0	100M		0.3				
1N701	S	1N5240B *	1N5221	DZ						9.5	10.5		0.25W
1N702	S	1N5223A *	1N5221	DZ						2.0	3.2		250M
1N702A	S	1N5223B *	1N5221	DZ						2.3	2.9		250M
1N703	S	1N5227A *	1N5221	DZ						3.0	3.9		250M
1N703A	S	1N5227B *	1N5221	DZ						3.23	3.67		250M
1N704	S	1N5229A *	1N5221	DZ						3.7	4.5		250M
1N704A	S	1N5229B *	1N5221	DZ						3.9	4.3		250M
1N705	S	1N5230A *	1N5221	DZ						4.3	5.4		250M
1N705A	S	1N5230B *	1N5221	DZ						4.58	5.12		250M
1N706	S	1N5232A *	1N5221	DZ						5.2	6.4		250M
1N706A	S	1N5232B *	1N5221	DZ						5.5	6.1		250M
1N707	S	1N5236A *	1N5221	DZ						6.2	8.0		250M
1N707A	S	1N5236B *	1N5221	DZ						6.65	7.55		250M
1N708	S	1N5232A *	1N5221	DZ							5.6*	10	250M
1N708A	S	1N5232B *	1N5221	DZ							5.6*	5.0	250M
1N709	S	1N5234A *	1N5221	DZ							6.2*	10	250M
1N709A	S	1N5234B *	1N5221	DZ							6.2*	5.0	250M
1N710	S	1N5235A *	1N5221	DZ							6.8*	10	250M
1N710A	S	1N5235B *	1N5221	DZ							6.8*	5.0	250M
1N711	S	1N5236A *	1N5221	DZ							7.5*	10	250M
1N711A	S	1N5236B *	1N5221	DZ							7.5*	5.0	250M
1N712	S	1N5237A *	1N5221	DZ							8.2*	10	250M
1N712A	S	1N5237B *	1N5221	DZ							8.2*	5.0	250M
1N713	S	1N5239A *	1N5221	DZ							9.1*	10	250M
1N713A	S	1N5239B *	1N5221	DZ							9.1*	5.0	250M
1N714	S	1N5240A *	1N5221	DZ							10*	10	250M
1N714A	S	1N5240B *	1N5221	DZ							10*	5.0	250M
1N715	S	1N5241A *	1N5221	DZ							11*	10	250M
1N715A	S	1N5241B *	1N5221	DZ							11*	5.0	250M
1N716	S	1N5242A *	1N5221	DZ							12*	10	250M
1N716A	S	1N5242B *	1N5221	DZ							12*	5.0	250M
1N717	S	1N5243A *	1N5221	DZ							13*	10	250M
1N717A	S	1N5243B *	1N5221	DZ							13*	5.0	250M
1N718	S	1N5245A *	1N5221	DZ							15*	10	250M
1N718A	S	1N5245B *	1N5221	DZ							15*	5.0	250M
1N719	S	1N5246A *	1N5221	DZ							16*	10	250M
1N719A	S	1N5246B *	1N5221	DZ							16*	5.0	250M
1N720	S	1N5248A *	1N5221	DZ							18*	10	250M
1N720A	S	1N5248B *	1N5221	DZ							18*	5.0	250M
1N721	S	1N5250A *	1N5221	DZ							20*	10	250M
1N721A	S	1N5250B *	1N5221	DZ							20*	5.0	250M

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TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N722	S	1N5251A*	1N5221	DZ							22*	10	250M
1N722A	S	1N5251B*	1N5221	DZ							22*	5.0	250M
1N723	S	1N5252A*	1N5221	DZ							24*	10	250M
1N723A	S	1N5252B*	1N5221	DZ							24*	5.0	250M
1N724	S	1N5254A*	1N5221	DZ							27*	10	250M
1N724A	S	1N5254B*	1N5221	DZ							27*	5.0	250M
1N725	S	1N5256A*	1N5221	DZ							30*	10	250M
1N725A	S	1N5256B*	1N5221	DZ							30*	5.0	250M
1N726	S	1N5257A*	1N5221	DZ							33*	10	250M
1N726A	S	1N5257B*	1N5221	DZ							33*	5.0	250M
1N727	S	1N5258A*	1N5221	DZ							36*	10	250M
1N727A	S	1N5258B*	1N5221	DZ							36*	5.0	250M
1N728	S	1N5259A*	1N5221	DZ							39*	10	250M
1N728A	S	1N5259B*	1N5221	DZ							39*	5.0	250M
1N729	S	1N5260A*	1N5221	DZ							43*	10	250M
1N729A	S	1N5260B*	1N5221	DZ							43*	5.0	250M
1N730	S	1N5261A*	1N5221	DZ							47*	10	250M
1N730A	S	1N5261B*	1N5221	DZ							47*	5.0	250M
1N731	S	1N5262A*	1N5221	DZ							51*	10	250M
1N731A	S	1N5262B*	1N5221	DZ							51*	5.0	250M
1N732	S	1N5263A*	1N5221	DZ							56*	10	250M
1N732A	S	1N5263B*	1N5221	DZ							56*	5.0	250M
1N733	S	1N5265A*	1N5221	DZ							62*	10	250M
1N733A	S	1N5265B*	1N5221	DZ							62*	5.0	250M
1N734	S	1N5266A*	1N5221	DZ							68*	10	250M
1N734A	S	1N5266B*	1N5221	DZ							68*	5.0	250M
1N735	S	1N5267A*	1N5221	DZ							75*	10	250M
1N735A	S	1N5267B*	1N5221	DZ							75*	5.0	250M
1N736	S	1N5268A*	1N5221	DZ							82*	10	250M
1N736A	S	1N5268B*	1N5221	DZ							82*	5.0	250M
1N737	S	1N5270A*	1N5221	DZ							91*	10	250M
1N737A	S	1N5270B*	1N5221	DZ							91*	5.0	250M
1N738	S	1N5271A*	1N5221	DZ							100*	10	250M
1N738A	S	1N5271B*	1N5221	DZ							100*	5.0	250M
1N739	S	1N5272A*	1N5221	DZ							110*	10	250M
1N739A	S	1N5272B*	1N5221	DZ							110*	5.0	250M
1N740	S	1N5273A*	1N5221	DZ							120*	10	250M
1N740A	S	1N5273B*	1N5221	DZ							120*	5.0	250M
1N741	S	1N5274A*	1N5221	DZ							130*	10	250M
1N741A	S	1N5274B*	1N5221	DZ							130*	5.0	250M
1N742	S	1N5276A*	1N5221	DZ							150*	10	250M
1N742A	S	1N5276B*	1N5221	DZ							150*	5.0	250M
1N743	S	1N5277A*	1N5221	DZ							160*	10	250M
1N743A	S	1N5277B*	1N5221	DZ							160*	5.0	250M
1N744	S	1N5279A*	1N5221	DZ							180*	10	250M
1N744A	S	1N5279B*	1N5221	DZ							180*	5.0	250M
1N745	S	1N5281A*	1N5221	DZ							200*	0	250M
1N745A	S	1N5281B*	1N5221	DZ							200*	5.0	250M
1N746	S		1N702	DZ							3.3*	10	400M
1N746A	S		1N702	DZ							3.3*	5.0	400M
1N747	S		1N702	DZ							3.6*	10	400M
1N747A	S		1N702	DZ							3.6*	5.0	400M
1N748	S		1N702	DZ							3.9*	10	400M
1N748A	S		1N702	DZ							3.9*	5.0	400M
1N749	S		1N702	DZ							4.3*	10	400M
1N749A	S		1N702	DZ							4.3*	5.0	400M
1N750	S		1N702	DZ							4.7*	10	400M
1N750A	S		1N702	DZ							4.7*	5.0	400M
1N751	S		1N702	DZ							5.1*	10	400M
1N751A	S		1N702	DZ							5.1*	5.0	400M
1N752	S		1N702	DZ							5.6*	10	400M
1N752A	S		1N702	DZ							5.6*	5.0	400M
1N753	S		1N702	DZ							6.2*	10	400M
1N753A	S		1N702	DZ							6.2*	5.0	400M
1N754	S		1N702	DZ							6.8*	10	400M
1N754A	S		1N702	DZ							6.8*	5.0	400M
1N755	S		1N702	DZ							7.5*	10	400M
1N755A	S		1N702	DZ							7.5*	5.0	400M
1N756	S		1N702	DZ							8.2*	10	400M
1N756A	S		1N702	DZ							8.2*	5.0	400M
1N757	S		1N702	DZ							9.1*	10	400M
1N757A	S		1N702	DZ							9.1*	5.0	400M
1N758	S		1N702	DZ							10.0*	10	400M
1N758A	S		1N702	DZ							10.0*	5.0	400M
1N759	S		1N702	DZ							12.0*	10	400M
1N759A	S		1N702	DZ							12.0*	5.0	400M
1N761	S	1N5230A *	1N5221	DZ						4.3	5.4		250M
1N762	S	1N5232B *	1N5221	DZ						5.2	6.4		250M
1N763	S	1N5238B *	1N5221	DZ						6.2	8.0		250M
1N764	S	1N5238A *	1N5221	DZ						7.5	10.0		250M
1N765	S	1N5240A *	1N5221	DZ						9.0	12.0		250M
1N766	S	1N5243A *	1N5221	DZ						11.0	14.5		250M

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TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * / V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts)	@ I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N767	S	1N5246A *	1N5221	DZ						13.5	18.0		250M
1N768	S	1N5249A *	1N5221	DZ						17.0	21.0		250M
1N769	S	1N5252A *	1N5221	DZ						20.0	27.0		250M
1N770	G			DS	20	0.42	5.0M	40*	0.35				
1N771	G			DS	80	1.0	100M	25*					
1N771A	G			DS	80	1.0	200M	25*					
1N771B	G			DS	80	1.0	400M	25*					
1N772	G			DS	70	1.0	100M	50*					
1N772A	G			DS	70	1.0	200M	50*					
1N773	G			DS	65	1.0	100M	10*					
1N773A	G			DS	65	1.0	200M	10*					
1N774	G			DS	60	1.0	100M	15*					
1N774A	G			DS	60	1.0	200M	15*					
1N775	G			DS	60	1.0	100M	20*					
1N776	G			DS	20	1.0	50M	200*					
1N777	G			DS	60	1.0	100M	25*	3.5				
1N778	S			DS	100	1.0	10M	0.5*	0.3				
1N779	S			DS	175	1.0	10M	0.5*	0.3				
1N781	G			DS	40	0.45	10M	5.0*	0.5				
1N781A	G			DS	40	0.45	10M	5.0*	0.5				
1N789	S			DS		1.0	10M	1.0*	0.5				
1N790	S			DS		1.0	10M	5.0*	0.25				
1N791	S			DS		1.0	50M	5.0*	0.5				
1N792	S			DS		1.0	100M	5.0*	0.5				
1N793	S			DS		1.0	10M	1.0*	0.5				
1N794	S			DS		1.0	10M	5.0*	0.25				
1N795	S			DS		1.0	50M	5.0*	0.5				
1N796	S			DS		1.0	100M	5.0*	0.5				
1N797	S			DS		1.0	10M	1.0*	0.5				
1N798	S			DS		1.0	10M	5.0*	0.25				
1N799	S			DS		1.0	50M	5.0*	0.5				
1N800	S			DS		1.0	100M	5.0*	0.5				
1N801	S			DS		1.0	10M	1.0*	0.5				
1N802	S			DS		1.0	50M	5.0*	0.5				
1N803	S			DS		1.0	10M	5.0*	0.5				
1N804	S			DS		1.0	50M	10*	0.5				
1N805	G			DS	40	1.0	3.0M	100*					
1N806	S			DS	100	1.0	4.0M	0.5*	0.3				
1N807	S			DS	180	1.0	4.0M	0.5*	0.3				
1N808	S			DS	100	1.0	100M	1.0*	0.3				
1N809	S			DS	200	1.0	100M	1.0*	0.3				
1N810	S			DS	50	1.0	10M	1.0*	50				
1N811	S			DS	20	1.0	1.0M	1.0*	0.25				
1N812	S			DS	30	1.0	1.0M	0.1*	0.25				
1N813	S			DS	15	1.0	5.0M	0.5*	0.25				
1N814	S			DS	40	1.0	2.0M	0.1*	0.25				
1N815	S			DS	15	1.5	100M	0.5*	0.25				
1N816	S			DS	6.0	1.0	100M	0.1*					
1N817	S			DS	200	1.5	6.0M	20*	1.0				
1N818	S			DS	80	1.5	30M	0.25*	0.5				
1N819	S			DS	80	1.0	200M	25N					
1N821	S		1N821	DR						0.01	6.2	-55	100
1N821A	S		1N821	DR						0.01	6.2	-55	100
1N822	S			DR						0.01	6.2	-55	100
1N823	S		1N821	DR						0.005	6.2	-55	100
1N823A	S		1N821	DR						0.005	6.2	-55	100
1N824	S			DR						0.005	6.2	-55	100
1N825	S		1N821	DR						0.002	6.2	-55	100
1N825A	S		1N821	DR						0.002	6.2	-55	100
1N826	S	1N825	1N821	DR						0.002	6.5	-50	100
1N827	S		1N821	DR						0.001	6.2	-55	100
1N827A	S		1N821	DR						0.001	6.2	-55	100
1N828	S	1N827	1N821	DR						0.001	6.5	-50	100
1N829	S		1N821	DR						0.0005	6.2	-50	100
1N830	S	Micro-min. UHF Detector											
1N830A	S	Micro-min. UHF Detector											
1N831	S	Microwave S-band Mixer; NF = 8.3 to 6.5 dB											
1N831A	S	Microwave S-band Mixer; NF = 8.3 to 6.5 dB											
1N831B	S	Microwave S-band Mixer; NF = 8.3 to 6.5 dB											
1N832	S	Microwave X-band Mixer; NF = 9.5 to 7.0 dB											
1N832A	S	Microwave X-band Mixer; NF = 9.5 to 7.0 dB											
1N832B	S	Microwave X-band Mixer; NF = 9.5 to 7.0 dB											
1N833	S	Microwave X-band Detector											
1N833A	S	Microwave X-band Detector											
1N835	G			DS	30	0.5	5.0M	20*	0.5				
1N836	G			DS	5.0								
1N837	S			DS		1.0	150M	0.1*	0.5				
1N837A	S			DS		1.0	150M	0.1*	0.3				
1N838	S			DS		1.0	150M	0.1*	0.5				
1N839	S			DS		1.0	150M	0.1*	0.5				
1N840	S			DS		1.0	150M	0.1*	0.3				
1N841	S			DS		1.0	150M	0.1*	0.3				

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					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N842	S			DS		1.0	150M	0.1*	0.3				
1N843	S			DS		1.0	150M	0.1*	0.3				
1N844	S			DS		1.0	200M	0.1*	0.5				
1N845	S			DS		1.0	200M	0.1*	0.5				
1N846	S	1N4001	1N4001	R*	50	0.6	200M	20*					
1N847	S	1N4002	1N4001	R*	100	0.6	200M	20*					
1N848	S	1N4003	1N4001	R*	200	0.6	200M	20*					
1N849	S	1N4004	1N4001	R*	300	0.6	200M	20*					
1N850	S	1N4004	1N4001	R*	400	0.6	200M	20*					
1N851	S	1N4005	1N4001	R*	500	0.6	200M	20*					
1N852	S	1N4005	1N4001	R*	600	0.6	200M	20*					
1N853	S	1N4006	1N4001	R*	700	0.6	200M	20*					
1N854	S	1N4006	1N4001	R*	800	0.6	200M	20*					
1N855	S	1N4007	1N4001	R*	900	0.6	200M	20*					
1N856	S	1N4007	1N4001	R*	1.0K	0.6	200M	20*					
1N857	S	1N4001	1N4001	R*	50	0.6	150M	20*					
1N858	S	1N4002	1N4001	R*	100	0.6	150M	20*					
1N859	S	1N4003	1N4001	R*	200	0.6	150M	20*					
1N860	S	1N4004	1N4001	R*	300	0.6	150M	20*					
1N861	S	1N4004	1N4001	R*	400	0.6	150M	20*					
1N862	S	1N4005	1N4001	R*	500	0.6	150M	20*					
1N863	S	1N4005	1N4001	R*	600	0.6	150M	20*					
1N864	S	1N4006	1N4001	R*	700	0.6	150M	20*					
1N865	S	1N4006	1N4001	R*	800	0.6	150M	20*					
1N866	S	1N4007	1N4001	R*	900	0.6	150M	20*					
1N867	S	1N4007	1N4001	R*	1.0K	0.6	150M	20*					
1N868	S	1N4001	1N4001	R*	50	0.6	100M	20*					
1N869	S	1N4002	1N4001	R*	100	0.6	100M	20*					
1N870	S	1N4003	1N4001	R*	200	0.6	100M	20*					
1N871	S	1N4004	1N4001	R*	300	0.6	100M	20*					
1N872	S	1N4004	1N4001	R*	400	0.6	100M	20*					
1N873	S	1N4005	1N4001	R*	500	0.6	100M	20*					
1N874	S	1N4005	1N4001	R*	600	0.6	100M	20*					
1N875	S	1N4006	1N4001	R*	700	0.6	100M	20*					
1N876	S	1N4006	1N4001	R*	800	0.6	100M	20*					
1N877	S	1N4007	1N4001	R*	900	0.6	100M	20*					
1N878	S	1N4007	1N4001	R*	1.0K	0.6	100M	20*					
1N879	S	1N4001	1N4001	R*	50	0.6	50M	20*					
1N880	S	1N4002	1N4001	R*	100	0.6	50M	20*					
1N881	S	1N4003	1N4001	R*	200	0.6	50M	20*					
1N882	S	1N4004	1N4001	R*	300	0.6	50M	20*					
1N883	S	1N4004	1N4001	R*	400	0.6	50M	20*					
1N884	S	1N4005	1N4001	R*	500	0.6	50M	20*					
1N885	S	1N4005	1N4001	R*	600	0.6	50M	20*					
1N886	S	1N4006	1N4001	R*	700	0.6	50M	20*					
1N887	S	1N4006	1N4001	R*	800	0.6	50M	20*					
1N888	S	1N4007	1N4001	R*	900	0.6	50M	20*					
1N889	S	1N4007	1N4001	R*	1.0K	0.6	50M	20*					
1N890	S			DS	60	1.0	20M	25N					
1N891	S			DS		1.0	50M	0.1*	0.3				
1N892	S			DS		1.0	50M	0.1*	0.3				
1N893	S			DS		1.0	50M	0.1*	0.3				
1N894	G			DS	5.0								
1N895	G			DS	5.0								
1N896	G			DS	5.0								
1N897	S			DS	2.5	1.0	5.0M	0.1*	1.0				
1N898	S			DS	2.5	1.0	100M	5.0*	0.3				
1N899	S			DS	85	1.0	5.0M	0.1*	0.3				
1N900	S			DS	85	1.0	50M	0.1*	0.3				
1N901	S			DS	85	1.0	100M	0.5*	0.3				
1N902	S			DS	170	1.0	10M	1.0*	0.3				
1N903	S			DS	40	1.0	10M	0.1*	4.0				
1N903A	S			DS	40	1.0	20M	0.1*	4.0				
1N904	S			DS	30	1.0	10M	0.1*	4.0				
1N904A	S			DS	30	1.0	20M	0.1*	4.0				
1N905	S			DS	20	1.0	10M	0.1*	4.0				
1N905A	S			DS	20	1.0	20M	0.1*	4.0				
1N906	S			DS	20	1.0	10M	0.1*	4.0				
1N906A	S			DS	20	1.0	20M	0.1*	4.0				
1N907	S			DS	30	1.0	10M	0.1*	4.0				
1N907A	S			DS	30	1.0	20M	0.1*	4.0				
1N908	S			DS	40	1.0	10M	0.1*	4.0				
1N908A	S			DS	40	1.0	20M	0.1*	4.0				
1N909	G			DS	50	1.0	100M	10*					
1N910	G			DS	30	1.0	100M	10*					
1N911	G			DS	20	1.0	100M	10*					
1N912	S			DS	10	0.62	1.0M	1.0*					
1N912A	S			DS	10	0.62	1.0M	1.0*					
1N913	S			DS	10	0.62	1.0M	5.0*					
1N913A	S			DS	10	0.62	1.0M	1.0*					
1N914	S			DS	75	1.0	10M	5.0*	4.0				
1N914A	S			DS	75	1.0	20M	5.0*	4.0				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * / V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N914B	S			DS	75	1.0	100M	5.0*	4.0				
1N915	S			DS	50	1.0	50M	5.0*	10				
1N916	S			DS	75	1.0	10M	5.0*	4.0				
1N916A	S			DS	75	1.0	20M	5.0*	4.0				
1N916B	S			DS	75	1.0	30M	5.0*	4.0				
1N917	S			DS	30	1.0	10M	0.05*	3.0				
1N918	S	Microwave Ku-band Mixer											
1N919	S			DS	150	1.0	100M	0.5*	0.3				
1N920	S			DS	36	1.0	500M	0.25*	0.3				
1N921	S			DS	70	1.0	500M	0.25*	0.3				
1N922	S			DS	100	1.0	500M	0.25*	0.3				
1N923	S			DS	130	1.0	500M	0.25*	0.3				
1N925	S			DS	32	1.0	5.0M	1.0*	0.15				
1N926	S			DS	32	1.0	5.0M	0.1*	0.15				
1N927	S			DS	52	1.0	10M	0.1*	0.15				
1N928	S			DS	96	1.0	10M	0.1*	0.15				
1N929	S			DS	20	1.0	20M	0.1*					
1N930	S			DS	50	1.0	20M	0.1*					
1N931	S			DS	100	1.0	20M	0.1*					
1N932	S			DS	200	1.0	20M	0.1*					
1N933	G			DS	100	1.0	14M	10*	0.4				
1N934	S			DS	60	1.0	30M	25N	1.0				
1N935	S		1N935	DR						0.01	9.45	0	75
1N935A	S		1N935	DR						0.01	9.45	-55	100
1N935B	S		1N935	DR						0.01	9.45	-55	150
1N936	S		1N935	DR						0.005	9.45	0	75
1N936A	S		1N935	DR						0.005	9.45	-55	100
1N936B	S		1N935	DR						0.005	9.45	-55	150
1N937	S		1N935	DR						0.002	9.45	0	75
1N937A	S		1N935	DR						0.002	9.45	-55	100
1N937B	S		1N935	DR						0.002	9.45	-55	150
1N938	S		1N935	DR						0.001	9.45	0	75
1N938A	S		1N935	DR						0.001	9.45	-55	100
1N938B	S		1N935	DR						0.001	9.45	-55	150
1N939	S		1N935	DR						0.0005	9.45	0	75
1N939A	S		1N935	DR						0.0005	9.45	-55	100
1N939B	S		1N935	DR						0.0005	9.45	-55	150
1N940	S			DR						0.0002	9.0	0	75
1N940A	S			DR						0.0002	9.0	-55	100
1N940B	S			DR						0.0002	9.0	-55	150
1N941	S		1N941	DR						0.01	12.28	0	75
1N941A	S		1N941	DR						0.01	12.28	-55	100
1N941B	S		1N941	DR						0.01	12.28	-55	150
1N942	S		1N941	DR						0.005	12.28	0	75
1N942A	S		1N941	DR						0.005	12.28	-55	100
1N942B	S		1N941	DR						0.005	12.28	-55	150
1N943	S		1N941	DR						0.002	12.28	0	75
1N943A	S		1N941	DR						0.002	12.28	-55	100
1N943B	S		1N941	DR						0.002	12.28	-55	150
1N944	S		1N941	DR						0.001	12.28	0	75
1N944A	S		1N941	DR						0.001	12.28	-55	100
1N944B	S		1N941	DR						0.001	12.28	-55	150
1N945	S		1N941	DR						0.0005	12.28	0	75
1N945A	S		1N941	DR						0.0005	12.28	-55	100
1N945B	S		1N941	DR						0.0005	12.28	-55	150
1N946	S		1N941	DR						0.0002	11.7	0	75
1N946A	S		1N941	DR						0.0002	11.7	-55	100
1N946B	S		1N941	DR						0.0002	11.7	-55	150
1N947	S			DS		1.0	400M	2.0*					
1N948	S			DS	36	1.5	100M	0.25*	1.0				
1N949	G			DS	50	0.39	10M	10*					
1N950 thru 1N956	S	Varactor Diodes, see Table on Page 92											
1N957	S		1N957	DZ							6.8*	20	400M
1N957A	S		1N957	DZ							6.8*	10	400M
1N957B	S		1N957	DZ							6.8*	5.0	400M
1N958	S		1N957	DZ							7.5*	20	400M
1N958A	S		1N957	DZ							7.5*	10	400M
1N958B	S		1N957	DZ							7.5*	5.0	400M
1N959	S		1N957	DZ							8.2*	20	400M
1N959A	S		1N957	DZ							8.2*	10	400M
1N959B	S		1N957	DZ							8.2*	5.0	400M
1N960	S		1N957	DZ							9.1*	20	400M
1N960A	S		1N957	DZ							9.1*	10	400M
1N960B	S		1N957	DZ							9.1*	5.0	400M
1N961	S		1N957	DZ							10*	20	400M
1N961A	S		1N957	DZ							10*	10	400M
1N961B	S		1N957	DZ							10*	5.0	400M
1N962	S		1N957	DZ							11*	20	400M
1N962A	S		1N957	DZ							11*	10	400M
1N962B	S		1N957	DZ							11*	5.0	400M

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N963	S		1N957	DZ							12*	20	400M
1N963A	S		1N957	DZ							12*	10	400M
1N963B	S		1N957	DZ							12*	5.0	400M
1N964	S		1N957	DZ							13*	20	400M
1N964A	S		1N957	DZ							13*	10	400M
1N964B	S		1N957	DZ							13*	5.0	400M
1N965	S		1N957	DZ							15*	20	400M
1N965A	S		1N957	DZ							15*	10	400M
1N965B	S		1N957	DZ							15*	5.0	400M
1N966	S		1N957	DZ							16*	20	400M
1N966A	S		1N957	DZ							16*	10	400M
1N966B	S		1N957	DZ							16*	5.0	400M
1N967	S		1N957	DZ							18*	20	400M
1N967A	S		1N957	DZ							18*	10	400M
1N967B	S		1N957	DZ							18*	5.0	400M
1N968	S		1N957	DZ							20*	20	400M
1N968A	S		1N957	DZ							20*	10	400M
1N968B	S		1N957	DZ							20*	5.0	400M
1N969	S		1N957	DZ							22*	20	400M
1N969A	S		1N957	DZ							22*	10	400M
1N969B	S		1N957	DZ							22*	5.0	400M
1N970	S		1N957	DZ							24*	20	400M
1N970A	S		1N957	DZ							24*	10	400M
1N970B	S		1N957	DZ							24*	5.0	400M
1N971	S		1N957	DZ							27*	20	400M
1N971A	S		1N957	DZ							27*	10	400M
1N971B	S		1N957	DZ							27*	5.0	400M
1N972	S		1N957	DZ							30*	20	400M
1N972A	S		1N957	DZ							30*	10	400M
1N972B	S		1N957	DZ							30*	5.0	400M
1N973	S		1N957	DZ							33*	20	400M
1N973A	S		1N957	DZ							33*	10	400M
1N973B	S		1N957	DZ							33*	5.0	400M
1N974	S		1N957	DZ							36*	20	400M
1N974A	S		1N957	DZ							36*	10	400M
1N974B	S		1N957	DZ							36*	5.0	400M
1N975	S		1N957	DZ							39*	20	400M
1N975A	S		1N957	DZ							39*	10	400M
1N975B	S		1N957	DZ							39*	5.0	400M
1N976	S		1N957	DZ							43*	20	400M
1N976A	S		1N957	DZ							43*	10	400M
1N976B	S		1N957	DZ							43*	5.0	400M
1N977	S		1N957	DZ							47*	20	400M
1N977A	S		1N957	DZ							47*	10	400M
1N977B	S		1N957	DZ							47*	5.0	400M
1N978	S		1N957	DZ							51*	20	400M
1N978A	S		1N957	DZ							51*	10	400M
1N978B	S		1N957	DZ							51*	5.0	400M
1N979	S		1N957	DZ							56*	20	400M
1N979A	S		1N957	DZ							56*	10	400M
1N979B	S		1N957	DZ							56*	5.0	400M
1N980	S		1N957	DZ							62*	20	400M
1N980A	S		1N957	DZ							62*	10	400M
1N980B	S		1N957	DZ							62*	5.0	400M
1N981	S		1N957	DZ							68*	20	400M
1N981A	S		1N957	DZ							68*	10	400M
1N981B	S		1N957	DZ							68*	5.0	400M
1N982	S		1N957	DZ							75*	20	400M
1N982A	S		1N957	DZ							75*	10	400M
1N982B	S		1N957	DZ							75*	5.0	400M
1N983	S		1N957	DZ							82*	20	400M
1N983A	S		1N957	DZ							82*	10	400M
1N983B	S		1N957	DZ							82*	5.0	400M
1N984	S		1N957	DZ							91*	20	400M
1N984A	S		1N957	DZ							91*	10	400M
1N984B	S		1N957	DZ							91*	5.0	400M
1N985	S		1N957	DZ							100*	20	400M
1N985A	S		1N957	DZ							100*	10	400M
1N985B	S		1N957	DZ							100*	5.0	400M
1N986	S		1N957	DZ							110*	20	400M
1N986A	S		1N957	DZ							110*	10	400M
1N986B	S		1N957	DZ							110*	5.0	400M
1N987	S		1N957	DZ							120*	20	400M
1N987A	S		1N957	DZ							120*	10	400M
1N987B	S		1N957	DZ							120*	5.0	400M
1N988	S		1N957	DZ							130*	20	400M
1N988A	S		1N957	DZ							130*	10	400M
1N988B	S		1N957	DZ							130*	5.0	400M
1N989	S		1N957	DZ							150*	20	400M
1N989A	S		1N957	DZ							150*	10	400M
1N989B	S		1N957	DZ							150*	5.0	400M
1N990	S		1N957	DZ							160*	20	400M

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N990A	S		1N957	DZ							160*	10	400M
1N990B	S		1N957	DZ							160*	5.0	400M
1N991	S		1N957	DZ							180*	20	400M
1N991A	S		1N957	DZ							180*	10	400M
1N991B	S		1N957	DZ							180*	5.0	400M
1N992	S		1N957	DZ							200*	20	400M
1N992A	S		1N957	DZ							200*	10	400M
1N992B	S		1N957	DZ							200*	5.0	400M
1N993	S			DS	20	1.2	10M	1.0*	4.0				
1N994	G			DS	6.5	1.0	10M	30*	2.0				
1N995	G			DS	15	0.5	10M	10*	6.0				
1N996	G			DS	20	0.8	40M	15*	0.3				
1N997	S			DS	35	1.0	10M	25N	0.15				
1N998	S			DS	150	1.0	200M	1.0N					
1N999	S			DS	100	1.0	50M	1.0N	4.0				
1N1005	G			R*	380	0.15	0.25						
1N1007	G			R*	380	0.3	0.35						
1N1008	S			R*	380	0.3	0.4						
1N1013	G			R*	380	0.15	0.25						
1N1016	G			R*	380	0.15	0.4						
1N1021	G			R*	380	0.15	0.25						
1N1022	G			R*	380	0.15	0.3						
1N1023	G			R*	380	0.15	0.35						
1N1024	G			R*	380	0.15	0.4						
1N1028	S			R*	50	1.5	0.25		15				
1N1029	S			R*	100	1.5	0.25		15				
1N1030	S			R*	150	1.5	0.25		15				
1N1031	S			R*	200	1.5	0.25		15				
1N1032	S			R*	300	1.5	0.25		15				
1N1033	S			R*	400	1.5	0.25		15				
1N1034	S			R*	50	1.5	0.5		15				
1N1035	S			R*	100	1.5	0.5		15				
1N1036	S			R*	150	1.5	0.5		15				
1N1037	S			R*	200	1.5	0.5		15				
1N1038	S			R*	300	1.5	0.5		15				
1N1039	S			R*	400	1.5	0.5		15				
1N1040	S			R*	50	1.5	0.5		15				
1N1041	S			R*	100	1.5	0.5		15				
1N1042	S			R*	150	1.5	0.5		15				
1N1043	S			R*	200	1.5	0.5		15				
1N1044	S			R*	300	1.5	0.5		15				
1N1045	S			R*	400	1.5	0.5		15				
1N1046	S			R*	50	1.5	0.5		15				
1N1047	S			R*	100	1.5	0.5		15				
1N1048	S			R*	150	1.5	0.5		15				
1N1049	S			R*	200	1.5	0.5		15				
1N1050	S			R*	300	1.5	0.5		15				
1N1051	S			R*	400	1.5	0.5		15				
1N1052	S			R*	50	1.5	0.5		20				
1N1053	S			R*	100	1.5	0.5		20				
1N1054	S			R*	150	1.5	0.5		20				
1N1055	S			R*	200	1.5	0.5		20				
1N1056	S			R*	300	1.5	0.5		20				
1N1057	S			R*	400	1.5	0.5		20				
1N1058	S			R*	50	1.5	1.5		20				
1N1059	S			R*	100	1.5	1.5		20				
1N1060	S			R*	150	1.5	1.5		20				
1N1061	S			R*	200	1.5	1.5		20				
1N1062	S			R*	300	1.5	1.5		20				
1N1063	S			R*	400	1.5	1.5		20				
1N1064	S			R*	50	1.5	1.5		20				
1N1065	S			R*	100	1.5	1.5		20				
1N1066	S			R*	150	1.5	1.5		20				
1N1067	S			R*	200	1.5	1.5		20				
1N1068	S			R*	300	1.5	1.5		20				
1N1069	S			R*	400	1.5	1.5		20				
1N1070	S			R*	50	1.5	1.5		20				
1N1071	S			R*	100	1.5	1.5		20				
1N1072	S			R*	150	1.5	1.5		20				
1N1073	S			R*	200	1.5	1.5		20				
1N1074	S			R*	300	1.5	1.5		20				
1N1075	S			R*	400	1.5	1.5		20				
1N1076	S			R*	50	1.5	5.0		50				
1N1077	S			R*	100	1.5	5.0		50				
1N1078	S			R*	150	1.5	5.0		50				
1N1079	S			R*	200	1.5	5.0		50				
1N1080	S			R*	300	1.5	5.0		50				
1N1081	S	1N4002	1N4001	R*	100	1.5	0.25		15				
1N1082	S	1N4003	1N4001	R*	200	1.5	0.25		15				
1N1083	S	1N4004	1N4001	R*	300	1.5	0.25		15				
1N1084	S	1N4004	1N4001	R*	400	1.5	0.25		15				
1N1085	S			R*	100	1.5	0.6		24				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1086	S			R*	200	1.5	0.6		24				
1N1087	S			R*	300	1.5	0.6		24				
1N1088	S			R*	400	1.5	0.6		24				
1N1089	S			R*	100	1.5	2.0		24				
1N1090	S			R*	200	1.5	2.0		24				
1N1091	S			R*	300	1.5	2.0		24				
1N1092	S			R*	400	1.5	2.0		24				
1N1093	G			DS	15	0.4	5.0M	25*	0.5				
1N1095	S	1N4005	1N4001	R*	500	0.5	0.425	0.3	15				
1N1096	S	1N4005	1N4001	R*	600	0.5	0.4	0.3	15				
1N1100	S	1N4002	1N4001	R*	100	1.2	0.25	0.2	15				
1N1101	S	1N4003	1N4001	R*	200	1.2	0.25	0.2	15				
1N1102	S	1N4004	1N4001	R*	300	1.2	0.25	0.2	15				
1N1103	S	1N4004	1N4001	R*	400	1.2	0.25	0.2	15				
1N1104	S	1N4005	1N4001	R*	500	1.2	0.25	0.2	15				
1N1105	S	1N4005	1N4001	R*	600	1.2	0.25	0.2	15				
1N1108	S			R*	800	3.0	0.225		13.5				
1N1109	S			R*	1200	4.5	0.212		12.7				
1N1110	S			R*	1600	6.0	0.2		12				
1N1111	S			R*	2000	7.5	0.187		11.2				
1N1112	S			R*	2400	9.0	0.175		10.5				
1N1113	S			R*	2800	10.5	0.162		9.7				
1N1115	S	MR1121 *	MR1120	R*	100	0.65	0.6	0.4	15				
1N1116	S	MR1122 *	MR1120	R*	200	0.65	0.6	0.3	15				
1N1117	S	MR1123 *	MR1120	R*	300	0.65	0.6	0.3	15				
1N1118	S	MR1124 *	MR1120	R*	400	0.65	0.6	0.3	15				
1N1119	S	MR1125 *	MR1120	R*	500	0.65	0.6	0.3	15				
1N1120	S	MR1126 *	MR1120	R*	600	0.65	0.6	0.3	15				
1N1124	S	*		R*	200	1.1		0.3	25				
1N1124A	S	1N1124 *		R*	200		3.3	0.3	25				
1N1125	S	*		R*	300	1.1		0.3	25				
1N1125A	S	1N1125 *		R*	300		3.3	0.3	25				
1N1126	S	*		R*	400	1.1	1.0	0.3	25				
1N1126A	S	1N1126 *		R*	400		3.3	0.3	25				
1N1127	S	*		R*	500	1.1	1.0	0.3	25				
1N1127A	S	1N1126 *		R*	500		3.3	0.3	25				
1N1128	S	*		R*	600	1.1	1.0	0.3	25				
1N1128A	S	1N1126 *		R*	600		3.3	0.3	25				
1N1130	S			R*	1500	15	0.3	0.05					
1N1131	S			R*	1500	15	0.3	0.05					
1N1132	S	Microwave S-X-band Mixer; NF = 9.5 dB											
1N1133	S			R*	1500	15	0.085	0.025	3.5				
1N1134	S			R*	1500	7.5	0.115	0.025	3.5				
1N1135	S			R*	1800	18	0.075	0.025	3.5				
1N1136	S			R*	1800	9.0	0.095	0.025	3.5				
1N1137	S			R*	2400	24	0.057	0.025	3.5				
1N1138	S			R*	2400	12	0.070	0.025	3.5				
1N1139	S			R*	3600	27	0.075	0.025	3.5				
1N1140	S			R*	3600	18	0.075	0.025	3.5				
1N1141	S			R*	4800	36	0.070	0.025	3.5				
1N1142	S			R*	4800	24	0.057	0.025	3.5				
1N1143	S			R*	6000	45	0.057	0.025	3.5				
1N1143A	S			R*	6000	30	0.075	0.025	3.5				
1N1144	S			R*	7200	54	0.057	0.025	3.5				
1N1145	S			R*	7200	36	0.070	0.025	3.5				
1N1146	S			R*	8000	60	0.050	0.025	3.5				
1N1147	S			R*	12K	60	0.050	0.025	3.5				
1N1148	S			R*	14K	52	0.057	0.025	3.5				
1N1149	S			R*	16K	60	0.050	0.025	3.5				
1N1150	S			R*	1600		0.75		8.0				
1N1150A	S			R*	1600	6.5	0.375	1.0	10				
1N1157	S			R*	50		20		200				
1N1158	S			R*	100		20						
1N1159	S			R*	200		20						
1N1160	S			R*	300		20						
1N1161	S			R*	50		35		350				
1N1162	S			R*	100		35		350				
1N1163	S			R*	200		35		350				
1N1164	S			R*	300		35		350				
1N1165	S			R*	50		100		1000				
1N1166	S			R*	100		100		1000				
1N1167	S			R*	200		100		1000				
1N1168	S			R*	300		100		1000				
1N1169	S	1N4004	1N4001	R*			0.5						
1N1169A	S	1N4004	1N4001	R*	400		0.5	3.5					
1N1170	G			DS	50	1.0	4.0M	5.0*					
1N1171	S			R*	50		20						
1N1172	S			R*	100		20						
1N1173	S			R*	200		20						
1N1174	S			R*	300		20						
1N1175	S			R*	50		35		350				
1N1176	S			R*	100		35		350				

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TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1177	S			R*	200		35		350				
1N1178	S			R*	300		35		350				
1N1179	S			R*	50		100		1000				
1N1180	S			R*	100		100		1000				
1N1181	S			R*	200		100		1000				
1N1182	S			R*	300		100		1000				
1N1183	S		1N1183	R*	50	1.7	35	10	500				
1N1184	S		1N1183	R*	100	1.7	35	10	500				
1N1185	S		1N1183	R*	150	1.7	35	10	500				
1N1186	S		1N1183	R*	200	1.7	35	10	500				
1N1187	S		1N1183	R*	300	1.7	35	10	500				
1N1188	S		1N1183	R*	400	1.7	35	10	500				
1N1189	S		1N1183	R*	500	1.7	35	10	500				
1N1189A	S			R*	500	1.2	40	2.0	800				
1N1190	S		1N1183	R*	600	1.7	35	10	500				
1N1190A	S			R*	600	1.2	40	1.8	800				
1N1191	S			R*	50	2.35	18	5.0	220				
1N1191A	S			R*	50	2.0	22	2.5	500				
1N1192	S			R*	100	2.35	18	5.0	220				
1N1192A	S			R*	100	2.0	22	2.5	500				
1N1193	S			R*	150	2.35	18	5.0	220				
1N1193A	S			R*	150	2.0	22	2.5	500				
1N1194	S			R*	200	2.35	18	5.0	220				
1N1194A	S			R*	200	2.0	22	2.5	500				
1N1195	S			R*	300	2.35	18	5.0	220				
1N1195A	S			R*	300	0.6	20	3.2	350				
1N1196	S			R*	400	2.35	18	5.0	220				
1N1196A	S			R*	400	0.6	20	2.5	350				
1N1197	S			R*	500	2.35	18	5.0	220				
1N1197A	S			R*	500	0.6	20	2.2	350				
1N1198	S			R*	600	2.35	18	5.0	220				
1N1198A	S			R*	600	0.6	20	1.5	350				
1N1199	S	*		R*	50		12	10					
1N1199A	S	1N1199 *		R*	50	1.35	12	3.0	240				
1N1199B	S			R*	50	1.2	12	0.9	250				
1N1200	S	*		R*	100		12	10					
1N1200A	S	1N1200 *		R*	100	1.35	50	2.5	12				
1N1200B	S			R*	100	1.2	12	0.9	250				
1N1201	S	*		R*	150		12	10					
1N1201A	S	1N1201 *		R*	150	1.35	50	2.25	12				
1N1201B	S			R*	150	1.2	12	0.9	250				
1N1202	S	*		R*	200		12	10					
1N1202A	S	1N1202 *		R*	200	1.35	50	2.0	12				
1N1202B	S			R*	200	1.2	12	0.9	250				
1N1203	S	*		R*	300		12	10					
1N1203A	S	1N1203 *		R*	300	1.35	50	1.75	12				
1N1203B	S			R*	300	1.2	12	0.9	250				
1N1204	S	*		R*	400		12	10					
1N1204A	S	1N1204 *		R*	400	1.35	50	1.5	12				
1N1204B	S			R*	400	1.2	12	0.9	250				
1N1205	S	*		R*	500		12	10					
1N1205A	S	1N1205 *		R*	500	1.35	50	1.25	12				
1N1205B	S			R*	500	1.2	12	0.9	250				
1N1206	S	*		R*	600		12	10					
1N1206A	S	1N1206 *		R*	600	1.35	50	1.0	12				
1N1206B	S			R*	600	1.2	12	0.9	250				
1N1217	S	1N4001	1N4001	R*	50	1.0	1.6	1.5	20				
1N1217A	S	1N4001	1N4001	R*	50	1.5	1.6	0.05					
1N1217B	S			R*	50	1.7	1.35	0.3	25				
1N1218	S	1N4002	1N4001	R*	100	1.0	1.6	1.5	20				
1N1218A	S	1N4002	1N4001	R*	100	1.5	1.6	0.05					
1N1218B	S			R*	100	1.7	1.35	0.3	25				
1N1219	S	1N4003	1N4001	R*	150	1.0	1.6	1.5	20				
1N1219A	S	1N4003	1N4001	R*	150	1.5	1.6	0.05					
1N1219B	S			R*	150	1.7	1.35	0.3	25				
1N1220	S	1N4003	1N4001	R*	200	1.0	1.6	1.5	20				
1N1220A	S	1N4003	1N4001	R*	200	1.5	1.6	0.05					
1N1220B	S			R*	200	1.7	1.35	0.3	25				
1N1221	S	1N4004	1N4001	R*	300	1.0	1.6	1.5	20				
1N1221A	S	1N4004	1N4001	R*	300	1.5	1.6	0.05					
1N1221B	S			R*	300	1.7	1.35	0.3	25				
1N1222	S	1N4004	1N4001	R*	400	1.0	1.6	1.5	20				
1N1222A	S	1N4004	1N4001	R*	400	1.5	1.6	0.05					
1N1222B	S			R*	400	1.7	1.35	0.3	25				
1N1223	S	1N4005	1N4001	R*	500	1.0	1.6	1.5	20				
1N1223A	S	1N4005	1N4001	R*	500	1.5	1.6	0.05					

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1223B	S			R*	500	1.7	1.35	0.3	25				
1N1224	S	1N4005	1N4001	R*	600	1.0	1.6	1.5	20				
1N1224A	S	1N4005	1N4001	R*	600	1.5	1.6	0.05					
1N1224B	S			R*	600	1.62	1.25	0.3	25				
1N1225	S	1N4006	1N4001	R*	700	1.0	1.6	1.5	20				
1N1225A	S	1N4006	1N4001	R*	700	1.55	1.1	0.5	25				
1N1225B	S			R*	700	1.62	1.25	0.3	25				
1N1226	S	1N4006	1N4001	R*	800	1.0	1.6	1.5	20				
1N1226A	S	1N4006	1N4001	R*	800	1.50	1.1	0.5	25				
1N1226B	S			R*	800	1.58	1.15	0.3	25				
1N1227	S			R*	50	1.0	1.6	1.5	20				
1N1227A	S	MR1120	MR1120	R*	50	1.5	1.6	0.05					
1N1228	S			R*	100	1.0	1.6	1.5	20				
1N1228A	S	MR1121	MR1120	R*	100	1.5	1.6	0.05					
1N1229	S			R*	150	1.0	1.6	1.5	20				
1N1229A	S	MR1122	MR1120	R*	150	1.5	1.6	0.05					
1N1230	S			R*	200	1.0	1.6	1.5	20				
1N1230A	S	MR1122	MR1120	R*	200	1.5	1.6	0.05					
1N1231	S			R*	300	1.0	1.6	1.5	20				
1N1231A	S	MR1123	MR1120	R*	300	1.5	1.6	0.05					
1N1232	S			R*	400	1.0	1.6	1.5	20				
1N1232A	S	MR1124	MR1120	R*	400	1.5	1.6	0.05					
1N1233	S			R*	500	1.0	1.6	1.5	20				
1N1233A	S	MR1125	MR1120	R*	500	1.5	1.6	0.05					
1N1234	S			R*	600	1.0	1.6	1.5	20				
1N1234A	S	MR1126	MR1120	R*	600	1.5	1.6	0.05					
1N1235	S			R*	700	1.0	1.6	1.5	20				
1N1236	S			R*	800	1.0	1.6	1.5	20				
1N1237	S			R*	1600		0.75		8.0				
1N1238	S			R*	1600		0.75		8.0				
1N1239	S			R*	2800		0.5		5.0				
1N1240	S			R*	50	1.0	0.25	0.5	5.0				
1N1241	S			R*	100	1.0	0.25	0.5	5.0				
1N1242	S			R*	200	1.0	0.25	0.5	5.0				
1N1243	S			R*	300	1.0	0.2	0.5	5.0				
1N1244	S			R*	400	1.0	0.15	0.5					
1N1244A	S			R*	400	1.0	0.2	0.5	5.0				
1N1245	S			R*	500	1.0	0.13	0.4					
1N1246	S			R*	600	1.0	0.115	0.3					
1N1247	S			R*	700	1.0	0.1	0.2					
1N1248	S			R*	800	1.0	0.08	0.1					
1N1249	S			R*	900	1.0	0.065	0.1					
1N1250	S			R*	1000	1.0	0.05	0.1					
1N1251	S	1N4001	1N4001	R*	50	1.0	0.25	0.5	5.0				
1N1252	S	1N4002	1N4001	R*	100	1.0	0.25	0.5	5.0				
1N1253	S	1N4003	1N4001	R*	200	1.0	0.25	0.5	5.0				
1N1254	S	1N4004	1N4001	R*	300	1.0	0.2	0.5	5.0				
1N1255	S	1N4004	1N4001	R*	400	1.0	0.15	0.5					
1N1255A	S			R*	400	1.0	0.2	0.5	5.0				
1N1256	S			R*	500	1.0	0.13	0.4					
1N1257	S			R*	600	1.0	0.115	0.3					
1N1258	S			R*	700	1.0	0.1	0.2					
1N1259	S			R*	800	1.0	0.08	0.1					
1N1260	S			R*	900	1.0	0.065	0.1					
1N1261	S			R*	1000	1.0	0.05	0.1					
1N1262	S			R*	4500		0.25		2.5				
1N1263	S			R*	50		150		1500				
1N1263A	S			R*	50		200		2000				
1N1264	S			R*	100		150		1500				
1N1264A	S			R*	100		200		2000				
1N1265	S			R*	200		150		1500				
1N1265A	S			R*	200		200		2000				
1N1266	S			R*	300		150		1500				
1N1266A	S			R*	300		200		2000				
1N1267	S			R*	50		150		1500				
1N1267A	S			R*	50		200		2000				
1N1268	S			R*	100		150		1500				
1N1268A	S			R*	100		200		2000				
1N1269	S			R*	200		150		1500				
1N1269A	S			R*	200		200		2000				
1N1270	S			R*	300		150		1500				
1N1270A	S			R*	300		200		2000				
1N1271	S			R*	50		160	40					
1N1272	S			R*	100		160	40					
1N1273	S			R*	150		160	40					
1N1274	S			R*	200		160	40					
1N1275	S			R*	300		160	40					
1N1276	S			R*	400		160	40					
1N1277	S			R*	500		160	40					
1N1281	S			R*	50		160	40					
1N1282	S			R*	100		160	40					
1N1283	S			R*	150		160	40					
1N1284	S			R*	200		160	40					

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1285	S			R*	300		160	40					
1N1286	S			R*	400		160	40					
1N1287	S			R*	500		160	40					
1N1291	S			R*	50		160	40					
1N1292	S			R*	100		160	40					
1N1293	S			R*	150		160	40					
1N1294	S			R*	200		160	40					
1N1295	S			R*	300		160	40					
1N1296	S			R*	400		160	40					
1N1297	S			R*	500		160	40					
1N1301	S			R*	50	0.63	17.5	15	300				
1N1302	S			R*	100	0.63	17.5	5.0	300				
1N1304	S			R*	200	0.63	17.5	5.0	300				
1N1306	S			R*	300	0.63	17.5	5.0	300				
1N1313	S	1N5238A *	1N5221	DZ							8*	5.0	150M
1N1313A	S	1N5238B *	1N5221	DZ							9.1*	5.0	150M
1N1314	S	1N5240A *	1N5221	DZ							10*	5.0	150M
1N1314A	S	1N5240B *	1N5221	DZ							10*	5.0	150M
1N1315	S	1N5243A *	1N5221	DZ							12*	5.0	150M
1N1315A	S	1N5243B *	1N5221	DZ							12*	5.0	150M
1N1316	S	1N5246A *	1N5221	DZ							15*	5.0	150M
1N1316A	S	1N5246B *	1N5221	DZ							15*	5.0	150M
1N1317	S	1N5249A *	1N5221	DZ							20*	5.0	150M
1N1317A	S	1N5249B *	1N5221	DZ							18*	5.0	150M
1N1318	S	1N5252A *	1N5221	DZ							25*	5.0	150M
1N1318A	S	1N5252B *	1N5221	DZ							22*	5.0	150M
1N1319	S	1N5255A *	1N5221	DZ							30*	5.0	150M
1N1319A	S	1N5255B *	1N5221	DZ							27*	5.0	150M
1N1320	S	1N5258A *	1N5221	DZ							35*	5.0	150M
1N1320A	S	1N5258B *	1N5221	DZ							33*	5.0	150M
1N1321	S	1N5259A *	1N5221	DZ							40*	5.0	150M
1N1321A	S	1N5259B *	1N5221	DZ							39*	5.0	150M
1N1322	S	1N5261A *	1N5221	DZ							50*	5.0	150M
1N1322A	S	1N5261B *	1N5221	DZ							47*	5.0	150M
1N1323	S	1N5264A *	1N5221	DZ							60*	5.0	150M
1N1323A	S	1N5264B *	1N5221	DZ							56*	5.0	150M
1N1324	S	1N5266A *	1N5221	DZ							70*	5.0	150M
1N1325	S	1N5269A *	1N5221	DZ							90*	5.0	150M
1N1326	S	1N5271A *	1N5221	DZ							105*	5.0	150M
1N1327	S	1N5274A *	1N5221	DZ							125*	5.0	150M
1N1329	S			R*	1500	1.3	0.1	0.02	2.0				
1N1330	S			R*	50		240	50					
1N1331	S			R*	100		240	50					
1N1332	S			R*	150		240	50					
1N1333	S			R*	200		240	50					
1N1334	S			R*	300		240	50					
1N1335	S			R*	400		240	50					
1N1336	S			R*	500		240	50					
1N1341	S	*		R*	50	1.6	6.0	4.0	150				
1N1341A	S	MR1120*	MR1120	R*	50	1.4	6.0	3.0	150				
1N1341B	S			R*	50	1.2	6.0	0.45	160				
1N1342	S	*		R*	100	1.6	6.0	4.0	150				
1N1342A	S	MR1121*	MR1120	R*	100	1.4	6.0	2.5	150				
1N1342B	S			R*	100	1.2	6.0	0.45	160				
1N1343	S	*		R*	150	1.6	6.0	4.0	150				
1N1343A	S	MR1122*	MR1120	R*	150	1.4	6.0	2.25	150				
1N1343B	S			R*	150	1.2	6.0	0.45	160				
1N1344	S	*		R*	200	1.6	6.0	4.0	150				
1N1344A	S	MR1122*	MR1120	R*	200	1.4	6.0	2.0	150				
1N1344B	S			R*	200	1.2	6.0	0.45	160				
1N1345	S	*		R*	300	1.6	6.0	4.0	150				
1N1345A	S	MR1123*	MR1120	R*	300	1.4	6.0	1.75	150				
1N1345B	S			R*	300	1.2	6.0	0.45	160				
1N1346	S	*		R*	400	1.6	6.0	4.0	150				
1N1346A	S	MR1124*	MR1120	R*	400	1.4	6.0	1.5	150				
1N1346B	S			R*	400	1.2	6.0	0.45	160				
1N1347	S	*		R*	500	1.6	6.0	4.0	150				
1N1347A	S	MR1125*	MR1120	R*	500	1.4	6.0	1.25	150				
1N1347B	S			R*	500	1.2	6.0	0.45	160				
1N1348	S	*		R*	600	1.6	6.0	4.0	150				
1N1348A	S	MR1126*	MR1120	R*	600	1.4	6.0	1.0	150				
1N1348B	S			R*	600	1.2	6.0	0.45	160				
1N1351	S	1N2974A *	1N2970	DZ							10*	10	10W
1N1351A	S	1N2974B *	1N2970	DZ							10*	5.0	10W
1N1352	S	1N2975A *	1N2970	DZ							11*	10	10W
1N1352A	S	1N2975B *	1N2970	DZ							11*	5.0	10W
1N1353	S	1N2976A *	1N2970	DZ							12*	10	10W
1N1353A	S	1N2976B *	1N2970	DZ							12*	5.0	10W
1N1354	S	1N2977A *	1N2970	DZ							13*	10	10W
1N1354A	S	1N2977B *	1N2970	DZ							13*	5.0	10W
1N1355	S	1N2979A *	1N2970	DZ							15*	10	10W
1N1355A	S	1N2979B *	1N2970	DZ							15*	5.0	10W

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TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1356	S	1N2980A *	1N2970	DZ							16*	10	10W
1N1356A	S	1N2980B *	1N2970	DZ							16*	5.0	10W
1N1357	S	1N2982A *	1N2970	DZ							18*	10	10W
1N1357A	S	1N2982B *	1N2970	DZ							18*	5.0	10W
1N1358	S	1N2984A *	1N2970	DZ							20*	10	10W
1N1358A	S	1N2984B *	1N2970	DZ							20*	5.0	10W
1N1359	S	1N2985A *	1N2970	DZ							22*	10	10W
1N1359A	S	1N2985B *	1N2970	DZ							22*	5.0	10W
1N1360	S	1N2986A *	1N2970	DZ							24*	10	10W
1N1360A	S	1N2986B *	1N2970	DZ							24*	5.0	10W
1N1361	S	1N2988A *	1N2970	DZ							27*	10	10W
1N1361A	S	1N2988B *	1N2970	DZ							27*	5.0	10W
1N1362	S	1N2989A *	1N2970	DZ							30*	10	10W
1N1362A	S	1N2989B *	1N2970	DZ							30*	5.0	10W
1N1363	S	1N2990A *	1N2970	DZ							33*	10	10W
1N1363A	S	1N2990B *	1N2970	DZ							33*	5.0	10W
1N1364	S	1N2991A *	1N2970	DZ							36*	10	10W
1N1364A	S	1N2991B *	1N2970	DZ							36*	5.0	10W
1N1365	S	1N2992A *	1N2970	DZ							39*	10	10W
1N1365A	S	1N2992B *	1N2970	DZ							39*	5.0	10W
1N1366	S	1N2993A *	1N2970	DZ							43*	10	10W
1N1366A	S	1N2993B *	1N2970	DZ							43*	5.0	10W
1N1367	S	1N2995A *	1N2970	DZ							47*	10	10W
1N1367A	S	1N2995B *	1N2970	DZ							47*	5.0	10W
1N1368	S	1N2997A *	1N2970	DZ							51*	10	10W
1N1368A	S	1N2997B *	1N2970	DZ							51*	5.0	10W
1N1369	S	1N2999A *	1N2970	DZ							56*	10	10W
1N1369A	S	1N2999B *	1N2970	DZ							56*	5.0	10W
1N1370	S	1N3000A *	1N2970	DZ							62*	10	10W
1N1370A	S	1N3000B *	1N2970	DZ							62*	5.0	10W
1N1371	S	1N3001A *	1N2970	DZ							68*	10	10W
1N1371A	S	1N3001B *	1N2970	DZ							68*	5.0	10W
1N1372	S	1N3002A *	1N9270	DZ							75*	10	10W
1N1372A	S	1N3002B *	1N9270	DZ							75*	5.0	10W
1N1373	S	1N3003A *	1N2970	DZ							82*	10	10W
1N1373A	S	1N3003B *	1N2970	DZ							82*	5.0	10W
1N1374	S	1N3004A *	1N2970	DZ							91*	10	10W
1N1374A	S	1N3004B *	1N2970	DZ							91*	5.0	10W
1N1375	S	1N3005A *	1N2970	DZ							100*	10	10W
1N1375A	S	1N3005B *	1N2970	DZ							100*	5.0	10W
1N1376	S			R*	50		240	50					
1N1377	S			R*	100		240	50					
1N1378	S			R*	150		240	50					
1N1379	S			R*	200		240	50					
1N1380	S			R*	300		240	50					
1N1381	S			R*	400		240	50					
1N1382	S			R*	500		240	50					
1N1396	S	MR1810SB		R*	50	1.55	70	15	1200				
1N1397	S	MR1811SB		R*	100	1.55	70	15	1200				
1N1398	S	MR1812SB		R*	150	1.55	70	15	1200				
1N1399	S	MR1813SB		R*	200	1.55	70	15	1200				
1N1400	S	MR1815SB		R*	300	1.55	70	15	1200				
1N1401	S	MR1817SB		R*	400	1.55	70	15	1200				
1N1402	S	MR1818SB		R*	500	1.55	70	15	1200				
1N1403	S	MR1819SB		R*	600	1.55	70	15	1200				
1N1406	S	1N4005	1N4001	R*	600	5.0	0.1	0.1	3.5				
1N1407	S	1N4006	1N4001	R*	800	5.0	1.0	0.1	3.5				
1N1408	S	1N4007	1N4001	R*	1000	5.0	1.0	0.1	3.5				
1N1409	S	MR991A	MR990A	R*	1200	5.0	0.1	0.1	3.5				
1N1410	S	MR991A	MR990A	R*	1500	6.25	0.1	0.1	3.5				
1N1411	S	MR992A	MR990A	R*	1800	7.5	0.1	0.1	3.5				
1N1412	S	MR992A	MR990A	R*	2000	6.25	0.1	0.1	3.5				
1N1413	S	MR993A	MR990A	R*	2400	7.5	0.1	0.1	3.5				
1N1414	S			R*	400	1.25	10	1.0	100				
1N1415	S			DS		1.1	1.0	1.0*					
1N1416	S	1N2972B	1N2970	DZ							8.2*	5.0	10W
1N1417	S	1N2976B	1N2970	DZ							12*	5.0	10W
1N1418	S	1N2979B	1N2970	DZ							15*	5.0	10W
1N1419	S	1N2982B	1N2970	DZ							18*	5.0	10W
1N1420	S	1N2985B	1N2970	DZ							22*	5.0	10W
1N1421	S	1N2988B	1N2970	DZ							27*	5.0	10W
1N1422	S	1N3001B	1N2970	DZ							68*	5.0	10W
1N1423	S	1N3005B	1N2970	DZ							100*	5.0	10W
1N1424	S	1N3011B	1N2970	DZ							150*	5.0	10W
1N1425	S	1N4738A	1N2970	DZ							8.2*	5.0	1.0W
1N1426	S	1N4742A	1N2970	DZ							12*	5.0	1.0W
1N1427	S	1N4744A	1N2970	DZ							15*	5.0	1.0W
1N1428	S	1N4746A	1N2970	DZ							18*	5.0	1.0W
1N1429	S	1N4748A	1N2970	DZ							22*	5.0	1.0W
1N1430	S	1N4750A	1N2070	DZ							27*	5.0	1.0W
1N1431	S	1N4760A	1N2070	DZ							68*	5.0	1.0W
1N1432	S	1N4764A	1N2070	DZ							100*	5.0	1.0W

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					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1433	S	1M150ZS5		DZ							150*	5.0	10W
1N1434	S	1N1183	1N1183	R*	50	1.2	30	5.0					
1N1435	S	1N1184	1N1183	R*	100	1.2	30	5.0					
1N1436	S	1N1186	1N1183	R*	200	1.2	30	5.0					
1N1437	S	1N1188	1N1183	R*	400	1.2	30	5.0					
1N1438	S	1N1190	1N1183	R*	600	1.2	30	5.0					
1N1440	S			R*	200	1.2	0.75	0.5	30				
1N1441	S			R*	300	1.2	0.75	0.5	30				
1N1442	S			R*	400	1.2	0.75	0.5	30				
1N1443	S	1N4007	1N4001	R*	1000	1.0	1.6	1.5	20				
1N1443A	S			R*	1000	1.45	1.1	0.5	25				
1N1443B	S			R*	1000	1.55	1.1	0.3	25				
1N1444	S	MR1130	MR1120	R*	1000	1.0	1.6	1.5	20				
1N1445	S			R*	360	2.0	0.2	4.0					
1N1446	S			R*	100	2.0		2.0					
1N1447	S			R*	200	2.0		2.0					
1N1448	S			R*	300	1.4		2.0					
1N1449	S			R*	400	2.0		2.0					
1N1450	S			R*	100	1.4		5.0					
1N1451	S			R*	200	1.4		5.0					
1N1452	S			R*	300	1.4		5.0					
1N1453	S			R*	400	1.4		5.0					
1N1454	S			R*	100	1.5	25	25					
1N1455	S			R*	200	1.5	25	25					
1N1456	S			R*	300	1.5	25	25					
1N1457	S			R*	400	1.5	25	25					
1N1458	S			R*	100	1.5	35	25					
1N1459	S			R*	200	1.5	35	25					
1N1460	S			R*	300	1.5	35	25					
1N1461	S			R*	400	1.5	35	25					
1N1462	S			R*	100	1.5	50	50					
1N1463	S			R*	200	1.5	50	50					
1N1464	S			R*	300	1.5	50	50					
1N1465	S			R*	400	1.5	50	50					
1N1466	S	MR1221FB		R*	100	1.5	75	50					
1N1467	S	MR1223FB		R*	200	1.5	75	50					
1N1468	S	MR1225FB		R*	300	1.5	75	50					
1N1469	S	MR1227FB		R*	400	1.5	75	50					
1N1470	S			R*	100	1.5	100	100					
1N1471	S			R*	200	1.5	100	100					
1N1472	S			R*	300	1.5	100	100					
1N1473	S			R*	400	1.5	100	100					
1N1474	S			R*	100	1.5	150	100					
1N1475	S			R*	200	1.5	150	100					
1N1476	S			R*	300	1.5	150	100					
1N1477	S			R*	400	1.5	150	100					
1N1478	S	MR1241FB	MR1240	R*	100	1.5	200	100					
1N1479	S	MR1243FB	MR1240	R*	200	1.5	200	100					
1N1480	S	MR1245FB	MR1240	R*	300	1.5	200	100					
1N1481	S	MR1247FB	MR1240	R*	400	1.5	200	100					
1N1482	S	1N3995A	1N3993	DZ						4.47	4.93		10W
1N1483	S	1N3998A	1N3993	DZ						5.90	6.50		10W
1N1484	S	1N4732A	1N4728	DZ						4.47	4.93		1.0W
1N1485	S	1N4735A	1N4728	DZ							6.2*	5.0	1.0W
1N1486	S	1N4005	1N4001	R*	500		0.5	3.5					
1N1487	S	1N4002	1N4001	R*	100	0.55	0.25	0.4	15				
1N1488	S	1N4003	1N4001	R*	200	0.55	0.25	0.3	15				
1N1489	S	1N4004	1N4001	R*	300	0.55	0.25	0.3	15				
1N1490	S	1N4004	1N4001	R*	400	0.55	0.25	0.3	15				
1N1491	S	1N4005	1N4001	R*	500	0.55		0.3	15				
1N1492	S	1N4005	1N4001	R*	600	0.55		0.3	15				
1N1507	S	1N4730 *	1N4728	DZ							3.9*	10	750M
1N1507A	S	1N4730A *	1N4728	DZ							3.9*	5.0	750M
1N1508	S	1N4732 *	1N4728	DZ							4.7*	10	750M
1N1508A	S	1N4732A *	1N4728	DZ							4.7*	5.0	750M
1N1509	S	1N4734 *	1N4728	DZ							5.6*	10	750M
1N1509A	S	1N4734A *	1N4728	DZ							5.6*	5.0	750M
1N1510	S	1N4736 *	1N4728	DZ							6.8*	10	750M
1N1510A	S	1N4736A *	1N4728	DZ							6.8*	5.0	750M
1N1511	S	1N4738 *	1N4728	DZ							8.2*	10	750M
1N1511A	S	1N4738A *	1N4728	DZ							8.2*	5.0	750M
1N1512	S	1N4740 *	1N4728	DZ							10*	10	750M
1N1512A	S	1N4740A *	1N4728	DZ							10*	5.0	750M
1N1513	S	1N4742 *	1N4728	DZ							12*	10	750M
1N1513A	S	1N4742A *	1N4728	DZ							12*	5.0	750M
1N1514	S	1N4744 *	1N4728	DZ							15*	10	750M
1N1514A	S	1N4744A *	1N4728	DZ							15*	5.0	750M
1N1515	S	1N4746 *	1N4728	DZ							18*	10	750M
1N1515A	S	1N4746A *	1N4728	DZ							18*	5.0	750M
1N1516	S	1N4748 *	1N4728	DZ							22*	10	750M
1N1516A	S	1N4748A *	1N4728	DZ							22*	5.0	750M
1N1517	S	1N4750 *	1N4728	DZ							27*	10	750M

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					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1517A	S	1N4750A *	1N4728	DZ							27*	5.0	750M
1N1518	S	1N4730 *	1N4728	DZ							3.9*	10	1.0W
1N1518A	S	1N4730A *	1N4728	DZ							3.9*	5.0	1.0W
1N1519	S	1N4732 *	1N4728	DZ							4.7*	10	1.0W
1N1519A	S	1N4732A *	1N4728	DZ							4.7*	5.0	1.0W
1N1520	S	1N4734 *	1N4728	DZ							5.6*	10	1.0W
1N1520A	S	1N4734A *	1N4728	DZ							5.6*	5.0	1.0W
1N1521	S	1N4736 *	1N4728	DZ							6.8*	10	1.0W
1N1521A	S	1N4736A *	1N4728	DZ							6.8*	5.0	1.0W
1N1522	S	1N4738 *	1N4728	DZ							8.2*	10	1.0W
1N1522A	S	1N4738A *	1N4728	DZ							8.2*	5.0	1.0W
1N1523	S	1N4740 *	1N4728	DZ							10*	10	1.0W
1N1523A	S	1N4740A *	1N4728	DZ							10*	5.0	1.0W
1N1524	S	1N4742 *	1N4728	DZ							12*	10	1.0W
1N1524A	S	1N4742A *	1N4728	DZ							12*	5.0	1.0W
1N1525	S	1N4744 *	1N4728	DZ							15*	10	1.0W
1N1525A	S	1N4744A *	1N4728	DZ							15*	5.0	1.0W
1N1526	S	1N4746 *	1N4728	DZ							18*	10	1.0W
1N1526A	S	1N4746A *	1N4728	DZ							18*	5.0	1.0W
1N1527	S	1N4748 *	1N4728	DZ							22*	10	1.0W
1N1527A	S	1N4748A *	1N4728	DZ							22*	5.0	1.0W
1N1528	S	1N4750 *	1N4728	DZ							27*	10	1.0W
1N1528A	S	1N4750A *	1N4728	DZ							27*	5.0	1.0W
1N1530	S	1N3156 *	1N3154	DR							8.4	-55	100
1N1530A	S	1N3157 *	1N3154	DR							8.4	-55	100
1N1537	S	MR1120 *		R*	50	1.5	1.6	0.05					
1N1538	S	MR1121 *		R*	100	1.5	1.6	0.05					
1N1539	S	MR1122 *		R*	150	1.5	1.6	0.05					
1N1540	S	MR1122 *		R*	200	1.5	1.6	0.05					
1N1541	S	MR1123 *		R*	300	1.5	1.6	0.05					
1N1542	S	MR1124 *		R*	400	1.5	1.6	0.05					
1N1543	S	MR1125 *		R*	500	1.5	1.6	0.05					
1N1544	S	MR1126 *		R*	600	1.5	1.6	0.05					
1N1551	S	MR1121		R*	100	1.4		1.0					
1N1552	S	MR1122		R*	200	1.4		1.0					
1N1553	S	MR1123		R*	300	1.4		1.0					
1N1554	S	MR1124		R*	400	1.4		1.0					
1N1555	S	MR1125		R*	500	1.4		1.0					
1N1556	S			R*	100	1.4		1.0					
1N1557	S			R*	200	1.4		1.0					
1N1558	S			R*	300	1.4		1.0					
1N1559	S			R*	400	1.4		1.0					
1N1560	S			R*	500	1.4		1.0					
1N1561	G			DS	25	0.4	12M	25*					
1N1562	G			DS	25	0.4	8.0M	25*					
1N1563	S			R*	100	1.5	1.0	0.003	70				
1N1563A	S			R*	100	1.5	1.5	0.003	70				
1N1564	S			R*	200	1.5	1.0	0.003	70				
1N1564A	S			R*	200	1.5	1.5	0.003	70				
1N1565	S			R*	300	1.5	1.0	0.003	70				
1N1565A	S			R*	300	1.5	1.5	0.003	70				
1N1566	S			R*	400	1.5	1.0	0.003	70				
1N1566A	S			R*	400	1.5	1.5	0.003	70				
1N1567	S			R*	500	1.2	1.0	0.005	70				
1N1567A	S			R*	500	1.5	1.5	0.003	70				
1N1568	S			R*	600	1.2	1.0	0.005	70				
1N1568A	S			R*	600	1.5	1.5	0.003	70				
1N1569	S			R*	100	1.5	1.0	0.005	70				
1N1570	S			R*	200	1.5	1.0	0.005	70				
1N1571	S			R*	300	1.5	1.0	0.005	70				
1N1572	S			R*	400	1.5	1.0	0.005	70				
1N1573	S			R*	500	1.5	1.0	0.005	70				
1N1574	S			R*	600	1.5	1.0	0.005	70				
1N1575	S			R*	100	1.5	3.5	0.005	70				
1N1576	S			R*	200	1.5	3.5	0.005	70				
1N1577	S			R*	300	1.5	3.5	0.005	70				
1N1578	S			R*	400	1.5	3.5	0.005	70				
1N1579	S			R*	500	1.5	3.5	0.005	70				
1N1580	S			R*	600	1.5	3.5	0.005	70				
1N1581	S	MR1120	MR1120	R*	50	1.5	3.0	5.0	40				
1N1582	S	MR1121	MR1120	R*	100	1.5	3.0	5.0	40				
1N1583	S	MR1122	MR1120	R*	200	1.5	3.0	5.0	40				
1N1584	S	MR1123	MR1120	R*	300	1.5	3.0	5.0	40				
1N1585	S	MR1124	MR1120	R*	400	1.5	3.0	5.0	40				
1N1586	S	MR1125	MR1120	R*	500	1.5	3.0	5.0	40				
1N1587	S	MR1126	MR1120	R*	600	1.5	3.0	5.0	40				
1N1588	S	1N3993 *	1N3993	DZ							3.9*	10	3.5W
1N1588A	S	1N3993A *	1N3993	DZ							3.9*	5.0	3.5W
1N1589	S	1N3995 *	1N3993	DZ							4.7*	10	3.5W
1N1589A	S	1N3995A *	1N3993	DZ							4.7*	5.0	3.5W
1N1590	S	1N3997 *	1N3993	DZ							5.6*	10	3.5W
1N1590A	S	1N3997A *	1N3993	DZ							5.6*	5.0	3.5W

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TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1591	S	1N2970RA *	1N2970	DZ							6.8*	10	3.5W
1N1591A	S	1N2970RB *	1N2970	DZ							6.8*	5.0	3.5W
1N1592	S	1N2972RA *	1N2970	DZ							8.2*	10	3.5W
1N1592A	S	1N2972RB *	1N2970	DZ							8.2*	5.0	3.5W
1N1593	S	1N2974RA *	1N2970	DZ							10*	10	3.5W
1N1593A	S	1N2974RB *	1N2970	DZ							10*	5.0	3.5W
1N1594	S	1N2976RA *	1N2970	DZ							12*	10	3.5W
1N1594A	S	1N2976RB *	1N2970	DZ							12*	5.0	3.5W
1N1595	S	1N2979RA *	1N2970	DZ							15*	10	3.5W
1N1595A	S	1N2979RB *	1N2970	DZ							15*	5.0	3.5W
1N1596	S	1N2982RA *	1N2970	DZ							18*	10	3.5W
1N1596A	S	1N2982RB *	1N2970	DZ							18*	5.0	3.5W
1N1597	S	1N2985RA *	1N2970	DZ							22*	10	3.5W
1N1597A	S	1N2985RB *	1N2970	DZ							22*	5.0	3.5W
1N1598	S	1N2988RA *	1N2970	DZ							27*	10	3.5W
1N1598A	S	1N2988RB *	1N2970	DZ							27*	5.0	3.5W
1N1599	S	1N3993 *	1N3993	DZ							3.9*	10	10W
1N1599A	S	1N3993A *	1N3993	DZ							3.9*	5.0	10W
1N1600	S	1N3995 *	1N3993	DZ							4.7*	10	10W
1N1600A	S	1N3995A *	1N3993	DZ							4.7*	5.0	10W
1N1601	S	1N3997 *	1N3993	DZ							5.6*	10	10W
1N1601A	S	1N3997A *	1N3993	DZ							5.6*	5.0	10W
1N1602	S	1N2970RA *	1N2970	DZ							6.8*	10	10W
1N1602A	S	1N2970RB *	1N2970	DZ							6.8*	5.0	10W
1N1603	S	1N2972RA *	1N2970	DZ							8.2*	10	10W
1N1603A	S	1N2972RB *	1N2970	DZ							8.2*	5.0	10W
1N1604	S	1N2974RA *	1N2970	DZ							10*	10	10W
1N1604A	S	1N2974RB *	1N2970	DZ							10*	5.0	10W
1N1605	S	1N2976RA *	1N2970	DZ							12*	10	10W
1N1605A	S	1N2976RB *	1N2970	DZ							12*	5.0	10W
1N1606	S	1N2979RA *	1N2970	DZ							15*	10	10W
1N1606A	S	1N2979RB *	1N2970	DZ							15*	5.0	10W
1N1607	S	1N2982RA *	1N2970	DZ							18*	10	10W
1N1607A	S	1N2982RB *	1N2970	DZ							18*	5.0	10W
1N1608	S	1N2985RA *	1N2970	DZ							22*	10	10W
1N1608A	S	1N2985RB *	1N2970	DZ							22*	5.0	10W
1N1609	S	1N2988RA *	1N2970	DZ							27*	10	10W
1N1609A	S	1N2988RB *	1N2970	DZ							27*	5.0	10W
1N1610	S	Microwave S-X-band Detector											
1N1611	S	Microwave C-X-band Detector											
1N1611A	S	Microwave C-X-band Detector											
1N1611B	S	Microwave C-X-band Detector											
1N1612	S	MR1120 *	MR1120	R*	50	1.5	5.0	1.0					
1N1613	S	MR1121 *	MR1120	R*	100	1.5	5.0	1.0					
1N1614	S	MR1122 *	MR1120	R*	200	1.5	5.0	1.0					
1N1615	S	MR1124 *	MR1120	R*	400	1.5	5.0	1.0					
1N1616	S	MR1126 *	MR1120	R*	600	1.5	5.0	1.0					
1N1617	S	1N4002	1N4001	R*	100	1.2	1.5		60				
1N1618	S	1N4003	1N4001	R*	200	1.2	1.5		60				
1N1619	S	1N4004	1N4001	R*	300	1.2	1.5		60				
1N1620	S	1N4004	1N4001	R*	400	1.2	1.5		60				
1N1621	S			R*	100	1.2	10		80				
1N1622	S			R*	200	1.2	10		80				
1N1623	S			R*	300	1.2	10		80				
1N1624	S			R*	400	1.2	10		80				
1N1625	Se			R*	48	1.0		0.015	0.005				
1N1625A	Se			R*	48	1.0		0.015	0.01				
1N1626	Se			R*	96	2.0		0.015	0.005				
1N1626A	Se			R*	96	2.0		0.015	0.01				
1N1627	Se			R*	48	1.0		0.027	0.08				
1N1628	Se			R*	96	2.0		0.027	0.08				
1N1629	Se			R*	144	3.0		0.027	0.08				
1N1630	Se			R*	192	4.0		0.027	0.08				
1N1631	Se			R*	240	5.0		0.027	0.08				
1N1632	Se			R*	288	6.0		0.027	0.08				
1N1633	Se			R*	336	7.0		0.027	0.08				
1N1634	Se			R*	384	8.0		0.027	0.08				
1N1635	Se			R*	48	1.0		0.108	0.25				
1N1636	Se			R*	96	2.0		0.108	0.25				
1N1637	Se			R*	144	3.0		0.108	0.25				
1N1638	Se			R*	192	4.0		0.108	0.25				
1N1639	Se			R*	240	5.0		0.108	0.25				
1N1640	Se			R*	48	1.0	0.028	0.240	0.55				
1N1641	Se			R*	96	2.0	0.028	0.240	0.55				
1N1642	Se			R*	144	3.0	0.028	0.240	0.55				
1N1644	S			R*	50	0.5	0.25	0.4	15				
1N1645	S			R*	100	0.5	0.25	0.4	15				
1N1646	S			R*	150	0.5	0.25	0.3	15				
1N1647	S			R*	200	0.5	0.25	0.3	15				
1N1648	S			R*	250	0.5	0.25	0.3	15				
1N1649	S			R*	300	0.5	0.25	0.3	15				
1N1650	S			R*	350	0.5	0.25	0.3	15				

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					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1651	S			R*	400	0.5	0.25	0.3	15				
1N1652	S			R*	500	0.5	0.25	0.3	15				
1N1653	S			R*	600	0.5	0.25	0.3	15				
1N1660	S			R*	50		160	40					
1N1661	S	MR1221SB	MR1220	R*	100		160	40					
1N1662	S	MR1222SB	MR1220	R*	150		160	40					
1N1663	S	MR1223SB	MR1220	R*	200		160	40					
1N1664	S	MR1225SB	MR1220	R*	300		160	40					
1N1665	S	MR1227SB	MR1220	R*	400		160	40					
1N1666	S	MR1228SB	MR1220	R*	500		160	40					
1N1670	S			R*	50		240	50					
1N1671	S			R*	100		240	50					
1N1672	S			R*	150		240	50					
1N1673	S			R*	200		240	50					
1N1674	S			R*	300		240	50					
1N1675	S			R*	400		240	50					
1N1676	S			R*	500		240	50					
1N1680	S			R*	150	1.1	50	25	700				
1N1681	S			R*	250	1.1	50	25	700				
1N1682	S			R*	300	1.1	50	25	700				
1N1683	S			R*	350	1.1	50	25	700				
1N1684	S			R*	400	1.1	50	25	700				
1N1685	S			R*	450	1.1	50	25	700				
1N1686	S			R*	500	1.1	50	25	700				
1N1687	S			R*	600	1.1	50	25	700				
1N1688	S			R*	700	1.1	50	25	700				
1N1689	S			R*	800	1.1	50	25	700				
1N1690	S			R*	900	1.1	50	25	700				
1N1691	S			R*	1000	1.1	50	25	700				
1N1692	S	1N4002	1N4001	R*	100	0.6	0.25	0.5	20				
1N1693	S	1N4003	1N4001	R*	200	0.6	0.25	0.5	20				
1N1694	S	1N4004	1N4001	R*	300	0.6	0.25	0.5	20				
1N1695	S	1N4004	1N4001	R*	400	0.6	0.25	0.5	20				
1N1696	S	1N4005	1N4001	R*	500	0.6		0.5	20				
1N1697	S	1N4005	1N4001	R*	600	0.6		0.5	20				
1N1698	S			R*	6600	33	0.062						
1N1699	S			R*	10K	37	0.058						
1N1700	S			R*	12K	45	0.05						
1N1701	S	1N4001	1N4001	R*	50	1.3	0.3	0.2	8.0				
1N1702	S	1N4002	1N4001	R*	100	1.3	0.3	0.2	8.0				
1N1703	S	1N4003	1N4001	R*	200	1.3	0.3	0.2	8.0				
1N1704	S	1N4004	1N4001	R*	300	1.3	0.3	0.2	8.0				
1N1705	S	1N4004	1N4001	R*	400	1.3	0.3	0.2	8.0				
1N1706	S	1N4005	1N4001	R*	500	1.3	0.3	0.2	8.0				
1N1707	S	1N4001	1N4001	R*	50	1.15	0.5	0.2	10				
1N1708	S	1N4002	1N4001	R*	100	1.15	0.5	0.2	10				
1N1709	S	1N4003	1N4001	R*	200	1.15	0.5	0.2	10				
1N1710	S	1N4004	1N4001	R*	300	1.15	0.5	0.2	10				
1N1711	S	1N4004	1N4001	R*	400	1.15	0.5	0.2	10				
1N1712	S	1N4005	1N4001	R*	500	1.15	0.5	0.2	10				
1N1730	S	1N4007	1N4001	R*	1000	5.0		0.1	2.5				
1N1730A	S			R*	1000		0.35		6.0				
1N1731	S	MR991A	MR990A	R*	1500	5.0		0.1	2.5				
1N1731A	S			R*	1500		0.35		6.0				
1N1732	S	MR992A	MR990A	R*	2000	9.0		0.1	2.5				
1N1732A	S			R*	2000		0.35		6.0				
1N1733	S	MR994A	MR990A	R*	3000	12		0.1	2.5				
1N1733A	S			R*	3000		0.35		6.0				
1N1734	S	MR996A	MR990A	R*	5000	18		0.1	2.5				
1N1734A	S			R*	5000		0.35		6.0				
1N1735	S	1N821 *	1N821	DR						0.01	6.2	-55	100
1N1736	S	1N941A *	1N941	DR						0.01	12.4	-55	100
1N1736A	S	1N942A *	1N941	DR						0.005	12.4	-55	100
1N1737	S	1N4060 *	1N429	DR						0.01	18.6	-55	100
1N1737A	S	1N4060A *	1N429	DR						0.005	18.6	-55	100
1N1738	S	1N4062 *	1N429	DR						0.01	24.8	-55	100
1N1738A	S	1N4062A *	1N429	DR						0.005	24.8	-55	100
1N1739	S	1N4064 *	1N429	DR						0.01	31.0	-55	100
1N1739A	S	1N4064A *	1N429	DR						0.005	31.0	-55	100
1N1740	S	1N4066 *	1N429	DR						0.01	37.2	-55	100
1N1740A	S	1N4066A *	1N429	DR						0.005	37.2	-55	100
1N1741	S	1N4067 *	1N429	DR						0.01	43.4	-55	100
1N1741A	S	1N4067A *	1N429	DR						0.005	43.4	-55	100
1N1742	S	1N4069 *	1N429	DR						0.01	49.6	-55	100
1N1742A	S	1N4069A *	1N429	DR						0.005	49.6	-55	100
1N1743	S	1N2974A	1N2970	DZ							10*	5.0	10W
1N1744	S	1N4740	1N4728	DZ							10*	10	1.0W
1N1745	S			R*	1500	15	0.32	0.2	3.5				
1N1746	S			R*	1500	7.5	0.5	0.2	3.5				
1N1747	S			R*	1800	18	0.31	0.2	3.5				
1N1748	S			R*	1800	9.0	0.38	0.2	3.5				
1N1749	S			R*	2400	24	0.37	0.2	3.5				

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1750	S			R*	2400	12	0.32	0.2	3.5				
1N1751	S			R*	3600	27	0.42	0.2	3.5				
1N1752	S			R*	3600	18	0.41	0.2	3.5				
1N1753	S			R*	4800	36	0.38	0.2	3.5				
1N1754	S			R*	4800	24	0.37	0.2	3.5				
1N1755	S			R*	6000	45	0.33	0.2	3.5				
1N1756	S			R*	6000	30	0.41	0.2	3.5				
1N1757	S			R*	7200	54	0.33	0.2	3.5				
1N1758	S			R*	7200	36	0.38	0.2	3.5				
1N1759	S			R*	8000	60	0.29	0.2	3.5				
1N1760	S			R*	12K	60	0.29	0.2	3.5				
1N1761	S			R*	14K	52	0.34	0.2	3.5				
1N1762	S			R*	16K	60	0.29	0.2	3.5				
1N1763	S	1N4004	1N4001	R*	400	3.0	0.5	0.1	35				
1N1763A	S			R*	400	1.2	1.0	0.5	25				
1N1764	S	1N4005	1N4001	R*	500	3.0	0.5	0.1	35				
1N1764A	S			R*	500	1.2	1.0	0.5	25				
1N1765	S	1N4734 *	1N4728	DZ							5.6*	10	1.0W
1N1765A	S	1N4734A *	1N4728	DZ							5.6*	5.0	1.0W
1N1766	S	1N4735 *	1N4728	DZ							6.2*	10	1.0W
1N1766A	S	1N4735A *	1N4728	DZ							6.2*	5.0	1.0W
1N1767	S	1N4736 *	1N4728	DZ							6.8*	10	1.0W
1N1767A	S	1N4736A *	1N4728	DZ							6.8*	5.0	1.0W
1N1768	S	1N4737 *	1N4728	DZ							7.5*	10	1.0W
1N1768A	S	1N4737A *	1N4728	DZ							7.5*	5.0	1.0W
1N1769	S	1N4738 *	1N4728	DZ							8.2*	10	1.0W
1N1769A	S	1N4738A *	1N4728	DZ							8.2*	5.0	1.0W
1N1770	S	1N4739 *	1N4728	DZ							9.1*	10	1.0W
1N1770A	S	1N4739A *	1N4728	DZ							9.1*	5.0	1.0W
1N1771	S	1N4740 *	1N4728	DZ							10*	10	1.0W
1N1771A	S	1N4740A *	1N4728	DZ							10*	5.0	1.0W
1N1772	S	1N4741 *	1N4728	DZ							11*	10	1.0W
1N1772A	S	1N4741A *	1N4728	DZ							11*	5.0	1.0W
1N1773	S	1N4742 *	1N4728	DZ							12*	10	1.0W
1N1773A	S	1N4742A *	1N4728	DZ							12*	5.0	1.0W
1N1774	S	1N4743 *	1N4728	DZ							13*	10	1.0W
1N1174A	S	1N4743A *	1N4728	DZ							13*	5.0	1.0W
1N1775	S	1N4744 *	1N4728	DZ							15*	10	1.0W
1N1775A	S	1N4744A *	1N4728	DZ							15*	5.0	1.0W
1N1776	S	1N4745 *	1N4728	DZ							16*	10	1.0W
1N1776A	S	1N4745A *	1N4728	DZ							16*	5.0	1.0W
1N1777	S	1N4746 *	1N4728	DZ							18*	10	1.0W
1N1777A	S	1N4746A *	1N4728	DZ							18*	5.0	1.0W
1N1778	S	1N4747 *	1N4728	DZ							20*	10	1.0W
1N1778A	S	1N4747A *	1N4728	DZ							20*	5.0	1.0W
1N1779	S	1N4748 *	1N4728	DZ							22*	10	1.0W
1N1779A	S	1N4748A *	1N4728	DZ							22*	5.0	1.0W
1N1780	S	1N4749 *	1N4728	DZ							24*	10	1.0W
1N1780A	S	1N4749A *	1N4728	DZ							24*	5.0	1.0W
1N1781	S	1N4750 *	1N4728	DZ							27*	10	1.0W
1N1781A	S	1N4750A *	1N4728	DZ							27*	5.0	1.0W
1N1782	S	1N4751 *	1N4728	DZ							30*	10	1.0W
1N1782A	S	1N4751A *	1N4728	DZ							30*	5.0	1.0W
1N1783	S	1N4752 *	1N4728	DZ							33*	10	1.0W
1N1783A	S	1N4752A *	1N4728	DZ							33*	5.0	1.0W
1N1784	S	1N4753 *	1N4728	DZ							36*	10	1.0W
1N1784A	S	1N4753A *	1N4728	DZ							36*	5.0	1.0W
1N1785	S	1N4754 *	1N4728	DZ							39*	10	1.0W
1N1785A	S	1N4754A *	1N4728	DZ							39*	5.0	1.0W
1N1786	S	1N4755 *	1N4728	DZ							43*	10	1.0W
1N1786A	S	1N4755A *	1N4728	DZ							43*	5.0	1.0W
1N1787	S	1N4756 *	1N4728	DZ							47*	10	1.0W
1N1787A	S	1N4756A *	1N4728	DZ							47*	5.0	1.0W
1N1788	S	1N4757 *	1N4728	DZ							51*	10	1.0W
1N1788A	S	1N4757A *	1N4728	DZ							51*	5.0	1.0W
1N1789	S	1N4758 *	1N4728	DZ							56*	10	1.0W
1N1789A	S	1N4758A *	1N4728	DZ							56*	5.0	1.0W
1N1790	S	1N4759 *	1N4728	DZ							62*	10	1.0W
1N1790A	S	1N4759A *	1N4728	DZ							62*	5.0	1.0W
1N1791	S	1N4760 *	1N4728	DZ							68*	10	1.0W
1N1791A	S	1N4760A *	1N4728	DZ							68*	5.0	1.0W
1N1792	S	1N4761 *	1N4728	DZ							75*	10	1.0W
1N1792A	S	1N4761A *	1N4728	DZ							75*	5.0	1.0W
1N1793	S	1N4762 *	1N4728	DZ							82*	10	1.0W
1N1793A	S	1N4762A *	1N4728	DZ							82*	5.0	1.0W
1N1794	S	1N4763 *	1N4728	DZ							91*	10	1.0W
1N1794A	S	1N4763A *	1N4728	DZ							91*	5.0	1.0W
1N1795	S	1N4764 *	1N4728	DZ							100*	10	1.0W
1N1795A	S	1N4764A *	1N4728	DZ							100*	5.0	1.0W
1N1796	S	1M110ZS10*	1N4728	DZ							110*	10	1.0W
1N1796A	S	1M110ZS5 *	1N4728	DZ							110*	5.0	1.0W
1N1797	S	1M120ZS10*	1N4728	DZ							120*	10	1.0W

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1797A	S	1M120ZS5 *	1N4728	DZ							120*	5.0	1.0W
1N1798	S	1M130ZS10 *	1N4728	DZ							130*	10	1.0W
1N1798A	S	1M130ZS5 *	1N4728	DZ							130*	5.0	1.0W
1N1799	S	1M150ZS10 *	1N4728	DZ							150*	10	1.0W
1N1799A	S	1M150ZS5 *	1N4728	DZ							150*	5.0	1.0W
1N1800	S	1M160ZS10 *	1N4728	DZ							160*	10	1.0W
1N1800A	S	1M160ZS5 *	1N4728	DZ							160*	5.0	1.0W
1N1801	S	1M180ZS10 *	1N4728	DZ							180*	10	1.0W
1N1801A	S	1M180ZS5 *	1N4728	DZ							180*	5.0	1.0W
1N1802	S	1M200ZS10 *	1N4728	DZ							200*	10	1.0W
1N1802A	S	1M200ZS5 *	1N4728	DZ							200*	5.0	1.0W
1N1803	S	1N3997R *	1N3993	DZ							5.6*	10	10W
1N1803A	S	1N3997RA *	1N3993	DZ							5.6*	5.0	10W
1N1804	S	1N3998R *	1N3993	DZ							6.2*	10	10W
1N1804A	S	1N3998RA *	1N3993	DZ							6.2*	5.0	10W
1N1805	S	1N2970A *	1N2970	DZ							6.8*	10	10W
1N1805A	S	1N2970B *	1N2970	DZ							6.8*	5.0	10W
1N1806	S	1N2971A *	1N2970	DZ							7.5*	10	10W
1N1806A	S	1N2971B *	1N2970	DZ							7.5*	5.0	10W
1N1807	S	1N2972A *	1N2970	DZ							8.2*	10	10W
1N1807A	S	1N2972B *	1N2970	DZ							8.2*	5.0	10W
1N1808	S	1N2973A *	1N2970	DZ							9.1*	10	10W
1N1808A	S	1N2973B *	1N2970	DZ							9.1*	5.0	10W
1N1809	S	1N3007A *	1N2970	DZ							110*	10	10W
1N1809A	S	1N3007B *	1N2970	DZ							110*	5.0	10W
1N1810	S	1N3008A *	1N2970	DZ							120*	10	10W
1N1810A	S	1N3008B *	1N2970	DZ							120*	5.0	10W
1N1811	S	1N3009A *	1N2970	DZ							130*	10	10W
1N1811A	S	1N3009B *	1N2970	DZ							130*	5.0	10W
1N1812	S	1N3011A *	1N2970	DZ							150*	10	10W
1N1812A	S	1N3011B *	1N2970	DZ							150*	5.0	10W
1N1813	S	1N3012A *	1N2970	DZ							160*	10	10W
1N1813A	S	1N3012B *	1N2970	DZ							160*	5.0	10W
1N1814	S	1N3014A *	1N2970	DZ							180*	10	10W
1N1814A	S	1N3014B *	1N2970	DZ							180*	5.0	10W
1N1815	S	1N3015A *	1N2970	DZ							200*	10	10W
1N1815A	S	1N3015B *	1N2970	DZ							200*	5.0	10W
1N1816	S	1N2977A *	1N2970	DZ							13*	10	10W
1N1816A	S	1N2977B *	1N2970	DZ							13*	5.0	10W
1N1817	S	1N2979A *	1N2970	DZ							15*	10	10W
1N1817A	S	1N2979B *	1N2970	DZ							15*	5.0	10W
1N1818	S	1N2980A *	1N2970	DZ							16*	10	10W
1N1818A	S	1N2980B *	1N2970	DZ							16*	5.0	10W
1N1819	S	1N2982A *	1N2970	DZ							18*	10	10W
1N1819A	S	1N2982B *	1N2970	DZ							18*	5.0	10W
1N1820	S	1N2984A *	1N2970	DZ							20*	10	10W
1N1820A	S	1N2984B *	1N2970	DZ							20*	5.0	10W
1N1821	S	1N2985A *	1N2970	DZ							22*	10	10W
1N1821A	S	1N2985B *	1N2970	DZ							22*	5.0	10W
1N1822	S	1N2986A *	1N2970	DZ							24*	10	10W
1N1822A	S	1N2986B *	1N2970	DZ							24*	5.0	10W
1N1823	S	1N2988A *	1N2970	DZ							27*	10	10W
1N1823A	S	1N2988B *	1N2970	DZ							27*	5.0	10W
1N1824	S	1N2989A *	1N2970	DZ							30*	10	10W
1N1824A	S	1N2989B *	1N2970	DZ							30*	5.0	10W
1N1825	S	1N2990A *	1N2970	DZ							33*	10	10W
1N1825A	S	1N2990B *	1N2970	DZ							33*	5.0	10W
1N1826	S	1N2991A *	1N2970	DZ							36*	10	10W
1N1826A	S	1N2991B *	1N2970	DZ							36*	5.0	10W
1N1827	S	1N2992A *	1N2970	DZ							39*	10	10W
1N1827A	S	1N2992B *	1N2970	DZ							39*	5.0	10W
1N1828	S	1N2993A *	1N2970	DZ							43*	10	10W
1N1828A	S	1N2993B *	1N2970	DZ							43*	5.0	10W
1N1829	S	1N2995A *	1N2970	DZ							47*	10	10W
1N1829A	S	1N2995B *	1N2970	DZ							47*	5.0	10W
1N1830	S	1N2997A *	1N2970	DZ							51*	10	10W
1N1830A	S	1N2997B *	1N2970	DZ							51*	5.0	10W
1N1831	S	1N2999A *	1N2970	DZ							56*	10	10W
1N1831A	S	1N2999B *	1N2970	DZ							56*	5.0	10W
1N1832	S	1N3000A *	1N2970	DZ							62*	10	10W
1N1832A	S	1N3000B *	1N2970	DZ							62*	5.0	10W
1N1833	S	1N3001A *	1N2970	DZ							68*	10	10W
1N1833A	S	1N3001B *	1N2970	DZ							68*	5.0	10W
1N1834	S	1N3002A *	1N2970	DZ							75*	10	10W
1N1834A	S	1N3002B *	1N2970	DZ							75*	5.0	10W
1N1835	S	1N3003A *	1N2970	DZ							82*	10	10W
1N1835A	S	1N3003B *	1N2970	DZ							82*	5.0	10W
1N1836	S	1N3004A *	1N2970	DZ							91*	10	10W
1N1836A	S	1N3004B *	1N2970	DZ							91*	5.0	10W
1N1838	G	Microwave X-Ku-band Mixer; NF = 32 dB											
1N1839	S			R*	6.8		0.085		0.26				
1N1840	S			R*	10		0.077		0.23				

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1841	S			R*	15		0.063		0.19				
1N1842	S			R*	22		0.05		0.15				
1N1843	S			R*	33		0.04		0.12				
1N1844	S			R*	47		0.03		0.095				
1N1845	S			R*	68		0.023	0.001	0.072				
1N1846	S			R*	100		0.016	0.001	0.050				
1N1847	S			R*	150		0.011	0.003	0.035				
1N1848	S			R*	220		0.009	0.005	0.028				
1N1849	S			R*	330			0.005	0.024				
1N1850	S			R*	470		0.006	0.005	0.020				
1N1851	S			R*	6.8		0.085		0.26				
1N1852	S			R*	10		0.077		0.23				
1N1853	S			R*	15		0.063		0.190				
1N1854	S			R*	22		0.05		0.150				
1N1855	S			R*	33		0.04		0.120				
1N1856	S			R*	47		0.03		0.095				
1N1857	S			R*	68		0.023	0.001	0.072				
1N1858	S			R*	100		0.016	0.001	0.050				
1N1859	S			R*	150		0.011	0.003	0.035				
1N1860	S			R*	220		0.009	0.005	0.028				
1N1861	S			R*	330			0.005	0.024				
1N1862	S			R*	470		0.006	0.005	0.020				
1N1863	S			R*	6.8		0.085		0.260				
1N1864	S			R*	10		0.077		0.230				
1N1865	S			R*	15		0.063		0.190				
1N1866	S			R*	22		0.05		0.150				
1N1867	S			R*	33		0.04		0.120				
1N1868	S			R*	47		0.03		0.095				
1N1869	S			R*	68		0.023	0.001	0.072				
1N1870	S			R*	100		0.016	0.001	0.050				
1N1871	S			R*	150		0.011	0.003	0.035				
1N1872	S			R*	220		0.009	0.005	0.028				
1N1873	S			R*	330			0.005	0.024				
1N1874	S			R*	470		0.006	0.005	0.020				
1N1875	S	1N4738	1N4728	DZ							8.2*	10	1.0W
1N1876	S	1N4740	1N4728	DZ							10*	10	1.0W
1N1877	S	1N4742	1N4728	DZ							12*	10	1.0W
1N1878	S	1N4744	1N4728	DZ							15*	10	1.0W
1N1879	S	1N4746	1N4728	DZ							18*	10	1.0W
1N1880	S	1N4748	1N4728	DZ							22*	10	1.0W
1N1881	S	1N4750	1N4728	DZ							27*	10	1.0W
1N1882	S	1N4752	1N4728	DZ							33*	10	1.0W
1N1883	S	1N4754	1N4728	DZ							39*	10	1.0W
1N1884	S	1N4756	1N4728	DZ							47*	10	1.0W
1N1885	S	1N4758	1N4728	DZ							56*	10	1.0W
1N1886	S	1N4760	1N4728	DZ							68*	10	1.0W
1N1887	S	1N4762	1N4728	DZ							82*	10	1.0W
1N1888	S	1N4764	1N4728	DZ							100*	10	1.0W
1N1889	S	1M120ZS10	1N4728	DZ							120*	10	1.0W
1N1890	S	1M150ZS10	1N4728	DZ							150*	10	1.0W
1N1891	S	1N2972A	1N2970	DZ							8.2*	10	10W
1N1892	S	1N2974A	1N2970	DZ							10*	10	10W
1N1893	S	1N2976A	1N2970	DZ							10*	10	10W
1N1894	S	1N2979A	1N2970	DZ							15*	10	10W
1N1895	S	1N2982A	1N2970	DZ							18*	10	10W
1N1896	S	1N2985A	1N2970	DZ							22*	10	10W
1N1897	S	1N2988A	1N2970	DZ							27*	10	10W
1N1898	S	1N2990A	1N2970	DZ							33*	10	10W
1N1899	S	1N2992A	1N2970	DZ							39*	10	10W
1N1900	S	1N2995A	1N2970	DZ							47*	10	10W
1N1901	S	1N2999A	1N2970	DZ							56*	10	10W
1N1902	S	1N3001A	1N2970	DZ							68*	10	10W
1N1903	S	1N3003A	1N2970	DZ							82*	10	10W
1N1904	S	1N3005A	1N2970	DZ							100*	10	10W
1N1905	S	1N3008A	1N2970	DZ							120*	10	10W
1N1906	S	1N3011A	1N2970	DZ							150*	10	10W
1N1907	S	1N4001	1N4001	R*	50	1.0	1.5	0.01	30				
1N1908	S	1N4002	1N4001	R*	100	1.0	1.5	0.01	30				
1N1909	S	1N4003	1N4001	R*	200	1.0	1.5	0.01	30				
1N1910	S			R*	300	1.0	1.5	0.01	30				
1N1911	S	1N4004	1N4001	R*	400	1.0	1.5	0.01	30				
1N1912	S	1N4005	1N4001	R*	500	1.0	1.5	0.01	30				
1N1913	S	1N4005	1N4001	R*	600	1.0	1.5	0.01	30				
1N1914	S	1N4006	1N4001	R*	700	1.0	1.5	0.01	30				
1N1915	S	1N4006	1N4001	R*	800	1.0	1.5	0.01	30				
1N1916	S	1N4007	1N4001	R*	900	1.0	1.5	0.01	30				
1N1917	S			R*	50	1.0	4.0	0.01	30				
1N1918	S			R*	100	1.0	4.0	0.01	30				
1N1919	S			R*	200	1.0	4.0	0.01	30				
1N1920	S			R*	300	1.0	4.0	0.01	30				
1N1921	S			R*	400	1.0	4.0	0.01	30				
1N1922	S			R*	500	1.0	4.0	0.01	30				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N1923	S			R*	600	1.0	4.0	0.01	30				
1N1924	S			R*	700	1.0	4.0	0.01	30				
1N1925	S			R*	800	1.0	4.0	0.01	30				
1N1926	S			R*	900	1.0	4.0	0.01	30				
1N1927	S	1N5228A	1N5221	DZ							3.9*	10	200M
1N1928	S	1N5230A	1N5221	DZ							4.7*	10	200M
1N1929	S	1N5232A	1N5221	DZ							5.6*	10	200M
1N1930	S	1N5235A	1N5221	DZ							6.8*	10	200M
1N1931	S	1N5237A	1N5221	DZ							8.2*	10	200M
1N1932	S	1N5240A	1N5221	DZ							10*	10	200M
1N1933	S	1N5242A	1N5221	DZ							12*	10	200M
1N1934	S	1N5245A	1N5221	DZ							15*	10	200M
1N1935	S	1N5248A	1N5221	DZ							18*	10	200M
1N1936	S	1N5251A	1N5221	DZ							22*	10	200M
1N1937	S	1N5254A	1N5221	DZ							27*	10	200M
1N1938	S	1N5257A	1N5221	DZ							33*	10	200M
1N1939	S	1N5259A	1N5221	DZ							39*	10	200M
1N1940	S	1N5261A	1N5221	DZ							47*	10	200M
1N1941	S	1N5263A	1N5221	DZ							56*	10	200M
1N1942	S	1N5266A	1N5221	DZ							68*	10	200M
1N1943	S	1N5268A	1N5221	DZ							82*	10	200M
1N1944	S	1N5271A	1N5221	DZ							100*	10	200M
1N1945	S	1N5273A	1N5221	DZ							120*	10	200M
1N1946	S	1N5276A	1N5221	DZ							150*	10	200M
1N1947	S	1N5279A	1N5221	DZ							180*	10	200M
1N1948	S	.5M110ZSB10		DZ							220*	10	200M
1N1949	S	.5M135ZSB10		DZ							270*	10	200M
1N1950	S	.5M165ZSB10		DZ							330*	10	200M
1N1951	S	.5M195ZSB10		DZ							390*	10	200M
1N1952	S	.5M155ZSC10		DZ							470*	10	200M
1N1953	S	.5M185ZSC10		DZ							560*	10	200M
1N1954	S	1N5228A	1N5221	DZ							3.9*	10	400M
1N1955	S	1N5230A	1N5221	DZ							4.7*	10	400M
1N1956	S	1N5232A	1N5221	DZ							5.6*	10	400M
1N1957	S	1N5235A	1N5221	DZ							6.8*	10	400M
1N1958	S	1N5237A	1N5221	DZ							8.2*	10	400M
1N1959	S	1N5240A	1N5221	DZ							10*	10	400M
1N1960	S	1N5242A	1N5221	DZ							12*	10	400M
1N1961	S	1N5245A	1N5221	DZ							15*	10	400M
1N1962	S	1N5248A	1N5221	DZ							18*	10	400M
1N1963	S	1N5251A	1N5221	DZ							22*	10	400M
1N1964	S	1N5254A	1N5221	DZ							27*	10	400M
1N1965	S	1N5257A	1N5221	DZ							33*	10	400M
1N1966	S	1N5259A	1N5221	DZ							39*	10	400M
1N1967	S	1N5261A	1N5221	DZ							47*	10	400M
1N1968	S	1N5263A	1N5221	DZ							56*	10	400M
1N1969	S	1N5266A	1N5221	DZ							68*	10	400M
1N1970	S	1N5268A	1N5221	DZ							82*	10	400M
1N1971	S	1N5271A	1N5221	DZ							100*	10	400M
1N1972	S	1N5273A	1N5221	DZ							120*	10	400M
1N1973	S	1N5276A	1N5221	DZ							150*	10	400M
1N1974	S	1N5279A	1N5221	DZ							180*	10	400M
1N1975	S	.5M110ZSB10		DZ							220*	10	400M
1N1976	S	.5M135ZSB10		DZ							270*	10	400M
1N1977	S	.5M165ZSB10		DZ							330*	10	400M
1N1978	S	.5M195ZSB10		DZ							390*	10	400M
1N1979	S	.5M155ZSC10		DZ							470*	10	400M
1N1980	S	.5M185ZSC10		DZ							560*	10	400M
1N1981	S	1N5228A	1N5221	DZ							3.9*	10	150M
1N1982	S	1N5230A	1N5221	DZ							4.7*	10	150M
1N1983	S	1N5232A	1N5221	DZ							5.6*	10	150M
1N1984	S	1N5235A	1N5221	DZ							6.8*	10	150M
1N1985	S	1N5237A	1N5221	DZ							8.2*	10	150M
1N1986	S	1N5240A	1N5221	DZ							10*	10	150M
1N1987	S	1N5242A	1N5221	DZ							12*	10	150M
1N1988	S	1N5245A	1N5221	DZ							15*	10	150M
1N1989	S	1N5248A	1N5221	DZ							18*	10	150M
1N1990	S	1N5251A	1N5221	DZ							22*	10	150M
1N1991	S	1N5254A	1N5221	DZ							27*	10	150M
1N1992	S	1N5257A	1N5221	DZ							33*	10	150M
1N1993	S	1N5259A	1N5221	DZ							39*	10	150M
1N1994	S	1N5261A	1N5221	DZ							47*	10	150M
1N1995	S	1N5263A	1N5221	DZ							56*	10	150M
1N1996	S	1N5266A	1N5221	DZ							68*	10	150M
1N1997	S	1N5268A	1N5221	DZ							82*	10	150M
1N1998	S	1N5271A	1N5221	DZ							100*	10	150M
1N1999	S	1N5273A	1N5221	DZ							120*	10	150M
1N2000	S	1N5276A	1N5221	DZ							150*	10	150M
1N2001	S	1N5279A	1N5221	DZ							180*	10	150M
1N2002	S	.5M110ZSB10		DZ							220*	10	150M
1N2003	S	.5M135ZSB10		DZ							270*	10	150M
1N2004	S	.5M165ZSB10		DZ							330*	10	150M

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2005	S	.5M195ZSB10		DZ							390*	10	150M
1N2006	S	.5M155ZSC10		DZ							470*	10	150M
1N2007	S	.5M185ZSC10		DZ							560*	10	150M
1N2008	S	1N3005A *	1N2970	DZ							100*	10	10W
1N2009	S	1N3007A *	1N2970	DZ							110*	10	10W
1N2010	S	1N3008A *	1N2970	DZ							120*	10	10W
1N2011	S	1N3009A *	1N2970	DZ							130*	10	10W
1N2012	S	1N3011A *	1N2970	DZ							150*	10	10W
1N2013	S			R*	50	1.2	0.25	0.25	10				
1N2014	S			R*	100	1.2	0.25	0.25	10				
1N2015	S			R*	150	1.2	0.25	0.25	10				
1N2016	S			R*	200	1.2	0.25	0.25	10				
1N2017	S			R*	250	1.2	0.25	0.25	10				
1N2018	S			R*	300	1.2	0.25	0.25	10				
1N2019	S			R*	350	1.2	0.25	0.25	10				
1N2020	S			R*	400	1.2	0.25	0.25	10				
1N2021	S	1N1185	1N1183	R*	150	1.5	10	5.0	110				
1N2022	S	1N1187	1N1183	R*	250	1.5	10	5.0	110				
1N2023	S	1N1187	1N1183	R*	300	1.5	10	5.0	110				
1N2024	S	1N1188	1N1183	R*	350	1.5	10	5.0	110				
1N2025	S	1N1188	1N1183	R*	400	1.5	10	5.0	110				
1N2026	S	MR1120	MR1120	R*	50	2.0	1.0	0.5	25				
1N2027	S	MR1122	MR1120	R*	200	2.0	1.0	0.5	25				
1N2028	S	MR1123	MR1120	R*	300	2.0	1.0	0.5	25				
1N2029	S	MR1124	MR1120	R*	400	2.0	1.0	0.5	25				
1N2030	S	MR1125	MR1120	R*	500	2.0	1.0	0.5	25				
1N2031	S	MR1126	MR1120	R*	600	2.0	1.0	0.5	25				
1N2032	S	1N4732*	1N4728	DZ						4.3	5.4		250M
1N2033	S	1N4734*	1N4728	DZ						5.2	6.4		750M
1N2034	S	1N4736*	1N4728	DZ						6.2	8.0		750M
1N2035	S	1N4739*	1N4728	DZ						7.5	10.0		750M
1N2036	S	1N4740*	1N4728	DZ						9.0	12.0		750M
1N2037	S	1N4743*	1N4728	DZ						11.0	14.5		750M
1N2038	S	1N4745*	1N4728	DZ						13.5	18.0		750M
1N2039	S	1N4747*	1N4728	DZ						17.0	21.0		750M
1N2040	S	1N4749*	1N4728	DZ						20.0	27.0		750M
1N2041	S	1N3995*	1N3993	DZ						4.3	5.4		10W
1N2042	S	1N3997*	1N3993	DZ						5.2	6.4		10W
1N2043	S	1N2970RA *	1N2970	DZ						6.2	8.0		10W
1N2044	S	1N2973RA *	1N2970	DZ						7.5	10.0		10W
1N2045	S	1N2974RB *	1N2970	DZ						9.0	12.0		10W
1N2046	S	1N2977RA *	1N2970	DZ						11.0	14.5		10W
1N2047	S	1N2980RA *	1N2970	DZ						13.5	18.0		10W
1N2048	S	1N2983RA *	1N2970	DZ						17.0	21.0		10W
1N2049	S	1N2986RA *	1N2970	DZ						20.0	27.0		10W
1N2054	S	MR1230SB	MR1230	R*	50	1.6	250	55	4500				
1N2055	S	MR1231SB	MR1230	R*	100	1.6	250	55	4500				
1N2056	S	MR1232SB	MR1230	R*	150	1.6	250	55	4500				
1N2057	S	MR1233SB	MR1230	R*	200	1.6	250	55	4500				
1N2058	S	MR1234SB	MR1230	R*	250	1.6	250	55	4500				
1N2059	S	MR1235SB	MR1230	R*	300	1.6	250	55	4500				
1N2060	S	MR1236SB	MR1230	R*	350	1.6	250	55	4500				
1N2061	S	MR1237SB	MR1230	R*	400	1.6	250	55	4500				
1N2062	S	MR1238SB	MR1230	R*	450	1.6	250	55	4500				
1N2063	S	MR1238SB	MR1230	R*	500	1.6	250	55	4500				
1N2064	S	MR1239SB	MR1230	R*	600	1.6	250	55	4500				
1N2065	S			R*	700	1.6	250	55	4500				
1N2066	S			R*	800	1.6	250	55	4500				
1N2067	S			R*	900	1.6	250	55	4500				
1N2068	S			R*	1000	1.6	250	55	4500				
1N2069	S	1N4003	1N4001	R*	200	0.6	0.75	0.2	22				
1N2069A	S	1N4003	1N4001	R*	200	0.5	0.75	0.05	22				
1N2070	S	1N4004	1N4001	R*	400	0.6	0.75	0.2	22				
1N2070A	S	1N4004	1N4001	R*	400	0.5	0.75	0.05	22				
1N2071	S	1N4005	1N4001	R*	600	0.6	0.75	0.2	22				
1N2071A	S	1N4005	1N4001	R*	600	0.5	0.75	0.05	22				
1N2072	S	1N4001	1N4001	R*	50	1.1	0.625	0.25	30				
1N2073	S	1N4002	1N4001	R*	100	1.1	0.625	0.25	30				
1N2074	S	1N4003	1N4001	R*	150	1.1	0.625	0.25	30				
1N2075	S	1N4003	1N4001	R*	200	1.1	0.625	0.25	30				
1N2076	S	1N4004	1N4001	R*	250	1.1	0.625	0.25	30				
1N2077	S	1N4004	1N4001	R*	300	1.1	0.625	0.25	30				
1N2078	S	1N4004	1N4001	R*	400	1.1	0.625	0.25	30				
1N2079	S	1N4005	1N4001	R*	500	1.1	0.625	0.25	30				
1N2080	S	1N4001	1N4001	R*	50	0.75	0.5	0.35	15				
1N2081	S	1N4002	1N4001	R*	100	0.75	0.5	0.35	15				
1N2082	S	1N4003	1N4001	R*	200	0.75	0.5	0.35	15				
1N2083	S	1N4004	1N4001	R*	300	0.75	0.5	0.35	15				
1N2084	S	1N4004	1N4001	R*	400	0.75	0.5	0.35	15				
1N2085	S	1N4005	1N4001	R*	500	0.75	0.5	0.35	15				
1N2086	S			R*	600	0.75	0.5	0.35	15				
1N2088	S			R*	500	1.2	0.75	0.5	30				

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2089	S			R*	600	1.2	0.75	0.5	30				
1N2090	S			R*	50	0.5	0.5	0.25	15				
1N2091	S			R*	100	0.5	0.5	0.25	15				
1N2092	S			R*	200	0.5	0.5	0.25	15				
1N2093	S			R*	300	0.5	0.5	0.25	15				
1N2094	S			R*	400	0.5	0.5	0.25	15				
1N2095	S			R*	500	0.5	0.5	0.25	15				
1N2096	S			R*	600	0.5	0.5	0.25	15				
1N2102	S	Microwave L-S-band Detector											
1N2103	S	1N4001	1N4001	R*	50	1.2	0.75	0.3	10				
1N2104	S	1N4002	1N4001	R*	100	1.2	0.75	0.3	10				
1N2105	S	1N4003	1N4001	R*	200	1.2	0.75	0.3	10				
1N2106	S	1N4004	1N4001	R*	300	1.2	0.75	0.3	10				
1N2107	S	1N4004	1N4001	R*	400	1.2	0.75	0.3	10				
1N2108	S	1N4005	1N4001	R*	500	1.2	0.75	0.3	10				
1N2109	S			R*	50	1.2	2.0	0.3	10				
1N2110	S			R*	100	1.2	2.0	0.3	10				
1N2111	S			R*	200	1.2	2.0	0.3	10				
1N2112	S			R*	300	1.2	2.0	0.3	10				
1N2113	S			R*	400	1.2	2.0	0.3	10				
1N2114	S			R*	500	1.2	2.0	0.3	10				
1N2115	S	1N4004	1N4001	R*	365	0.8	0.2	0.25	10				
1N2116	S			R*	400	1.4	0.5	0.4	15				
1N2117	S	1N4006	1N4001	R*	720	1.3	0.75	0.010	15				
1N2127	S	Microwave L-X-band Detector											
1N2127A	S	Microwave L-X-band Detector											
1N2128	S	MR1200FL	MR1200	R*	50	2.0	60	10	700				
1N2128A	S	MR1200FL	MR1200	R*	50	2.0	60	10	900				
1N2129	S	MR1201FL	MR1200	R*	100	2.0	60	10	700				
1N2129A	S	MR1201FL	MR1200	R*	100	2.0	60	10	900				
1N2130	S	MR1202FL	MR1200	R*	150	2.0	60	10	700				
1N2130A	S	MR1202FL	MR1200	R*	150	2.0	60	10	900				
1N2131	S	MR1203FL	MR1200	R*	200	2.0	60	10	700				
1N2131A	S	MR1203FL	MR1200	R*	200	2.0	60	10	900				
1N2132	S	MR1204FL	MR1200	R*	250	2.0	60	10	700				
1N2132A	S	MR1204FL	MR1200	R*	250	2.0	60	10	900				
1N2133	S	MR1205FL	MR1200	R*	300	2.0	60	10	700				
1N2133A	S	MR1205FL	MR1200	R*	300	2.0	60	10	900				
1N2134	S	MR1206FL	MR1200	R*	350	2.0	60	10	700				
1N2134A	S	MR1206FL	MR1200	R*	350	2.0	60	10	900				
1N2135	S	MR1207FL	MR1200	R*	400	2.0	60	10	700				
1N2135A	S	MR1207FL	MR1200	R*	400	2.0	60	10	900				
1N2136	S			R*	450	2.0	60	10	700				
1N2136A	S			R*	450	2.0	60	10	900				
1N2137	S			R*	500	2.0	60	10	700				
1N2137A	S			R*	500	2.0	60	10	900				
1N2138	S			R*	600	2.0	60	10	700				
1N2138A	S			R*	600	2.0	60	10	900				
1N2139	S			R*	20K	60	0.052	0.2	3.5				
1N2146	S			DS	120	1.1	500M	1.0*	0.1				
1N2147	S			R*	50	1.2	6.0	0.5	150				
1N2147A	S			R*	50	1.0	6.0	0.1	150				
1N2148	S			R*	100	1.2	6.0	0.5	150				
1N2148A	S			R*	100	1.0	6.0	0.1	150				
1N2149	S			R*	200	1.2	6.0	0.5	150				
1N2149A	S			R*	200	1.0	6.0	0.1	150				
1N2150	S			R*	300	1.2	6.0	0.5	150				
1N2150A	S			R*	300	1.0	6.0	0.1	150				
1N2151	S			R*	400	1.2	6.0	0.5	150				
1N2151A	S			R*	400	1.0	6.0	0.1	150				
1N2152	S			R*	500	1.2	6.0	0.5	150				
1N2152A	S			R*	500	1.0	6.0	0.1	150				
1N2153	S			R*	600	1.2	6.0	0.5	150				
1N2153A	S			R*	600	1.0	6.0	0.1	150				
1N2154	S	1N1183	1N1183	R*	50	0.6	25	5.0	300				
1N2155	S	1N1184	1N1183	R*	100	0.6	25	4.5	300				
1N2156	S	1N1186	1N1183	R*	200	0.6	25	4.0	300				
1N2157	S	1N1187	1N1183	R*	300	0.6	25	3.5	300				
1N2158	S	1N1188	1N1183	R*	400	0.6	25	3.0	300				
1N2159	S	1N1189	1N1183	R*	500	0.6	25	2.5	300				
1N2160	S	1N1190	1N1183	R*	600	0.6	25	2.0	300				
1N2163	S		1N2163	DR						0.005	9.4	-65	200
1N2163A	S		1N2163	DR						0.005	9.4	-65	200
1N2164	S		1N2163	DR						0.005	9.4	-65	200
1N2164A	S		1N2163	DR						0.005	9.4	-65	200
1N2165	S		1N2163	DR						0.005	9.4	-65	200
1N2165A	S		1N2163	DR						0.005	9.4	-65	200
1N2166	S		1N2163	DR						0.001	9.4	-65	200
1N2166A	S		1N2163	DR						0.001	9.4	-65	200
1N2167	S		1N2163	DR						0.001	9.4	-65	200
1N2167A	S		1N2163	DR						0.001	9.4	-65	200

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES.					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2168	S		1N2163	DR						0.001	9.4	-65	200
1N2168A	S		1N2163	DR						0.001	9.4	-65	200
1N2169	S		1N2163	DR						0.0005	9.4	-65	200
1N2169A	S		1N2163	DR						0.0005	9.4	-65	200
1N2170	S		1N2163	DR						0.0005	9.4	-65	200
1N2170A	S		1N2163	DR						0.0005	9.4	-65	200
1N2171	S		1N2163	DR						0.0005	9.4	-65	200
1N2171A	S		1N2163	DR						0.0005	9.4	-65	200
1N2172	S			R*	50	1.5	50	0.25	525				
1N2173	S			R*	100	1.5	50	0.25	525				
1N2174	S			R*	200	1.5	50	0.25	525				
1N2175		Photosensitive Device; $I_{R(dark)}$ = 0.5 µA @ 50 V, Sensitivity = 0.22 µA/mW/cm^2											
1N2176	S			R*	50	1.1	3.0	0.3	15				
1N2177	S			R*	100	1.1	3.0	0.3	15				
1N2178	S			R*	150	1.1	3.0	0.3	15				
1N2179	S			R*	200	1.1	3.0	0.3	15				
1N2180	S			R*	300	1.1	3.0	0.3	15				
1N2181	S			R*	400	1.1	3.0	0.3	15				
1N2182	S			R*	500	1.1	3.0	0.3	15				
1N2183	S			R*	600	1.1	3.0	0.3	15				
1N2184	S			R*	50	1.5	3.0	5.0	40				
1N2185	S			R*	100	1.5	3.0	5.0	40				
1N2186	S			R*	150	1.5	3.0	5.0	40				
1N2187	S			R*	200	1.5	3.0	5.0	40				
1N2188	S			R*	300	1.5	3.0	5.0	40				
1N2189	S			R*	400	1.5	3.0	5.0	40				
1N2190	S			R*	500	1.5	3.0	5.0	40				
1N2191	S			R*	600	1.5	3.0	5.0	40				
1N2192	S			R*	800	1.5	3.0	5.0	40				
1N2193	S			R*	1000	1.5	3.0	5.0	40				
1N2194	S			R*	50	1.25	6.0	10	100				
1N2195	S			R*	100	1.25	6.0	10	100				
1N2196	S			R*	150	1.25	6.0	10	100				
1N2197	S			R*	200	1.25	6.0	10	100				
1N2198	S			R*	300	1.25	6.0	10	100				
1N2199	S			R*	400	1.25	6.0	10	100				
1N2200	S			R*	500	1.25	6.0	10	100				
1N2201	S			R*	600	1.25	6.0	10	100				
1N2202	S			R*	800	1.25	6.0	10	100				
1N2203	S			R*	1000	1.25	6.0	10	100				
1N2204	S			R*	50	1.25	12	10	200				
1N2205	S			R*	100	1.25	12	10	200				
1N2206	S			R*	150	1.25	12	10	200				
1N2207	S			R*	200	1.25	12	10	200				
1N2208	S			R*	300	1.25	12	10	200				
1N2209	S			R*	400	1.25	12	10	200				
1N2210	S			R*	500	1.25	12	10	200				
1N2211	S			R*	600	1.25	12	10	200				
1N2212	S			R*	800	1.25	12	10	200				
1N2213	S			R*	1000	1.25	12	10	200				
1N2214	S	1M5.5ZS1		DZ							5.6*	10	1.0W
1N2217	S	MR1120	MR1120	R*	50		1.5	0.003	20				
1N2218	S	MR1125	MR1120	R*	500	1.2	0.4	0.003	20				
1N2219	S			R*	500		1.5	0.003	20				
1N2220	S	MR1126	MR1120	R*	600	1.2	0.4	0.003	20				
1N2221	S			R*	600		1.5	0.003	20				
1N2222	S	MR1128	MR1120	R*	800	1.2	0.3	0.003	20				
1N2222A	S			R*	800	1.2	0.3	0.003	20				
1N2223	S			R*	800		1.0	0.003	20				
1N2223A	S			R*	800		1.0	0.003	20				
1N2224	S	MR1130	MR1120	R*	1000	1.2	0.3	0.003	20				
1N2224A	S			R*	1000	1.2	0.3	0.003	20				
1N2225	S			R*	1000		1.0	0.003	20				
1N2225A	S			R*	1000		1.0	0.003	20				
1N2226	S			R*	1200	1.2	0.3	0.003	20				
1N2226A	S			R*	1200	1.2	0.3	0.003	20				
1N2227	S			R*	1200		1.0	0.003	20				
1N2227A	S			R*	1200		1.0	0.003	20				
1N2228	S	MR1120	MR1120	R*	50	1.2	1.0	0.003	100				
1N2228A	S	MR1120	MR1120	R*	50	1.2	1.6	0.003	100				
1N2229	S			R*	50		5.0	0.003	100				
1N2229A	S			R*	50		5.0	0.003	100				
1N2230	S	MR1122	MR1120	R*	200	1.2	1.0	0.003	100				
1N2230A	S	MR1122	MR1120	R*	200	1.2	1.6	0.003	100				
1N2231	S			R*	200		5.0	0.003	100				
1N2231A	S	MR1123	MR1120	R*	200		5.0	0.003	100				
1N2232	S	MR1123	MR1120	R*	300	1.2	1.0	0.003	100				
1N2232A	S			R*	300	1.2	1.6	0.003	100				
1N2233	S			R*	300		5.0	0.003	100				
1N2233A	S			R*	300		5.0	0.003	100				
1N2234	S	MR1124	MR1120	R*	400	1.2	1.0	0.003	100				
1N2234A	S	MR1124	MR1120	R*	400	1.2	1.6	0.003	100				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z(min)	V_Z(nom) * V_Z(max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T(min) °C	T(max) °C
1N2235	S			R*	400		5.0	0.003	100				
1N2235A	S			R*	400		5.0	0.003	100				
1N2236	S	MR1125	MR1120	R*	500	1.2	1.0	0.003	100				
1N2236A	S	MR1125	MR1120	R*	500	1.2	1.6	0.003	100				
1N2237	S			R*	500		5.0	0.003	100				
1N2237A	S			R*	500		5.0	0.003	100				
1N2238	S	MR1126	MR1120	R*	600	1.2	1.0	0.003	100				
1N2238A	S	MR1126	MR1120	R*	600	1.2	1.6	0.003	100				
1N2239	S			R*	600		5.0	0.003	100				
1N2239A	S			R*	600		5.0	0.003	100				
1N2240	S	MR1128	MR1120	R*	800	1.2	1.5	0.003	100				
1N2240A	S	MR1128	MR1120	R*	800	1.2	1.5	0.003	100				
1N2241	S			R*	800		5.0	0.003	100				
1N2241A	S			R*	800		5.0	0.003	100				
1N2242	S	MR1130	MR1120	R*	1000	1.2	1.5	0.003	100				
1N2242A	S	MR1130	MR1120	R*	1000	1.2	1.6	0.003	100				
1N2243	S			R*	1000		5.0	0.003	100				
1N2243A	S			R*	1000		5.0	0.003	100				
1N2244	S			R*	1200	1.2	1.5	0.003	100				
1N2244A	S			R*	1200	1.2	1.6	0.003	100				
1N2245	S			R*	1200		5.0	0.003	100				
1N2245A	S			R*	1200		5.0	0.003	100				
1N2246	S			R*	50	1.2	3.0	0.005	200				
1N2246A	S			R*	50	1.2	3.0	0.003	200				
1N2247	S			R*	50		10	0.005	200				
1N2247A	S			R*	50		10	0.003	200				
1N2248	S			R*	100	1.2	3.0	0.005	200				
1N2248A	S			R*	100	1.2	3.0	0.003	200				
1N2249	S			R*	100		10	0.005	200				
1N2249A	S			R*	100		10	0.003	200				
1N2250	S			R*	200	1.2	3.0	0.005	200				
1N2250A	S			R*	200	1.2	3.0	0.003	200				
1N2251	S			R*	200		5.0	0.005	200				
1N2251A	S			R*	200		10	0.003	200				
1N2252	S			R*	300	1.2	3.0	0.005	200				
1N2252A	S			R*	300	1.2	3.0	0.003	200				
1N2253	S			R*	300		10	0.005	200				
1N2253A	S			R*	300		10	0.003	200				
1N2254	S			R*	400	1.2	3.0	0.005	200				
1N2254A	S			R*	400	1.2	3.0	0.003	200				
1N2255	S			R*	400		10	0.005	200				
1N2255A	S			R*	400		10	0.003	200				
1N2256	S			R*	500	1.2	3.0	0.005	200				
1N2256A	S			R*	500	1.2	3.0	0.003	200				
1N2257	S			R*	500		10	0.005	200				
1N2257A	S			R*	500		10	0.005	200				
1N2258	S			R*	600	1.2	3.0	0.005	200				
1N2258A	S			R*	600	1.2	3.0	0.003	200				
1N2259	S			R*	600		10	0.005	200				
1N2259A	S			R*	600		10	0.003	200				
1N2260	S			R*	800	1.2	3.0	0.003	200				
1N2260A	S			R*	800	1.2	3.0	0.005	200				
1N2261	S			R*	800		10	0.01	200				
1N2261A	S			R*	800		10	0.005	200				
1N2262	S			R*	1000	1.2	3.0	0.010	200				
1N2262A	S			R*	1000	1.2	3.0	0.005	200				
1N2263	S			R*	1000		10	0.01	200				
1N2263A	S			R*	1000		10	0.005	200				
1N2264	S			R*	1200	1.2	3.0	0.010	200				
1N2264A	S			R*	1200	1.2	3.0	0.005	200				
1N2265	S			R*	1200		10	0.01	200				
1N2265A	S			R*	1200		10	0.005	200				
1N2266	S	MR1120	MR1120	R*	50	1.2	0.3	0.003	20				
1N2267	S			R*	50		1.0	0.003	20				
1N2268	S	MR1125	MR1120	R*	500	1.2	0.3	0.003	20				
1N2269	S			R*	500		1.0	0.003	20				
1N2270	S	MR1126	MR1120	R*	600	1.2	0.3	0.003	20				
1N2271	S			R*	600		1.0	0.003	20				
1N2272	S	MR1120	MR1120	R*	50	1.2	6.0	1.0	400				
1N2273	S	MR1121	MR1120	R*	100	1.2	6.0	1.0	400				
1N2274	S	MR1122	MR1120	R*	200	1.2	6.0	1.0	400				
1N2275	S	MR1123	MR1120	R*	300	1.2	6.0	1.0	400				
1N2276	S	MR1124	MR1120	R*	400	1.2	6.0	1.0	400				
1N2277	S	MR1125	MR1120	R*	500	1.2	6.0	1.0	400				
1N2278	S	MR1126	MR1120	R*	600	1.2	6.0	1.0	400				
1N2279	S	MR1128	MR1120	R*	800	1.2	6.0	1.0	400				
1N2280	S			R*	1000	1.2	6.0	1.0	400				
1N2281	S			R*	1200	1.2	6.0	1.0	400				
1N2282	S			R*	300	1.5	20	5.0	400				
1N2283	S			R*	400	1.5	20	5.0	400				
1N2284	S			R*	500	1.5	20	5.0	400				
1N2285	S			R*	600	1.5	20	5.0	400				

					RECTIFIERS					ZENER DIODES			
TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2286	S			R*	800	1.5	20	5.0	400				
1N2287	S			R*	1000	1.5	20	5.0	400				
1N2288	S			R*	1200	1.5	20	5.0	400				
1N2289	S			R*	100		1.5	0.003	20				
1N2289A	S			R*	100		1.5	0.003	20				
1N2290	S			R*	100		5.0	0.003	100				
1N2290A	S			R*	100		5.0	0.003	100				
1N2291	S			R*	200		1.5	0.003	20				
1N2291A	S			R*	200		1.5	0.003	20				
1N2292	S			R*	300		1.5	0.003	20				
1N2292A	S			R*	300		1.5	0.003	20				
1N2293	S			R*	400		1.5	0.003	20				
1N2293A	S			R*	400		1.5	0.003	20				
1N2294	S			R*	50	1.1	22	10	160				
1N2295	S			R*	100	1.1	22	10	160				
1N2296	S			R*	150	1.1	22	10	160				
1N2297	S			R*	200	1.1	22	10	160				
1N2298	S			R*	250	1.1	22	10	160				
1N2299	S			R*	300	1.1	22	10	160				
1N2300	S			R*	350	1.1	22	10	160				
1N2301	S			R*	400	1.1	22	10	160				
1N2302	S			R*	50	1.1	22	10	160				
1N2303	S			R*	100	1.1	22	10	160				
1N2304	S			R*	150	1.1	22	10	160				
1N2305	S			R*	200	1.1	22	10	160				
1N2306	S			R*	250	1.1	22	10	160				
1N2307	S			R*	300	1.1	22	10	160				
1N2308	S			R*	350	1.1	22	10	160				
1N2309	S			R*	400	1.1	22	10	160				
1N2310	S			R*	50	1.1	35	20	300				
1N2311	S			R*	100	1.1	35	20	300				
1N2312	S			R*	150	1.1	35	20	300				
1N2313	S			R*	200	1.1	35	20	300				
1N2314	S			R*	250	1.1	35	20	300				
1N2315	S			R*	300	1.1	35	20	300				
1N2316	S			R*	350	1.1	35	20	300				
1N2317	S			R*	400	1.1	35	20	300				
1N2318	S			R*	50	1.1	35	20	300				
1N2319	S			R*	100	1.1	35	20	300				
1N2320	S			R*	150	1.1	35	20	300				
1N2321	S			R*	200	1.1	35	20	300				
1N2322	S			R*	250	1.1	35	20	300				
1N2323	S			R*	300	1.1	35	20	300				
1N2324	S			R*	350	1.1	35	20	300				
1N2325	S			R*	400	1.1	35	20	300				
1N2326	G			DS	1.0	0.150	2.0M						
1N2327	S			DS	300	3.3	400M	1.5*					
1N2328	S			DS	300	3.3	400M	1.5*					
1N2348	S	MR1120	MR1120	R*	50	1.1	3.0	0.3	15				
1N2349	S	MR1121	MR1120	R*	100	1.1	3.0	0.3	15				
1N2350	S	MR1122	MR1120	R*	150	1.1	3.0	0.3	15				
1N2357	S			R*	1400		0.4	0.001	15				
1N2358	S			R*	1500		0.4	0.001	15				
1N2359	S			R*	1600		0.4	0.001	15				
1N2360	S			R*	1800		0.4	0.001	15				
1N2361	S			R*	2000		0.4	0.001	15				
1N2362	S			R*	1400		1.0	0.001	15				
1N2362A	S			R*	1400		5.0	0.001	20				
1N2362B	S			R*	1400		10	0.001	25				
1N2363	S			R*	1400		1.0	0.001	15				
1N2363A	S			R*	1400		5.0	0.001	20				
1N2363B	S			R*	1400		10	0.001	25				
1N2364	S			R*	1500		1.0	0.001	15				
1N2364A	S			R*	1500		5.0	0.001	20				
1N2364B	S			R*	1500		10	0.001	25				
1N2365	S			R *	1500		1.0	0.001	15				
1N2365A	S			R*	1500		5.0	0.001	20				
1N2365B	S			R*	1500		10	0.001	25				
1N2366	S			R*	1600		1.0	0.001	15				
1N2366A	S			R*	1600		5.0	0.001	20				
1N2366B	S			R*	1600		10	0.001	25				
1N2367	S			R*	1600		1.0	0.001	15				
1N2367A	S			R*	1600		5.0	0.001	20				
1N2367B	S			R*	1600		10	0.001	25				
1N2368	S			R*	1800		1.0	0.001	15				
1N2368A	S			R*	1800		5.0	0.001	20				
1N2368B	S			R*	1800		10	0.001	25				
1N2369	S			R*	1800		1.0	0.001	15				
1N2369A	S			R*	1800		5.0	0.001	20				
1N2369B	S			R*	1800		10	0.001	25				
1N2370	S			R*	2000		1.0	0.001	15				
1N2370A	S			R*	2000		5.0	0.001	20				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * / V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2370B	S			R*	2000		10	0.001	25				
1N2371	S			R*	2000		1.0	0.001	15				
1N2371A	S			R*	2000		5.0	0.001	20				
1N2371B	S			R*	2000		10	0.001	25				
1N2372	S			R*	1000	2.0	0.2	0.5	12				
1N2373	S	1N4005	1N4001	R*	600	3.0	0.1	0.250	12				
1N2374	S	1N4007	1N4001	R*	1000	3.0	0.1	0.250	12				
1N2375	S	MR991A	MR990A	R*	1500	4.5	0.1	0.250	12				
1N2376	S	MR992A	MR990A	R*	2000	7.5	0.1	0.250	12				
1N2377	S	MR993A	MR990A	R*	2400	9.0	0.075	0.250	12				
1N2378	S	MR994A	MR990A	R*	3000	9.0	0.075	0.250	12				
1N2379	S	MR995A	MR990A	R*	4000	15.0	0.05	0.250	12				
1N2380	S	1N2383	1N1730	R*	6000	22.5	0.05	0.250	12				
1N2381	S	1N2385	1N1730	R*	10K	37.5	0.025	0.250	12				
1N2382	S		1N1730	R*	4000	18	0.15	0.2	6.0				
1N2382A	S			R*	4000	6.0	0.35	0.2	6.0				
1N2383	S		1N1730	R*	6000	27	0.1	0.2	6.0				
1N2383A	S			R*	6000	9.0	0.35	0.2	6.0				
1N2384	S		1N1730	R*	8000	27	0.07	0.2	6.0				
1N2384A	S			R*	8000	12	0.275	0.2	6.0				
1N2385	S			R*	10K	39	0.07	0.2	6.0				
1N2385A	S			R*	10K	15	0.2	0.2	6.0				
1N2386	G			DS	5.0								
1N2387	S	1N4751A *	1N4728	DZ							30*	5.0	1.0W
1N2389	S			R*	1600	4.8	0.6	0.5	15				
1N2390	S			R*	50	1.2	1.5	0.3	35				
1N2391	S			R*	100	1.2	1.5	0.3	35				
1N2392	S			R*	200	1.2	1.5	0.3	35				
1N2393	S			R*	300	1.2	1.5	0.3	35				
1N2394	S			R*	400	1.2	1.5	0.3	35				
1N2395	S			R*	500	1.2	1.5	0.3	35				
1N2396	S			R*	600	1.2	1.5	0.3	35				
1N2397	S			R*	700	1.2	1.5	0.3	35				
1N2398	S			R*	800	1.2	1.5	0.3	35				
1N2399	S			R*	50	1.2	1.5	0.3	35				
1N2400	S			R*	100	1.2	1.5	0.3	35				
1N2401	S			R*	200	1.2	1.5	0.3	35				
1N2402	S			R*	300	1.2	1.5	0.3	35				
1N2403	S			R*	400	1.2	1.5	0.3	35				
1N2404	S			R*	500	1.2	1.5	0.3	35				
1N2405	S			R*	600	1.2	1.5	0.3	35				
1N2406	S			R*	700	1.2	1.5	0.3	35				
1N2407	S			R*	800	1.2	1.5	0.3	35				
1N2408	S			R*	50	1.2	1.5	0.3	35				
1N2409	S			R*	100	1.2	1.5	0.3	35				
1N2410	S			R*	200	1.2	1.5	0.3	35				
1N2411	S			R*	300	1.2	1.5	0.3	35				
1N2412	S			R*	400	1.2	1.5	0.3	35				
1N2413	S			R*	500	1.2	1.5	0.3	35				
1N2414	S			R*	600	1.2	1.5	0.3	35				
1N2415	S			R*	700	1.2	1.5	0.3	35				
1N2416	S			R*	800	1.2	1.5	0.3	35				
1N2417	S			R*	50	1.2	1.5	0.3	35				
1N2418	S			R*	100	1.2	1.5	0.3	35				
1N2419	S			R*	200	1.2	1.5	0.3	35				
1N2420	S			R*	300	1.2	1.5	0.3	35				
1N2421	S			R*	400	1.2	1.5	0.3	35				
1N2422	S			R*	500	1.2	1.5	0.3	35				
1N2423	S			R*	600	1.2	1.5	0.3	35				
1N2424	S			R*	700	1.2	1.5	0.3	35				
1N2425	S			R*	800	1.2	1.5	0.3	35				
1N2482	S	1N4003	1N4001	R*	200	1.2	0.75	0.5	30				
1N2483	S	1N4004	1N4001	R*	400	1.2	0.75	0.5	30				
1N2484	S	1N4005	1N4001	R*	500	1.2	0.75	0.5	30				
1N2485	S	1N4003	1N4001	R*	200	1.2	0.75	0.5	30				
1N2486	S	1N4004	1N4001	R*	300	1.2	0.75	0.5	30				
1N2487	S	1N4004	1N4001	R*	400	1.2	0.75	0.5	30				
1N2488	S	1N4005	1N4001	R*	500	1.2	0.75	0.5	30				
1N2489	S	1N4005	1N4001	R*	600	1.2	0.75	0.5	30				
1N2490	S			R*	1600	4.8	0.5	0.5	15				
1N2491	S	MR1120	MR1120	R*	50	1.5	6.0	2.0	150				
1N2492	S	MR1121	MR1120	R*	100	1.5	6.0	2.0	150				
1N2493	S	MR1122	MR1120	R*	200	1.5	6.0	2.0	150				
1N2494	S	MR1123	MR1120	R*	300	1.5	6.0	2.0	150				
1N2495	S	MR1124	MR1120	R*	400	1.5	6.0	2.0	150				
1N2496	S	MR1125	MR1120	R*	500	1.5	6.0	2.0	150				
1N2497	S	MR1126	MR1120	R*	600	1.5	6.0	2.0	150				
1N2498	S	1N2974A *	1N2970	DZ							10*	10	10W
1N2498A	S	1N2974B *	1N2970	DZ							10*	5.0	10W
1N2499	S	1N2975A *	1N2970	DZ							11*	10	10W
1N2499A	S	1N2975B *	1N2970	DZ							11*	5.0	10W
1N2500	S	1N2976A *	1N2970	DZ							12*	10	10W

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2500A	S	1N2976B *	1N2970	DZ							12*	5.0	10W
1N2501	S	1N4006	1N4001	R*	800	1.7	0.15	0.2	2.5				
1N2502	S	1N4007	1N4001	R*	1000	1.7	0.15	0.2	2.5				
1N2503	S			R*	1200	1.7	0.15	0.2	2.5				
1N2504	S			R*	1500	1.7	0.15	0.2	2.5				
1N2505	S	1N4006	1N4001	R*	800	1.7	0.3	0.2	2.5				
1N2506	S	1N4006	1N4001	R*	1000	1.7	0.3	0.2	2.5				
1N2507	S			R*	1200	1.7	0.3	0.2	2.5				
1N2508	S			R*	1500	1.7	0.3	0.2	2.5				
1N2509	S	Microwave C-band Mixer; NF = 10 dB											
1N2510	S	Microwave X-band Mixer; NF = 9.5 dB											
1N2512	S			R*	100	1.1		0.002	30				
1N2513	S			R*	200	1.1		0.002	30				
1N2514	S			R*	300	1.1		0.002	30				
1N2515	S			R*	400	1.1		0.002	30				
1N2516	S			R*	500	1.1		0.002	30				
1N2517	S			R*	600	1.1		0.002	30				
1N2518	S			R*	100	1.1		0.002	30				
1N2519	S			R*	200	1.1		0.002	30				
1N2520	S			R*	300	1.1		0.002	30				
1N2521	S			R*	400	1.1		0.002	30				
1N2522	S			R*	500	1.1		0.002	30				
1N2523	S			R*	600	1.1		0.002	30				
1N2524	S			R*	50	1.2	2.5	0.5	50				
1N2525	S			R*	100	1.2	2.5	0.5	50				
1N2526	S			R*	200	1.2	2.5	0.5	50				
1N2527	S			R*	300	1.2	2.5	0.5	50				
1N2528	S			R*	400	1.2	2.5	0.5	50				
1N2529	S			R*	500	1.2	2.5	0.5	50				
1N2530	S			R*	600	1.2	2.5	0.5	50				
1N2531	S			R*	700	1.2	2.5	0.5	50				
1N2532	S			R*	800	1.2	2.5	0.5	50				
1N2533	S			R*	900	1.2	2.5	0.5	50				
1N2534	S			R*	1000	1.2	2.5	0.5	50				
1N2535	S			R*	50	1.0	2.5	0.1	50				
1N2536	S			R*	100	1.0	2.5	0.1	50				
1N2537	S			R*	200	1.0	2.5	0.1	50				
1N2538	S			R*	300	1.0	2.5	0.1	50				
1N2539	S			R*	400	1.0	2.5	0.1	50				
1N2540	S			R*	500	1.0	2.5	0.1	50				
1N2541	S			R*	600	1.0	2.5	0.1	50				
1N2542	S			R*	700	1.0	2.5	0.1	50				
1N2543	S			R*	800	1.0	2.5	0.1	50				
1N2544	S			R*	900	1.0	2.5	0.1	50				
1N2545	S			R*	1000	1.0	2.5	0.1	50				
1N2546	S			R*	50	1.5	2.5	1.0	50				
1N2547	S			R*	100	1.5	2.5	1.0	50				
1N2548	S			R*	200	1.5	2.5	1.0	50				
1N2549	S			R*	300	1.5	2.5	1.0	50				
1N2550	S			R*	400	1.5	2.5	1.0	50				
1N2551	S			R*	500	1.5	2.5	1.0	50				
1N2552	S			R*	600	1.5	2.5	1.0	50				
1N2553	S			R*	700	1.5	2.5	1.0	50				
1N2554	S			R*	800	1.5	2.5	1.0	50				
1N2555	S			R*	900	1.5	2.5	1.0	50				
1N2556	S			R*	1000	1.5	2.5	1.0	50				
1N2557	S			R*	700	1.2	6.0	0.5	150				
1N2558	S			R*	800	1.2	6.0	0.5	150				
1N2559	S			R*	900	1.2	6.0	0.5	150				
1N2560	S			R*	1000	1.2	6.0	0.5	150				
1N2561	S			R*	700	1.0	6.0	0.1	150				
1N2562	S			R*	800	1.0	6.0	0.1	150				
1N2563	S			R*	900	1.0	6.0	0.1	150				
1N2564	S			R*	1000	1.0	6.0	0.1	150				
1N2565	S			R*	50	1.5	6.0	1.0	150				
1N2566	S			R*	100	1.5	6.0	1.0	150				
1N2567	S			R*	200	1.5	6.0	1.0	150				
1N2568	S			R*	300	1.5	6.0	1.0	150				
1N2569	S			R*	400	1.5	6.0	1.0	150				
1N2570	S			R*	500	1.5	6.0	1.0	150				
1N2571	S			R*	600	1.5	6.0	1.0	150				
1N2572	S			R*	700	1.5	6.0	1.0	150				
1N2573	S			R*	800	1.5	6.0	1.0	150				
1N2574	S			R*	900	1.5	6.0	1.0	150				
1N2575	S			R*	1000	1.5	6.0	1.0	150				
1N2576	S			R*	50	1.2	12	1.0	250				
1N2577	S			R*	100	1.2	12	1.0	250				
1N2578	S			R*	200	1.2	12	1.0	250				
1N2579	S			R*	300	1.2	12	1.0	250				
1N2580	S			R*	400	1.2	12	1.0	250				
1N2581	S			R*	500	1.2	12	1.0	250				
1N2582	S			R*	600	1.2	12	1.0	250				

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2583	S			R*	700	1.2	12	1.0	250				
1N2584	S			R*	800	1.2	12	1.0	250				
1N2585	S			R*	900	1.2	12	1.0	250				
1N2586	S			R*	1000	1.2	12	1.0	250				
1N2587	S			R*	50	1.0	12	0.2	250				
1N2588	S			R*	100	1.0	12	0.2	250				
1N2589	S			R*	200	1.0	12	0.2	250				
1N2590	S			R*	300	1.0	12	0.2	250				
1N2591	S			R*	400	1.0	12	0.2	250				
1N2592	S			R*	500	1.0	12	0.2	250				
1N2593	S			R*	600	1.0	12	0.2	250				
1N2594	S			R*	700	1.0	12	0.2	250				
1N2595	S			R*	800	1.0	12	0.2	250				
1N2596	S			R*	900	1.0	12	0.2	250				
1N2597	S			R*	1000	1.0	12	0.2	250				
1N2598	S			R*	50	1.5	12	2.0	250				
1N2599	S			R*	100	1.5	12	2.0	250				
1N2600	S			R*	200	1.5	12	2.0	250				
1N2601	S			R*	300	1.5	12	2.0	250				
1N2602	S			R*	400	1.5	12	2.0	250				
1N2603	S			R*	500	1.5	12	2.0	250				
1N2604	S			R*	600	1.5	12	2.0	250				
1N2605	S			R*	700	1.5	12	2.0	250				
1N2606	S			R*	800	1.5	12	2.0	250				
1N2607	S			R*	900	1.5	12	2.0	250				
1N2608	S			R*	1000	1.5	12	2.0	250				
1N2609	S	1N4001	1N4001	R*	50	1.1	0.75	0.3	30				
1N2610	S	1N4002	1N4001	R*	100	1.1	0.75	0.3	30				
1N2611	S	1N4003	1N4001	R*	200	1.1	0.75	0.3	30				
1N2612	S	1N4004	1N4001	R*	300	1.1	0.75	0.3	30				
1N2613	S	1N4004	1N4001	R*	400	1.1	0.75	0.3	30				
1N2614	S	1N4005	1N4001	R*	500	1.1	0.75	0.3	30				
1N2615	S	1N4005	1N4001	R*	600	1.1	0.75	0.3	30				
1N2616	S	1N4006	1N4001	R*	800	1.1	0.75	0.3	30				
1N2617	S	1N4007	1N4001	R*	1000	1.1	0.75	0.3	30				
1N2618	S			R*	1200	1.1	0.75	0.3	30				
1N2619	S			R*	1500	1.1	0.75	0.3	30				
1N2620	S		1N2620	DR						0.01	9.7	0	75
1N2620A	S		1N2620	DR						0.01	9.7	-55	100
1N2620B	S		1N2620	DR						0.01	9.7	-55	150
1N2621	S		1N2620	DR						0.005	9.7	0	75
1N2621A	S		1N2620	DR						0.005	9.7	-55	100
1N2621B	S		1N2620	DR						0.005	9.7	-55	150
1N2622	S		1N2620	DR						0.002	9.7	0	75
1N2622A	S		1N2620	DR						0.002	9.7	-55	100
1N2622B	S		1N2620	DR						0.002	9.7	-55	150
1N2623	S		1N2620	DR						0.001	9.7	0	75
1N2623A	S		1N2620	DR						0.001	9.7	-55	100
1N2623B	S		1N2620	DR						0.001	9.7	-55	150
1N2624	S		1N2620	DR						0.0005	9.7	0	75
1N2624A	S		1N2620	DR						0.0005	9.7	-55	100
1N2624B	S		1N2620	DR						0.0005	9.7	-55	150
1N2625	S	1N937	1N935	DR						0.0002	9.4	0	75
1N2625A	S	1N937A	1N935	DR						0.0002	9.4	-55	100
1N2625B	S	1N937B	1N935	DR						0.0002	9.4	-55	150
1N2626	S	1N938	1N935	DR						0.0001	9.4	0	75
1N2626A	S	1N938A	1N935	DR						0.0001	9.4	-55	100
1N2626B	S	1N938B	1N935	DR						0.0001	9.4	-55	150
1N2627 thru		Varactor Diodes, see Table on Page 92											
1N2628													
1N2629	G			DS	5.0								
1N2630	S			R*	1500	2.25	0.085	0.5	5.0				
1N2631	S			R*	1600	3.0	0.6	0.5	5.0				
1N2632	S			R*	2800	6.0	0.2	0.5	5.0				
1N2633	S			R*	1600	3.0	0.6	0.5	5.0				
1N2634	S			R*	1600	3.0	0.6	0.5	5.0				
1N2635	S			R*	1500	2.25	0.085	0.5	5.0				
1N2636	S			R*	1500	2.25	0.085	0.5	5.0				
1N2637	S			R*		28.0	0.25	0.5	5.0				
1N2638	S			R*	100	1.3	1.5	0.3	15				
1N2641	S			R*	200	1.3	1.5	0.3	15				
1N2644	S			R*	300	1.3	1.5	0.3	15				
1N2647	S			R*	400	1.3	1.5	0.3	15				
1N2650	S			R*	600	2.6	1.5	0.3	15				
1N2653	S			R*	800	2.6	1.5	0.3	15				
1N2656	S			R*	1200	3.9	1.5	0.8	15				
1N2659	S			R*	1600	5.2	1.5	0.8	15				
1N2662	S			R*	2000	6.5	1.5	0.8	15				
1N2664	S			R*	2400	7.8	1.5	0.8	15				
1N2666	S			R*	3200	10.4	1.5	0.8	15				
1N2667	S			R*	4000	13	1.5	0.8	15				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2668	S			R*	4800	15.6	1.5	0.8	15				
1N2669	S			R*	100	1.3	3.6	0.3	15				
1N2673	S			R*	200	1.3	3.6	0.3	15				
1N2677	S			R*	300	1.3	3.6	0.3	15				
1N2681	S			R*	400	1.3	3.6	0.3	15				
1N2685	S			R*	600	2.6	3.6	0.3	15				
1N2687	S			R*	800	2.6	3.6	0.3	15				
1N2689	S			R*	900	3.9	3.6	0.8	15				
1N2690	S			R*	1200	3.9	3.6	0.8	15				
1N2691	S			R*	1600	5.2	3.6	0.8	15				
1N2692	S			R*	100	1.3	7.2	0.3	15				
1N2694	S			R*	200	1.3	7.2	0.3	15				
1N2696	S			R*	300	1.3	7.2	0.3	15				
1N2698	S			R*	400	1.3	7.2	0.3	15				
1N2700	S			R*	600	2.6	7.2	0.3	15				
1N2701	S			R*	800	2.6	7.2	0.3	15				
1N2702	S			R*	100	1.3	3.0	0.2	15				
1N2705	S			R*	200	1.3	3.0	0.2	15				
1N2708	S			R*	300	1.3	3.0	0.2	15				
1N2711	S			R*	400	1.3	3.0	0.2	15				
1N2714	S			R*	600	2.6	3.0	0.2	15				
1N2717	S			R*	800	2.6	3.0	0.2	15				
1N2720	S			R*	1200	3.9	3.0	0.8	15				
1N2722	S			R*	1600	5.2	3.0	0.8	15				
1N2723	S			R*	2000	6.5	3.0	0.8	15				
1N2724	S			R*	2400	7.8	3.0	0.8	15				
1N2725	S			R*	100	1.3	3.0	0.3	15				
1N2728	S			R*	200	1.3	3.0	0.3	15				
1N2731	S			R*	300	1.3	3.0	0.3	15				
1N2734	S			R*	400	1.3	3.0	0.3	15				
1N2737	S			R*	600	2.6	3.0	0.3	15				
1N2738	S			R*	800	2.6	3.0	0.3	15				
1N2739	S			R*	1200	3.9	3.0	0.8	15				
1N2740	S			R*	100	1.3	3.6	0.3	15				
1N2742	S			R*	200	1.3	3.6	0.3	15				
1N2744	S			R*	300	1.3	3.6	0.3	15				
1N2746	S			R*	400	1.3	3.6	0.3	15				
1N2748	S			R*	600	2.6	3.6	0.3	15				
1N2749	S			R*	800	2.6	3.6	0.3	15				
1N2750	S			R*	100	1.3	3.0	0.3	15				
1N2753	S			R*	200	1.3	3.0	0.3	15				
1N2756	S			R*	300	1.3	3.0	0.3	15				
1N2759	S			R*	400	1.3	3.0	0.3	15				
1N2762	S			R*	600	2.6	3.0	0.3	15				
1N2763	S			R*	800	2.6	3.0	0.3	15				
1N2764	S			R*	1200	3.9	3.0	0.8	15				
1N2765	S	1N823A	1N821	DR						0.005	6.8	-55	100
1N2765A	S	1N825A	1N821	DR						0.0025	6.8	-55	100
1N2766	S	1N1736A	1N429	DR						0.005	13.6	-55	100
1N2766A	S	1N1736A	1N429	DR						0.0025	13.6	-55	100
1N2767	S	1N4061	1N429	DR						0.005	20.4	-55	100
1N2767A	S	1N4061A	1N429	DR						0.0025	20.4	-55	100
1N2768	S	1N4063	1N429	DR						0.005	27.2	-55	100
1N2768A	S	1N4063A	1N429	DR						0.0025	27.2	-55	100
1N2769	S	1N4065	1N429	DR						0.005	34.0	-55	100
1N2769A	S	1N4065A	1N429	DR						0.0025	34.0	-55	100
1N2770	S	1N4067	1N429	DR						0.005	40.8	-55	100
1N2770A	S	1N4067A	1N429	DR						0.0025	40.8	-55	100
	S												
1N2772	S			R*	700	1.8	0.5		15				
1N2773	S			R*	800	1.8	0.5		15				
1N2774	S			R*	900	1.8	0.5		15				
1N2775	S			R*	1000	1.8	0.5		15				
1N2776	S			R*	1100	1.8	0.5		15				
1N2777	S			R*	1200	1.8	0.5		15				
1N2778	S			R*	1300	1.8	0.5		15				
1N2779	S			R*	1400	1.8	0.5		15				
1N2780	S			R*	1500	1.8	0.5		15				
1N2781	S			R*	1600	1.8	0.5		15				
1N2782	S			DS	5.0			2.0*					
1N2783	S	1N3000A	1N2970	DZ							62*	10	6.0W
1N2784	S			R*	200	1.5	8.0	5.0	200				
1N2785	S			R*	400	1.5	8.0	5.0	200				
1N2786	S			R*	200	1.2	10	10.0	180				
1N2787	S			R*	400	1.2	10	10.0	180				
1N2788	S			R*	200	1.3	12.5	5.0	340				
1N2789	S			R*	400	1.3	12.5	5.0	340				
1N2790	S	1N3156	1N3154	DR						0.002	8.5	-55	100
1N2791	S			DS		1.3	50M	0.05*	4.0				
1N2793	S	1N1183	1N1183	R*	50	1.25	5.0	5.0	75				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2794	S	1N1184	1N1183	R*	100	1.25	5.0	5.0	75				
1N2795	S	1N1185	1N1183	R*	150	1.25	5.0	5.0	75				
1N2796	S	1N1186	1N1183	R*	200	1.25	5.0	5.0	75				
1N2797	S	1N1187	1N1183	R*	250	1.25	5.0	5.0	75				
1N2798	S	1N1187	1N1183	R*	300	1.25	5.0	5.0	75				
1N2799	S	1N1188	1N1183	R*	350	1.25	5.0	5.0	75				
1N2800	S	1N1188	1N1183	R*	400	1.25	5.0	5.0	75				
1N2801	G			DS	20	0.36	5.0M	2.0*	500				
1N2802	S	Microwave X-band Mixer; NF = 7.5 dB											
1N2803	S			R*	400	1.2	250	36	3500				
1N2804	S		1N2804	DZ							6.8*	20	50W
1N2804A	S		1N2804	DZ							6.8*	10	50W
1N2804B	S		1N2804	DZ							6.8*	5.0	50W
1N2805	S		1N2804	DZ							7.5*	20	50W
1N2805A	S		1N2804	DZ							7.5*	10	50W
1N2805B	S		1N2804	DZ							7.5*	5.0	50W
1N2806	S		1N2804	DZ							8.2*	20	50W
1N2806A	S		1N2804	DZ							8.2*	10	50W
1N2806B	S		1N2804	DZ							8.2*	5.0	50W
1N2807	S		1N2804	DZ							9.1*	20	50W
1N2807A	S		1N2804	DZ							9.1*	10	50W
1N2807B	S		1N2804	DZ							9.1*	5.0	50W
1N2808	S		1N2804	DZ							10*	20	50W
1N2808A	S		1N2804	DZ							10*	10	50W
1N2808B	S		1N2804	DZ							10*	5.0	50W
1N2809	S		1N2804	DZ							11*	20	50W
1N2809A	S		1N2804	DZ							11*	10	50W
1N2809B	S		1N2804	DZ							11*	5.0	50W
1N2810	S		1N2804	DZ							12*	20	50W
1N2810A	S		1N2804	DZ							12*	10	50W
1N2810B	S		1N2804	DZ							12*	5.0	50W
1N2811	S		1N2804	DZ							13*	20	50W
1N2811A	S		1N2804	DZ							13*	10	50W
1N2811B	S		1N2804	DZ							13*	5.0	50W
1N2812	S		1N2804	DZ							14*	20	50W
1N2812A	S		1N2804	DZ							14*	10	50W
1N2812B	S		1N2804	DZ							14*	5.0	50W
1N2813	S		1N2804	DZ							15*	20	50W
1N2813A	S		1N2804	DZ							15*	10	50W
1N2813B	S		1N2804	DZ							15*	5.0	50W
1N2814	S		1N2804	DZ							16*	20	50W
1N2814A	S		1N2804	DZ							16*	10	50W
1N2814B	S		1N2804	DZ							16*	5.0	50W
1N2815	S		1N2804	DZ							17*	20	50W
1N2815A	S		1N2804	DZ							17*	10	50W
1N2815B	S		1N2804	DZ							17*	5.0	50W
1N2816	S		1N2804	DZ							18*	20	50W
1N2816A	S		1N2804	DZ							18*	10	50W
1N2816B	S		1N2804	DZ							18*	5.0	50W
1N2817	S		1N2804	DZ							19*	20	50W
1N2817A	S		1N2804	DZ							19*	10	50W
1N2817B	S		1N2804	DZ							19*	5.0	50W
1N2818	S		1N2804	DZ							20*	20	50W
1N2818A	S		1N2804	DZ							20*	10	50W
1N2818B	S		1N2804	DZ							20*	5.0	50W
1N2819	S		1N2804	DZ							22*	20	50W
1N2819A	S		1N2804	DZ							22*	10	50W
1N2819B	S		1N2804	DZ							22*	5.0	50W
1N2820	S		1N2804	DZ							24*	20	50W
1N2820A	S		1N2804	DZ							24*	10	50W
1N2820B	S		1N2804	DZ							24*	5.0	50W
1N2821	S		1N2804	DZ							25*	20	50W
1N2821A	S		1N2804	DZ							25*	10	50W
1N2821B	S		1N2804	DZ							25*	5.0	50W
1N2822	S		1N2804	DZ							27*	20	50W
1N2822A	S		1N2804	DZ							27*	10	50W
1N2822B	S		1N2804	DZ							27*	5.0	50W
1N2823	S		1N2804	DZ							30*	20	50W
1N2823A	S		1N2804	DZ							30*	10	50W
1N2823B	S		1N2804	DZ							30*	5.0	50W
1N2824	S		1N2804	DZ							33*	20	50W
1N2824A	S		1N2804	DZ							33*	10	50W
1N2824B	S		1N2804	DZ							33*	5.0	50W
1N2825	S		1N2804	DZ							36*	20	50W
1N2825A	S		1N2804	DZ							36*	10	50W
1N2825B	S		1N2804	DZ							36*	5.0	50W
1N2826	S		1N2804	DZ							39*	20	50W
1N2826A	S		1N2804	DZ							39*	10	50W
1N2826B	S		1N2804	DZ							39*	5.0	50W
1N2827	S		1N2804	DZ							43*	20	50W
1N2827A	S		1N2804	DZ							43*	10	50W
1N2827B	S		1N2804	DZ							43*	5.0	50W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2828	S		1N2804	DZ							45*	20	50W
1N2828A	S		1N2804	DZ							45*	10	50W
1N2828B	S		1N2804	DZ							45*	5.0	50W
1N2829	S		1N2804	DZ							45*	20	50W
1N2829A	S		1N2804	DZ							47*	10	50W
1N2829B	S		1N2804	DZ							47*	5.0	50W
1N2830	S		1N2804	DZ							50*	20	50W
1N2830A	S		1N2804	DZ							50*	10	50W
1N2830B	S		1N2804	DZ							50*	5.0	50W
1N2831	S		1N2804	DZ							51*	20	50W
1N2831A	S		1N2804	DZ							51*	10	50W
1N2831B	S		1N2804	DZ							51*	5.0	50W
1N2832	S		1N2804	DZ							56*	20	50W
1N2832A	S		1N2804	DZ							56*	10	50W
1N2832B	S		1N2804	DZ							56*	5.0	50W
1N2833	S		1N2804	DZ							62*	20	50W
1N2833A	S		1N2804	DZ							62*	10	50W
1N2833B	S		1N2804	DZ							62*	5.0	50W
1N2834	S		1N2804	DZ							68*	20	50W
1N2834A	S		1N2804	DZ							68*	10	50W
1N2834B	S		1N2804	DZ							68*	5.0	50W
1N2835	S		1N2804	DZ							75*	20	50W
1N2835A	S		1N2804	DZ							75*	10	50W
1N2835B	S		1N2804	DZ							75*	5.0	50W
1N2836	S		1N2804	DZ							82*	20	50W
1N2836A	S		1N2804	DZ							82*	10	50W
1N2836B	S		1N2804	DZ							82*	5.0	50W
1N2837	S		1N2804	DZ							91*	20	50W
1N2837A	S		1N2804	DZ							91*	10	50W
1N2837B	S		1N2804	DZ							91*	5.0	50W
1N2838	S		1N2804	DZ							100*	20	50W
1N2838A	S		1N2804	DZ							100*	10	50W
1N2838B	S		1N2804	DZ							100*	5.0	50W
1N2839	S		1N2804	DZ							105*	20	50W
1N2839A	S		1N2804	DZ							105*	10	50W
1N2839B	S		1N2804	DZ							105*	5.0	50W
1N2840	S		1N2804	DZ							110*	20	50W
1N2840A	S		1N2804	DZ							110*	10	50W
1N2840B	S		1N2804	DZ							110*	5.0	50W
1N2841	S		1N2804	DZ							120*	20	50W
1N2841A	S		1N2804	DZ							120*	10	50W
1N2841B	S		1N2804	DZ							120*	5.0	50W
1N2842	S		1N2804	DZ							130*	20	50W
1N2842A	S		1N2804	DZ							130*	10	50W
1N2842B	S		1N2804	DZ							130*	5.0	50W
1N2843	S		1N2804	DZ							140*	20	50W
1N2843A	S		1N2804	DZ							140*	10	50W
1N2843B	S		1N2804	DZ							140*	5.0	50W
1N2844	S		1N2804	DZ							160*	20	50W
1N2844A	S		1N2804	DZ							160*	10	50W
1N2844B	S		1N2804	DZ							160*	5.0	50W
1N2845	S		1N2804	DZ							180*	20	50W
1N2845A	S		1N2804	DZ							180*	10	50W
1N2845B	S		1N2804	DZ							180*	5.0	50W
1N2846	S		1N2804	DZ							200*	20	50W
1N2846A	S		1N2804	DZ							200*	10	50W
1N2846B	S		1N2804	DZ							200*	5.0	50W
1N2847	S			R*	100	2.0	1.5	0.3	15				
1N2848	S			R*	200	2.0	1.5	0.2	15				
1N2849	S			R*	300	2.0	1.5	0.2	15				
1N2850	S			R*	400	2.0	1.5	0.2	15				
1N2851	S			R*	500	2.0	1.5	0.2	15				
1N2852	S			R*	600	2.0	1.5	0.2	15				
1N2855	S			R*	600	1.2	250	25	3500				
1N2856	S			R*	800	1.2	250	20	4500				
1N2857	S			R*	1000	1.2	250	15	4500				
1N2858	S	1N4001	1N4001	R*	50	1.2	0.75	0.3	40				
1N2858A	S			R*	50	1.2	1.0	0.3	25				
1N2859	S	1N4002	1N4001	R*	100	1.2	0.75	0.3	40				
1N2859A	S			R*	100	1.2	1.0	0.3	25				
1N2860	S	1N4003	1N4001	R*	200	1.2	0.75	0.3	40				
1N2860A	S			R*	200	1.2	1.0	0.3	25				
1N2861	S	1N4004	1N4001	R*	300	1.2	0.75	0.2	40				
1N2861A	S			R*	300	1.2	1.0	0.3	25				
1N2862	S	1N4004	1N4001	R*	400	1.2	0.75	0.2	40				
1N2862A	S			R*	400	1.2	1.0	0.3	25				
1N2863	S	1N4005	1N4001	R*	500	1.2	0.75	0.2	40				
1N2863A	S			R*	500	1.2	1.0	0.3	25				
1N2864	S	1N4005	1N4001	R*	600	1.2	0.75	0.2	40				
1N2864A	S			R*	600	1.2	1.0	0.3	25				
1N2865	S			R*	1000	2.5	0.7	0.1	7.0				
1N2866	S			R*	1500	2.5	0.7	0.1	7.0				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2867	S			R*	1000	2.5	0.7	0.1	7.0				
1N2868	S			R*	1500	2.5	0.7	0.1	7.0				
1N2878	S	1N4006	1N4001	DS	700	2.0	250M	0.5*					
1N2879	S	1N4006	1N4001	DS	700	2.0	250M	0.5*					
1N2880	S	1N4007	1N4001	DS	1.0K	2.0	250M	0.5*					
1N2881	S	1N4007	1N4001	DS	1.0K	2.0	250M	0.5*					
1N2882	S	1N4007	1N4001	DS	500	3.0	250M	0.5*					
1N2883	S	1N4007	1N4001	DS	500	3.0	250M	0.5*					
1N2884	S	MR991A	MR990A	DS	400	4.0	250M	0.5*					
1N2885	S	MR991A	MR990A	DS	400	4.0	250M	0.5*					
1N2886	S	MR991A	MR990A	DS	500	3.0	250M	0.5*					
1N2887	S	MR991A	MR990A	DS	500	3.0	250M	0.5*					
1N2888	S			DS	750	5.0	250M	0.5*					
1N2889	S	MR992A	MR990A	DS	750	5.0	250M	0.5*					
1N2890	S	MR992A	MR990A	DS	2.0K	4.0	250M	0.5*					
1N2891	S	MR992A	MR990A	DS	2.0K	4.0	250M	0.5*					
1N2892	S	MR993A	MR990A	DS	100	6.0	250M	0.5*					
1N2893	S	MR993A	MR990A	DS	100	6.0	250M	0.5*					
1N2894	S	MR994A	MR990A	DS	450	7.0	250M	0.5*					
1N2895	S	MR994A	MR990A	DS	450	7.0	250M	0.5*					
1N2896	S	MR994A	MR990A	DS	500	5.0	250M	0.5*					
1N2897	S	MR994A	MR990A	DS	500	5.0	250M	0.5*					
1N2898	S	MR995A	MR990A	DS	800	8.0	250M	0.5*					
1N2899	S	MR995A	MR990A	DS	800	8.0	250M	0.5*					
1N2900	S	MR995A	MR990A	DS	3.0K	6.0	250M	0.5*					
1N2901	S	MR995A	MR990A	DS	3.0K	6.0	250M	0.5*					
1N2902	S			DS	150	9.0	250M	0.5*					
1N2903	S			DS	150	9.0	250M	0.5*					
1N2904	S			DS	500	7.0	250M	0.5*					
1N2905	S			DS	500	7.0	250M	0.5*					
1N2906	S			DS	500	10	250M	0.5*					
1N2907	S			DS	500	10	250M	0.5*					
1N2908	S			DS	850	11	250M	0.5*					
1N2909	S			DS	850	11	250M	0.5*					
1N2910	S			DS	4.0K	8.0	250M	0.5*					
1N2911	S			DS	4.0K	8.0	250M	0.5*					
1N2912	S			DS	200	12	250M	0.5*					
1N2913	S			DS	200	12	250M	0.5*					
1N2914	S			DS	500	9.0	250M	0.5*					
1N2915	S			DS	500	9.0	250M	0.5*					
1N2916	S			DS	550	13	250M	0.5*					
1N2917	S			DS	550	13	250M	0.5*					
1N2918	S			DS	5.0K	10	250M	0.5*					
1N2919	S			DS	5.0K	10	250M	0.5*					
1N2920	S			DS	500	11	250M	0.5*					
1N2921	S			DS	500	11	250M	0.5*					
1N2922	S			DS	6.0K	12	250M	0.5*					
1N2923	S			DS	6.0K	12	250M	0.5*					
1N2924	S			DS	500	13	250M	0.5*					
1N2925	S			DS	500	13	250M	0.5*					
1N2926		Microwave X-K band Detector											
1N2926A		Microwave X-K band Detector											
1N2927,A thru 1N2934,A		Tunnel Diodes, see Table on Page 98											
1N2937	S	1N2996A	1N2970	DZ						42.5	57.5		10W
1N2938	S			DZ						0.75	1.05		2.0W
1N2939,A thru 1N2941,A		Tunnel Diodes, see Table on Page 98											
1N2969		Tunnel Diode, see Table on Page 98											
1N2969A		Tunnel Diode, see Table on Page 98											
1N2970	S		1N2970	DZ							6.8*	20	10W
1N2970A	S		1N2970	DZ							6.8*	10	10W
1N2970B	S		1N2970	DZ							6.8*	5.0	10W
1N2971	S		1N2970	DZ							7.5*	20	10W
1N2971A	S		1N2970	DZ							7.5*	10	10W
1N2971B	S		1N2970	DZ							7.5*	5.0	10W
1N2972	S		1N2970	DZ							8.2*	20	10W
1N2972A	S		1N2970	DZ							8.2*	10	10W
1N2972B	S		1N2970	DZ							8.2*	5.0	10W
1N2973	S		1N2970	DZ							9.1*	20	10W
1N2973A	S		1N2970	DZ							9.1*	10	10W
1N2973B	S		1N2970	DZ							9.1*	5.0	10W
1N2974	S		1N2970	DZ							10*	20	10W
1N2974A	S		1N2970	DZ							10*	10	10W
1N2974B	S		1N2970	DZ							10*	5.0	10W
1N2975	S		1N2970	DZ							11*	20	10W
1N2975A	S		1N2970	DZ							11*	10	10W
1N2975B	S		1N2970	DZ							11*	5.0	10W
1N2976	S		1N2970	DZ							12*	20	10W
1N2976A	S		1N2970	DZ							12*	10	10W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N2976B	S		1N2970	DZ							12*	5.0	10W
1N2977	S		1N2970	DZ							13*	20	10W
1N2977A	S		1N2970	DZ							13*	10	10W
1N2977B	S		1N2970	DZ							13*	5.0	10W
1N2978	S		1N2970	DZ							14*	20	10W
1N2978A	S		1N2970	DZ							14*	10	10W
1N2978B	S		1N2970	DZ							14*	5.0	10W
1N2979	S		1N2970	DZ							15*	20	10W
1N2979A	S		1N2970	DZ							15*	10	10W
1N2979B	S		1N2970	DZ							15*	5.0	10W
1N2980	S		1N2970	DZ							16*	20	10W
1N2980A	S		1N2970	DZ							16*	10	10W
1N2980B	S		1N2970	DZ							16*	5.0	10W
1N2981	S		1N2970	DZ							17*	20	10W
1N2981A	S		1N2970	DZ							17*	10	10W
1N2981B	S		1N2970	DZ							17*	5.0	10W
1N2982	S		1N2970	DZ							18*	20	10W
1N2982A	S		1N2970	DZ							18*	10	10W
1N2982B	S		1N2970	DZ							18*	5.0	10W
1N2983	S		1N2970	DZ							19*	20	10W
1N2983A	S		1N2970	DZ							19*	10	10W
1N2983B	S		1N2970	DZ							19*	5.0	10W
1N2984	S		1N2970	DZ							20*	20	10W
1N2984A	S		1N2970	DZ							20*	10	10W
1N2984B	S		1N2970	DZ							20*	5.0	10W
1N2985	S		1N2970	DZ							22*	20	10W
1N2985A	S		1N2970	DZ							22*	10	10W
1N2985B	S		1N2970	DZ							22*	5.0	10W
1N2986	S		1N2970	DZ							24*	20	10W
1N2986A	S		1N2970	DZ							24*	10	10W
1N2986B	S		1N2970	DZ							24*	5.0	10W
1N2987	S		1N2970	DZ							25*	20	10W
1N2987A	S		1N2970	DZ							25*	10	10W
1N2987B	S		1N2970	DZ							25*	5.0	10W
1N2988	S		1N2970	DZ							27*	20	10W
1N2988A	S		1N2970	DZ							27*	10	10W
1N2988B	S		1N2970	DZ							27*	5.0	10W
1N2989	S		1N2970	DZ							30*	20	10W
1N2989A	S		1N2970	DZ							30*	10	10W
1N2989B	S		1N2970	DZ							30*	5.0	10W
1N2990	S		1N2970	DZ							33*	20	10W
1N2990A	S		1N2970	DZ							33*	10	10W
1N2990B	S		1N2970	DZ							33*	5.0	10W
1N2991	S		1N2970	DZ							36*	20	10W
1N2991A	S		1N2970	DZ							36*	10	10W
1N2991B	S		1N2970	DZ							36*	5.0	10W
1N2992	S		1N2970	DZ							39*	20	10W
1N2992A	S		1N2970	DZ							39*	10	10W
1N2992B	S		1N2970	DZ							39*	5.0	10W
1N2993	S		1N2970	DZ							43*	20	10W
1N2993A	S		1N2970	DZ							43*	10	10W
1N2993B	S		1N2970	DZ							43*	5.0	10W
1N2994	S		1N2970	DZ							45*	20	10W
1N2994A	S		1N2970	DZ							45*	10	10W
1N2994B	S		1N2970	DZ							45*	5.0	10W
1N2995	S		1N2970	DZ							47*	20	10W
1N2995A	S		1N2970	DZ							47*	10	10W
1N2995B	S		1N2970	DZ							47*	5.0	10W
1N2996	S		1N2970	DZ							50*	20	10W
1N2996A	S		1N2970	DZ							50*	10	10W
1N2996B	S		1N2970	DZ							50*	5.0	10W
1N2997	S		1N2970	DZ							51*	20	10W
1N2997A	S		1N2970	DZ							51*	10	10W
1N2997B	S		1N2970	DZ							51*	5.0	10W
1N2998	S		1N2970	DZ							52*	20	10W
1N2998A	S		1N2970	DZ							52*	10	10W
1N2998B	S		1N2970	DZ							52*	5.0	10W
1N2999	S		1N2970	DZ							56*	20	10W
1N2999A	S		1N2970	DZ							56*	10	10W
1N2999B	S		1N2970	DZ							56*	5.0	10W
1N3000	S		1N2970	DZ							62*	20	10W
1N3000A	S		1N2970	DZ							62*	10	10W
1N3000B	S		1N2970	DZ							62*	5.0	10W
1N3001	S		1N2970	DZ							68*	20	10W
1N3001A	S		1N2970	DZ							68*	10	10W
1N3001B	S		1N2970	DZ							68*	5.0	10W
1N3002	S		1N2970	DZ							75*	20	10W
1N3002A	S		1N2970	DZ							75*	10	10W
1N3002B	S		1N2970	DZ							75*	5.0	10W
1N3003	S		1N2970	DZ							82*	20	10W
1N3003A	S		1N2970	DZ							82*	10	10W
1N3003B	S		1N2970	DZ							82*	5.0	10W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3004	S		1N2970	DZ							91*	20	10W
1N3004A	S		1N2970	DZ							91*	10	10W
1N3004B	S		1N2970	DZ							91*	5.0	10W
1N3005	S		1N2970	DZ							100*	20	10W
1N3005A	S		1N2970	DZ							100*	10	10W
1N3005B	S		1N2970	DZ							100*	5.0	10W
1N3006	S		1N2970	DZ							105*	20	10W
1N3006A	S		1N2970	DZ							105*	10	10W
1N3006B	S		1N2970	DZ							105*	5.0	10W
1N3007	S		1N2970	DZ							110*	20	10W
1N3007A	S		1N2970	DZ							110*	10	10W
1N3007B	S		1N2970	DZ							110*	5.0	10W
1N3008	S		1N2970	DZ							120*	20	10W
1N3008A	S		1N2970	DZ							120*	10	10W
1N3008B	S		1N2970	DZ							120*	5.0	10W
1N3009	S		1N2970	DZ							130*	20	10W
1N3009A	S		1N2970	DZ							130*	10	10W
1N3009B	S		1N2970	DZ							130*	5.0	10W
1N3010	S		1N2970	DZ							140*	20	10W
1N3010A	S		1N2970	DZ							140*	10	10W
1N3010B	S		1N2970	DZ							140*	5.0	10W
1N3011	S		1N2970	DZ							150*	20	10W
1N3011A	S		1N2970	DZ							150*	10	10W
1N3011B	S		1N2970	DZ							150*	5.0	10W
1N3012	S		1N2970	DZ							160*	20	10W
1N3012A	S		1N2970	DZ							160*	10	10W
1N3012B	S		1N2970	DZ							160*	5.0	10W
1N3013	S		1N2970	DZ							175*	20	10W
1N3013A	S		1N2970	DZ							175*	10	10W
1N3013B	S		1N2970	DZ							175*	5.0	10W
1N3014	S		1N2970	DZ							180*	20	10W
1N3014A	S		1N2970	DZ							180*	10	10W
1N3014B	S		1N2970	DZ							180*	5.0	10W
1N3015	S		1N2970	DZ							200*	20	10W
1N3015A	S		1N2970	DZ							200*	10	10W
1N3015B	S		1N2970	DZ							200*	5.0	10W
1N3016	S		1N2970	DZ							6.8*	20	1.0W
1N3016A	S		1N2970	DZ							6.8*	10	1.0W
1N3016B	S		1N2970	DZ							6.8*	5.0	1.0W
1N3017	S		1N2970	DZ							7.5*	20	1.0W
1N3017A	S		1N2970	DZ							7.5*	10	1.0W
1N3017B	S		1N2970	DZ							7.5*	5.0	1.0W
1N3018	S		1N2970	DZ							8.2*	20	1.0W
1N3018A	S		1N2970	DZ							8.2*	10	1.0W
1N3018B	S		1N2970	DZ							8.2*	5.0	1.0W
1N3019	S		1N2970	DZ							9.1*	20	1.0W
1N3019A	S		1N2970	DZ							9.1*	10	1.0W
1N3019B	S		1N2970	DZ							9.1*	5.0	1.0W
1N3020	S		1N2970	DZ							10*	20	1.0W
1N3020A	S		1N2970	DZ							10*	10	1.0W
1N3020B	S		1N2970	DZ							10*	5.0	1.0W
1N3021	S		1N2970	DZ							11*	20	1.0W
1N3021A	S		1N2970	DZ							11*	10	1.0W
1N3021B	S		1N2970	DZ							11*	5.0	1.0W
1N3022	S		1N2970	DZ							12*	20	1.0W
1N3022A	S		1N2970	DZ							12*	10	1.0W
1N3022B	S		1N2970	DZ							12*	5.0	1.0W
1N3023	S		1N2970	DZ							13*	20	1.0W
1N3023A	S		1N2970	DZ							13*	10	1.0W
1N3023B	S		1N2970	DZ							13*	5.0	1.0W
1N3024	S		1N2970	DZ							15*	20	1.0W
1N3024A	S		1N2970	DZ							15*	10	1.0W
1N3024B	S		1N2970	DZ							15*	5.0	1.0W
1N3025	S		1N2970	DZ							16*	20	1.0W
1N3025A	S		1N2970	DZ							16*	10	1.0W
1N3025B	S		1N2970	DZ							16*	5.0	1.0W
1N3026	S		1N2970	DZ							18*	20	1.0W
1N3026A	S		1N2970	DZ							18*	10	1.0W
1N3026B	S		1N2970	DZ							18*	5.0	1.0W
1N3027	S		1N2970	DZ							20*	20	1.0W
1N3027A	S		1N2970	DZ							20*	10	1.0W
1N3027B	S		1N2970	DZ							20*	5.0	1.0W
1N3028	S		1N2970	DZ							22*	20	1.0W
1N3028A	S		1N2970	DZ							22*	10	1.0W
1N3028B	S		1N2970	DZ							22*	5.0	1.0W
1N3029	S		1N2970	DZ							24*	20	1.0W
1N3029A	S		1N2970	DZ							24*	10	1.0W
1N3029B	S		1N2970	DZ							24*	5.0	1.0W
1N3030	S		1N2970	DZ							27*	20	1.0W
1N3030A	S		1N2970	DZ							27*	10	1.0W
1N3030B	S		1N2970	DZ							27*	5.0	1.0W
1N3031	S		1N2970	DZ							30*	20	1.0W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3031A	S		1N2970	DZ							30*	10	1.0W
1N3031B	S		1N2970	DZ							30*	5.0	1.0W
1N3032	S		1N2970	DZ							33*	20	1.0W
1N3032A	S		1N2970	DZ							33*	10	1.0W
1N3032B	S		1N2970	DZ							33*	5.0	1.0W
1N3033	S		1N2970	DZ							36*	20	1.0W
1N3033A	S		1N2970	DZ							36*	10	1.0W
1N3033B	S		1N2970	DZ							36*	5.0	1.0W
1N3034	S		1N2970	DZ							39*	20	1.0W
1N3034A	S		1N2970	DZ							39*	10	1.0W
1N3034B	S		1N2970	DZ							39*	5.0	1.0W
1N3035	S		1N2970	DZ							43*	20	1.0W
1N3035A	S		1N2970	DZ							43*	10	1.0W
1N3035B	S		1N2970	DZ							43*	5.0	1.0W
1N3036	S		1N2970	DZ							47*	20	1.0W
1N3036A	S		1N2970	DZ							47*	10	1.0W
1N3036B	S		1N2970	DZ							47*	5.0	1.0W
1N3037	S		1N2970	DZ							51*	20	1.0W
1N3037A	S		1N2970	DZ							51*	10	1.0W
1N3037B	S		1N2970	DZ							51*	5.0	1.0W
1N3038	S		1N2970	DZ							56*	20	1.0W
1N3038A	S		1N2970	DZ							56*	10	1.0W
1N3038B	S		1N2970	DZ							56*	5.0	1.0W
1N3039	S		1N2970	DZ							62*	20	1.0W
1N3039A	S		1N2970	DZ							62*	10	1.0W
1N3039B	S		1N2970	DZ							62*	5.0	1.0W
1N3040	S		1N2970	DZ							68*	20	1.0W
1N3040A	S		1N2970	DZ							68*	10	1.0W
1N3040B	S		1N2970	DZ							68*	5.0	1.0W
1N3041	S		1N2970	DZ							75*	20	1.0W
1N3041A	S		1N2970	DZ							75*	10	1.0W
1N3041B	S		1N2970	DZ							75*	5.0	1.0W
1N3042	S		1N2970	DZ							82*	20	1.0W
1N3042A	S		1N2970	DZ							82*	10	1.0W
1N3042B	S		1N2970	DZ							82*	5.0	1.0W
1N3043	S		1N2970	DZ							91*	20	1.0W
1N3043A	S		1N2970	DZ							91*	10	1.0W
1N3043B	S		1N2970	DZ							91*	5.0	1.0W
1N3044	S		1N2970	DZ							100*	20	1.0W
1N3044A	S		1N2970	DZ							100*	10	1.0W
1N3044B	S		1N2970	DZ							100*	5.0	1.0W
1N3045	S		1N2970	DZ							110*	20	1.0W
1N3045A	S		1N2970	DZ							110*	10	1.0W
1N3045B	S		1N2970	DZ							110*	5.0	1.0W
1N3046	S		1N2970	DZ							120*	20	1.0W
1N3046A	S		1N2970	DZ							120*	10	1.0W
1N3046B	S		1N2970	DZ							120*	5.0	1.0W
1N3047	S		1N2970	DZ							130*	20	1.0W
1N3047A	S		1N2970	DZ							130*	10	1.0W
1N3047B	S		1N2970	DZ							130*	5.0	1.0W
1N3048	S		1N2970	DZ							150*	20	1.0W
1N3048A	S		1N2970	DZ							150*	10	1.0W
1N3048B	S		1N2970	DZ							150*	5.0	1.0W
1N3049	S		1N2970	DZ							160*	20	1.0W
1N3049A	S		1N2970	DZ							160*	10	1.0W
1N3049B	S		1N2970	DZ							160*	5.0	1.0W
1N3050	S		1N2970	DZ							180*	20	1.0W
1N3050A	S		1N2970	DZ							180*	10	1.0W
1N3050B	S		1N2970	DZ							180*	5.0	1.0W
1N3051	S		1N2970	DZ							200*	20	1.0W
1N3051A	S		1N2970	DZ							200*	10	1.0W
1N3051B	S		1N2970	DZ							200*	5.0	1.0W
1N3052	S			R*	12K	70	0.1	0.2	6.0				
1N3053	S			R*	14K	75	0.1	0.2	6.0				
1N3054	S			R*	16K	80	0.1	0.2	6.0				
1N3055	S			R*	18K	85	0.1	0.2	6.0				
1N3056	S			R*	20K	90	0.1	0.2	6.0				
1N3057	S			R*	22K	95	0.1	0.2	6.0				
1N3058	S			R*	24K	100	0.1	0.2	6.0				
1N3059	S			R*	26K	105	0.1	0.2	6.0				
1N3060	S			R*	28K	120	0.1	0.2	6.0				
1N3061	S			R*	30K	125	0.1	0.2	6.0				
1N3062	S			DS	75	1.0	20M	0.1*	2.0				
1N3063	S			DS	75	0.85	10M	0.1*	2.0				
1N3064	S			DS	75	1.0	10M	0.1*	4.0				
1N3065	S			DS	75	1.0	20M	0.1*	2.0				
1N3066	S			DS	75	1.0	10M	0.1*	2.0				
1N3067	S			DS	30	1.0	5.0M	0.1*	2.0				
1N3068	S			DS	30	1.0	5.0M	0.1*	50				
1N3069	S			DS	65	1.0	50M	0.1*	50				
1N3070	S			DS	200	1.0	100M	0.1*	50				
1N3071	S			DS	200	1.0	100M	0.1*	50				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3072	S	1N4001	1N4001	R*	50	1.5	0.2	0.5	10				
1N3073	S	1N4002	1N4001	R*	100	1.5	0.2	0.5	10				
1N3074	S	1N4003	1N4001	R*	150	1.5	0.2	0.5	10				
1N3075	S	1N4003	1N4001	R*	200	1.5	0.2	0.5	10				
1N3076	S	1N4004	1N4001	R*	250	1.5	0.2	0.5	10				
1N3077	S	1N4004	1N4001	R*	300	1.5	0.2	0.5	10				
1N3078	S	1N4004	1N4001	R*	350	1.5	0.2	0.5	10				
1N3079	S	1N4004	1N4001	R*	400	1.5	0.2	0.5	10				
1N3080	S	1N4005	1N4001	R*	500	1.5	0.2	0.5	10				
1N3081	S	1N4005	1N4001	R*	600	1.5	0.2	0.5	10				
1N3082	S	1N4003	1N4001	R*	200	1.25	0.5	0.2	15				
1N3083	S	1N4004	1N4001	R*	400	1.25	0.5	0.2	15				
1N3084	S	1N4005	1N4001	R*	600	1.25	0.5	0.2	15				
1N3085	S	MR1221SB	MR1220	R*	100	1.1	150	40	1500				
1N3086	S	MR1223SB	MR1220	R*	200	1.1	150	40	1500				
1N3087	S	MR1225SB	MR1200	R*	300	1.1	150	40	1500				
1N3088	S	MR1227SB	MR1200	R*	400	1.1	150	40	1500				
1N3089	S	MR1228SB	MR1200	R*	500	1.1	150	40	1500				
1N3090	S	MR1229SB	MR1220	R*	600	1.1	150	40	1500				
1N3091	S			R*	800	1.1	150	40	1500				
1N3092	S			R*	1000	1.1	150	40	1500				
1N3093	G	X-band Switch											
1N3097	G			DS	30	0.5	10M	4.0*	0.5				
1N3098	S	1N3046A	1N2970	DZ						110	130		1.0W
1N3099	S	1N3048A	1N2970	DZ						130	160		1.0W
1N3100	S	1N3050A	1N2970	DZ						160	200		1.0W
1N3101	S	1N3051A	1N2970	DZ						200	240		1.0W
1N3102	S	1N3008A	1N2970	DZ						110	130		10W
1N3103	S	1N3011A	1N2970	DZ						130	160		10W
1N3104	S	1N3014A	1N2970	DZ						160	200		10W
1N3105	S	1N3015A	1N2970	DZ						200	240		10W
1N3106	S			R*	800	1.6	0.75	0.3	30				
1N3107	S			R*	1200	3.2	0.5	0.3	15				
1N3108	S			R*	800	1.6	1.5	0.3	30				
1N3109	S			R*	1200	3.2	0.7	0.3	15				
1N3110	G			DS	8.0	0.45	5.0M	20*					
1N3111	S	MR1220SB	MR1220	R*	50	1.1	150	40	1500				
1N3112	S	1N4737A	1N4728	DZ						7.13	7.88		1.0W
1N3113 thru 1N3120		Tunnel Diodes, see Table on Page 98											
1N3121	G			DS	50	0.25	0.1M	3.5*	0.5				
1N3122	G			DS	20	0.3	1.0M	4.5*					
1N3123	S			DS	40	1.5	10M	0.1*	4.0				
1N3124	S			DS	40	1.0	20M	0.1*	4.0				
1N3125	G			DS	40	0.4	5.0M	100*	0.3				
1N3128 thru 1N3130		Tunnel Diodes, see Table on Page 98											
1N3138		Tunnel Diode, see Table on Page 98											
1N3139	S			R*	50	1.55	70	15	1200				
1N3140	S			R*	100	1.55	70	15	1200				
1N3141	S			R*	150	1.55	70	15	1200				
1N3142	S			R*	200	1.55	70	15	1200				
1N3143	G	Microwave C-X-band Detector											
1N3144	G			DS	20	0.3	1.0M	20*	0.5				
1N3145	G			DS	65	0.45	10M	25*					
1N3146	G			DS	20	1.0	50M	100*	2.0				
1N3147	S			DS	45	1.0	100M		1.0				
1N3148	S	1N3155A	1N3154	DR						0.005	8.5	-55	100
1N3149		Tunnel Diode, see Table on Page 98											
1N3149A		Tunnel Diode. see Table on Page 98											
1N3150		Tunnel Diode, see Table on Page 98											
1N3151	S			R*	7200	27	0.1	250	12				
1N3154	S		1N3154	DR						0.01	8.8	-55	100
1N3154A	S		1N3154	DR						0.01	8.8	-55	150
1N3155	S		1N3154	DR						0.005	8.8	-55	100
1N3155A	S		1N3154	DR						0.005	8.8	-55	150
1N3156	S		1N3154	DR						0.002	8.8	-55	100
1N3156A	S		1N3154	DR						0.002	8.8	-55	150
1N3157	S		1N3154	DR						0.001	8.8	-55	100
1N3157A	S		1N3154	DR						0.001	8.8	-55	150
1N3159	G			DS	15	0.45	10M		0.3				
1N3160	G			DS	60	1.0	5.0M	12*					
1N3161	S	MR1230SB	MR1230	R*	50	1.30	240	16	3000				
1N3162	S	MR1231SB	MR1230	R*	100	1.30	240	16	3000				
1N3163	S	MR1232SB	MR1230	R*	150	1.30	240	16	3000				
1N3164	S	MR1233SB	MR1230	R*	200	1.30	240	16	3000				
1N3165	S	MR1234SB	MR1230	R*	250	1.30	240	16	3000				
1N3166	S	MR1235SB	MR1230	R*	300	1.30	240	16	3000				
1N3167	S	MR1236SB	MR1230	R*	350	1.30	240	16	3000				
1N3168	S	MR1237SB	MR1230	R*	400	1.30	240	16	3000				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * / V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3169	S	MR1238SB	MR1230	R*	500	1.30	240	16	3000				
1N3170	S	MR1239SB	MR1230	R*	600	1.30	240	16	3000				
1N3171	S			R*	700	1.92	240	16	3000				
1N3171A	S			R*	700	1.9	240	16	3000				
1N3172	S			R*	800	1.92	240	16	3000				
1N3172A	S			R*	800	1.9	240	16	3000				
1N3173	S			R*	900	1.92	240	16	3000				
1N3173A	S			R*	900	1.9	240	16	3000				
1N3174	S			R*	1000	1.92	240	16	3000				
1N3174A	S			R*	1000	1.9	240	16	3000				
1N3175	S			R*	1200	1.4	240	15	3000				
1N3176	S			R*	1400	1.4	240	15	3000				
1N3177	S			R*	1600	1.4	240	15	3000				
1N3179	S			DS	200	1.0	100M	10*					
1N3180	S			DS	110	1.5	500M	5.0*					
1N3181	S	1N5237A	1N5221	DZ							8.2*	10	500M
1N3182		Varactor Diode, see Table on Page 92											
1N3183	S			R*	350	1.0	0.5		4.0				
1N3184	S			R*	500	1.0	0.5		4.0				
1N3185	S			R*	700	2.0	0.5		4.0				
1N3186	S			R*	1000	2.0	0.5		4.0				
1N3187	S			R*	1500	3.0	0.5		4.0				
1N3188	S			R*	2000	4.0	0.5		4.0				
1N3189	S	1N4003	1N4001	R*	200	1.1	1.0	0.2	30				
1N3190	S	1N4004	1N4001	R*	400	1.1	1.0	0.2	30				
1N3191	S	1N4005	1N4001	R*	600	1.1	1.0	0.2	30				
1N3192	S			DS	200	1.0	100M	10*					
1N3193	S	1N4003	1N4001	R*	200	1.2	0.75	0.2	40				
1N3194	S	1N4004	1N4001	R*	400	1.2	0.75	0.2	40				
1N3195	S	1N4005	1N4001	R*	600	1.2	0.75	0.2	40				
1N3196	S	1N4006	1N4001	R*	800	1.2	0.75	0.2	40				
1N3197	G			DS	30	1.0	150M	50*	0.3				
1N3198	S	1N5221B	1N5221	DZ							2.25*		400M
1N3199	S	1N3155	1N3154	DR						0.005	8.8	50	100
1N3200	S	1N3156	1N3154	DR						0.003	8.8	50	100
1N3201	S	1N3156	1N3154	DR						0.002	8.8	50	100
1N3202	S	1N3157	1N3154	DR						0.001	8.8	50	100
1N3203	G			DS	25	0.5	35M	50*	0.3				
1N3206	S			DS	80	1.0	10M	5.0*	4.0				
1N3207	S			DS	50	1.0	150M	0.05*	6.0				
1N3208	S		1N3189	R*	50	1.5	15	10	250				
1N3209	S		1N3189	R*	100	1.5	15	10	250				
1N3210	S		1N3189	R*	200	1.5	15	10	250				
1N3211	S		1N3189	R*	300	1.5	15	10	250				
1N3212	S		1N3189	R*	400	1.5	15	10	250				
1N3213	S		1N248B	R*	500	1.5	15	10	250				
1N3214	S		1N248B	R*	600	1.5	15	10	250				
1N3215	S			DS	80	0.7	1.0M	10*	0.25				
1N3217 thru 1N3222		Tunnel Diodes, see Table on Page 98											
1N3223	S			DS	150	1.5	4.0M	20*	800				
1N3225	G			DS	40	1.0	5.0M	33*	0.5				
1N3227	S			R*	100	3.3	0.5	0.250	12.5				
1N3228	S			R*	200	3.3	0.5	0.250	12.5				
1N3229	S			R*	400	3.3	0.5	0.250	12.5				
1N3230	S			R*	600	3.3	0.5	0.250	12.5				
1N3231	S			R*	800	3.3	0.5	0.250	12.5				
1N3232	S			R*	1000	3.3	0.5	0.250	12.5				
1N3233	S			R*	1200	3.3	0.5	0.250	12.5				
1N3234	S			R*	1500	3.3	0.5	0.250	12.5				
1N3235	S			R*	1800	3.3	0.5	0.250	12.5				
1N3236	S			R*	2000	3.3	0.5	0.250	12.5				
1N3237	S			R*	50	2.2	0.75	0.250	15.0				
1N3238	S			R*	100	2.2	0.75	0.250	15.0				
1N3239	S			R*	200	2.2	0.75	0.250	15.0				
1N3240	S			R*	400	2.2	0.75	0.250	15.0				
1N3241	S			R*	600	2.2	0.75	0.250	15.0				
1N3242	S			R*	800	2.2	0.75	0.250	15.0				
1N3243	S			R*	1000	2.2	0.75	0.250	15.0				
1N3244	S			R*	1200	2.2	0.75	0.250	15.0				
1N3245	S			R*	1500	2.2	0.75	0.250	15.0				
1N3246	S			R*	50	1.1	1.0	0.250	20.0				
1N3247	S			R*	100	1.1	1.0	0.250	20.0				
1N3248	S			R*	200	1.1	1.0	0.250	20.0				
1N3249	S			R*	400	1.1	1.0	0.250	20.0				
1N3250	S			R*	600	1.1	1.0	0.250	20.0				
1N3251	S			R*	800	1.1	1.0	0.250	20.0				
1N3252	S			R*	1000	1.1	1.0	0.250	20.0				
1N3253	S	1N4003	1N4001	R*	200	1.2	0.75	0.2	40				
1N3254	S	1N4004	1N4001	R*	400	1.2	0.75	0.2	40				
1N3255	S	1N4005	1N4001	R*	600	1.2	0.75	0.2	40				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3256	S	1N4006	1N4001	R*	800	1.2	0.5	0.2	40				
1N3260	S	MR1220SB	MR1220	R*	50	1.6	160	12	2000				
1N3261	S	MR1221SB	MR1220	R*	100	1.6	160	12	2000				
1N3262	S	MR1222SB	MR1220	R*	150	1.6	160	12	2000				
1N3263	S	MR1223SB	MR1220	R*	200	1.6	160	12	2000				
1N3264	S	MR1224SB	MR1220	R*	250	1.6	160	12	2000				
1N3265	S	MR1225SB	MR1220	R*	300	1.6	160	12	2000				
1N3266	S	MR1226SB	MR1220	R*	350	1.6	160	12	2000				
1N3267	S	MR1227SB	MR1220	R*	400	1.6	160	12	2000				
1N3268	S	MR1228SB	MR1220	R*	500	1.6	160	12	2000				
1N3269	S	MR1229SB	MR1220	R*	600	1.6	160	12	2000				
1N3270	S			R*	700	1.6	160	12	2000				
1N3271	S			R*	800	1.6	160	12	2000				
1N3272	S			R*	900	1.6	160	12	2000				
1N3273	S			R*	1000	1.6	160	12	2000				
1N3274	S			R*	1200	1.4	160	12	2000				
1N3275	S			R*	1400	1.4	160	12	2000				
1N3276	S			R*	1600	1.4	160	12	2000				
1N3277	S			R*	200	1.3	0.75		25				
1N3278	S			R*	400	1.3	0.75		25				
1N3279	S			R*	600	1.3	0.75		25				
1N3280	S			R*	800	1.3	0.75		25				
1N3281	S			R*	1000	1.3	0.75		25				
1N3282	S		1N3213	R*	1000	3.7	0.1		2.5				
1N3283	S		1N3213	R*	1500	3.7	0.1		2.5				
1N3284	S		1N3213	R*	2000	3.7	0.1		2.5				
1N3285	S		1N3213	R*	2500	3.7	0.1		2.5				
1N3286	S		1N3213	R*	3000	3.7	0.1		2.5				
1N3287	G			DS	6.0	0.312	1.0M	15*					
1N3288	S			R*	100	1.5	100	200	1600				
1N3288A	S	MR1811R		R*	100	1.5	100	24	2300				
1N3289	S			R*	200	1.5	100	300	1600				
1N3289A	S	MR1813R		R*	200	1.5	100	24	2300				
1N3290	S			R*	300	1.5	100	400	1600				
1N3290A	S	MR1815R		R*	300	1.5	100	24	2300				
1N3291	S			R*	400	1.5	100	525	1600				
1N3291A	S	MR1817R		R*	400	1.5	100	24	2300				
1N3292	S			R*	500	1.5	100	650	1600				
1N3292A	S			R*	500	1.5	100	21	1600				
1N3292B	S	MR1818SB		R*	500	1.5	100	21	2300				
1N3293	S			R*	600	1.5	100	800	1600				
1N3293A	S	MR1819SB		R*	600	1.5	100	17	2300				
1N3294	S			R*	800	1.5	100	1050	1600				
1N3294A	S			R*	800	1.5	100	13	2300				
1N3295	S			R*	1000	1.5	100	1300	1600				
1N3295A	S			R*	1000	1.5	100	11	2300				
1N3296	S			R*	1200	1.5	100	1600	1600				
1N3296A	S			R*	1200	1.5	100	9.0	2300				
1N3297	S			R*	1400	1.5	100	1800	1600				
1N3297A	S			R*	1400	1.5	100	7.0	2300				
1N3298	S			DS	70	0.9	500M	0.2*	20				
1N3298A	S			DS	70	0.9	0.5A	0.2*					
1N3299 thru 1N3304,A		4-Layer Diodes, see Table on Page 102											
1N3305	S		1N2804	DZ							6.8*	20	50W
1N3305A	S		1N2804	DZ							6.8*	10	50W
1N3305B	S		1N2804	DZ							6.8*	5.0	50W
1N3306	S		1N2804	DZ							7.5*	20	50W
1N3306A	S		1N2804	DZ							7.5*	10	50W
1N3306B	S		1N2804	DZ							7.5*	5.0	50W
1N3307	S		1N2804	DZ							8.2*	20	50W
1N3307A	S		1N2804	DZ							8.2*	10	50W
1N3307B	S		1N2804	DZ							8.2*	5.0	50W
1N3308	S		1N2804	DZ							9.1*	20	50W
1N3308A	S		1N2804	DZ							9.1*	10	50W
1N3308B	S		1N2804	DZ							9.1*	5.0	50W
1N3309	S		1N2804	DZ							10*	20	50W
1N3309A	S		1N2804	DZ							10*	10	50W
1N3309B	S		1N2804	DZ							10*	5.0	50W
1N3310	S		1N2804	DZ							11*	20	50W
1N3310A	S		1N2804	DZ							11*	10	50W
1N3310B	S		1N2804	DZ							11*	5.0	50W
1N3311	S		1N2804	DZ							12*	20	50W
1N3311A	S		1N2804	DZ							12*	10	50W
1N3311B	S		1N2804	DZ							12*	5.0	50W
1N3312	S		1N2804	DZ							13*	20	50W
1N3312A	S		1N2804	DZ							13*	10	50W
1N3312B	S		1N2804	DZ							13*	5.0	50W
1N3313	S		1N2804	DZ							14*	20	50W
1N3313A	S		1N2804	DZ							14*	10	50W
1N3313B	S		1N2804	DZ							14*	5.0	50W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3314	S		1N2804	DZ							15*	20	50W
1N3314A	S		1N2804	DZ							15*	10	50W
1N3314B	S		1N2804	DZ							15*	5.0	50W
1N3315	S		1N2804	DZ							16*	20	50W
1N3315A	S		1N2804	DZ							16*	10	50W
1N3315B	S		1N2804	DZ							16*	5.0	50W
1N3316	S		1N2804	DZ							17*	20	50W
1N3316A	S		1N2804	DZ							17*	10	50W
1N3316B	S		1N2804	DZ							17*	5.0	50W
1N3317	S		1N2804	DZ							18*	20	50W
1N3317A	S		1N2804	DZ							18*	10	50W
1N3317B	S		1N8204	DZ							18*	5.0	50W
1N3318	S		1N2804	DZ							19*	20	50W
1N3318A	S		1N2804	DZ							19*	10	50W
1N3318B	S		1N2804	DZ							19*	5.0	50W
1N3319	S		1N2804	DZ							20*	20	50W
1N3319A	S		1N2804	DZ							20*	10	50W
1N3319B	S		1N2804	DZ							20*	5.0	50W
1N3320	S		1N2804	DZ							22*	20	50W
1N3320A	S		1N2804	DZ							22*	10	50W
1N3320B	S		1N2804	DZ							22*	5.0	50W
1N3321	S		1N2804	DZ							24*	20	50W
1N3321A	S		1N2804	DZ							24*	10	50W
1N3321B	S		1N2804	DZ							24*	5.0	50W
1N3322	S		1N2804	DZ							25*	20	50W
1N3322A	S		1N2804	DZ							25*	10	50W
1N3322B	S		1N2804	DZ							25*	5.0	50W
1N3323	S		1N2804	DZ							27*	20	50W
1N3323A	S		1N2804	DZ							27*	10	50W
1N3323B	S		1N2804	DZ							27*	5.0	50W
1N3324	S		1N2804	DZ							30*	20	50W
1N3324A	S		1N2804	DZ							30*	10	50W
1N3324B	S		1N2804	DZ							30*	5.0	50W
1N3325	S		1N2804	DZ							33*	20	50W
1N3325A	S		1N2804	DZ							33*	10	50W
1N3325B	S		1N2804	DZ							33*	5.0	50W
1N3326	S		1N2804	DZ							36*	20	50W
1N3326A	S		1N2804	DZ							36*	10	50W
1N3326B	S		1N2804	DZ							36*	5.0	50W
1N3327	S		1N2804	DZ							39*	20	50W
1N3327A	S		1N2804	DZ							39*	10	50W
1N3327B	S		1N2804	DZ							39*	5.0	50W
1N3328	S		1N2804	DZ							43*	20	50W
1N3328A	S		1N2804	DZ							43*	10	50W
1N3328B	S		1N2804	DZ							43*	5.0	50W
1N3329	S		1N2804	DZ							45*	20	50W
1N3329A	S		1N2804	DZ							45*	10	50W
1N3329B	S		1N2804	DZ							45*	5.0	50W
1N3330	S		1N2804	DZ							47*	20	50W
1N3330A	S		1N2804	DZ							47*	10	50W
1N3330B	S		1N2804	DZ							47*	5.0	50W
1N3331	S		1N2804	DZ							50*	20	50W
1N3331A	S		1N2804	DZ							50*	10	50W
1N3331B	S		1N2804	DZ							50*	5.0	50W
1N3332	S		1N2804	DZ							51*	20	50W
1N3332A	S		1N2804	DZ							51*	10	50W
1N3332B	S		1N2804	DZ							51*	5.0	50W
1N3333	S		1N2804	DZ							52*	20	50W
1N3333A	S		1N2804	DZ							52*	10	50W
1N3333B	S		1N2804	DZ							52*	5.0	50W
1N3334	S		1N2804	DZ							56*	20	50W
1N3334A	S		1N2804	DZ							56*	10	50W
1N3334B	S		1N2804	DZ							56*	5.0	50W
1N3335	S		1N2804	DZ							62*	20	50W
1N3335A	S		1N2804	DZ							62*	10	50W
1N3335B	S		1N2804	DZ							62*	5.0	50W
1N3336	S		1N2804	DZ							68*	20	50W
1N3336A	S		1N2804	DZ							68*	10	50W
1N3336B	S		1N2804	DZ							68*	5.0	50W
1N3337	S		1N2804	DZ							75*	20	50W
1N3337A	S		1N2804	DZ							75*	10	50W
1N3337B	S		1N2804	DZ							75*	5.0	50W
1N3338	S		1N2804	DZ							82*	20	50W
1N3338A	S		1N2804	DZ							82*	10	50W
1N3338B	S		1N2804	DZ							82*	5.0	50W
1N3339	S		1N2804	DZ							91*	20	50W
1N3339A	S		1N2804	DZ							91*	10	50W
1N3339B	S		1N2804	DZ							91*	5.0	50W
1N3340	S		1N2804	DZ							100*	20	50W
1N3340A	S		1N2804	DZ							100*	10	50W
1N3340B	S		1N2804	DZ							100*	5.0	50W
1N3341	S		1N2804	DZ							105*	20	50W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3341A	S		1N2804	DZ							105*	10	50W
1N3341B	S		1N2804	DZ							105*	5.0	50W
1N3342	S		1N2804	DZ							110*	20	50W
1N3342A	S		1N2804	DZ							110*	10	50W
1N3342B	S		1N2804	DZ							110*	5.0	50W
1N3343	S		1N2804	DZ							120*	20	50W
1N3343A	S		1N2804	DZ							120*	10	50W
1N3343B	S		1N2804	DZ							120*	5.0	50W
1N3344	S		1N2804	DZ							130*	20	50W
1N3344A	S		1N2804	DZ							130*	10	50W
1N3344B	S		1N2804	DZ							130*	5.0	50W
1N3345	S		1N2804	DZ							140*	20	50W
1N3345A	S		1N2804	DZ							140*	10	50W
1N3345B	S		1N2804	DZ							140*	5.0	50W
1N3346	S		1N2804	DZ							150*	20	50W
1N3346A	S		1N2804	DZ							150*	10	50W
1N3346B	S		1N2804	DZ							150*	5.0	50W
1N3347	S		1N2804	DZ							160*	20	50W
1N3347A	S		1N2804	DZ							160*	10	50W
1N3347B	S		1N2804	DZ							160*	5.0	50W
1N3348	S		1N2804	DZ							175*	20	50W
1N3348A	S		1N2804	DZ							175*	10	50W
1N3348B	S		1N2804	DZ							175*	5.0	50W
1N3349	S		1N2804	DZ							180*	20	50W
1N3349A	S		1N2804	DZ							180*	10	50W
1N3349B	S		1N2804	DZ							180*	5.0	50W
1N3350	S		1N2804	DZ							200*	20	50W
1N3350A	S		1N2804	DZ							200*	10	50W
1N3350B	S		1N2804	DZ							200*	5.0	50W
1N3353	G	Backward Diode											
1N3354	S			R*	10	1.2	3.0	0.020	30				
1N3355	S			R*	15	1.2	3.0	0.020	30				
1N3356	S			R*	25	1.2	3.0	0.010	30				
1N3357	S			R*	50	1.2	3.0	0.010	30				
1N3358	S			R*	75	1.2	3.0	0.010	30				
1N3359	S			R*	100	1.2	3.0	0.010	30				
1N3360	S			R*	150	1.2	3.0	0.010	30				
1N3361	S			R*	200	1.2	3.0	0.010	30				
1N3362	S			R*	300	1.2	3.0	0.010	30				
1N3363	S			R*	400	1.2	3.0	0.010	30				
1N3364	S			R*	500	1.2	3.0	0.010	30				
1N3365	S			R*	600	1.2	3.0	0.010	30				
1N3366	S			R*	700	1.2	3.0	0.010	30				
1N3367	S			R*	800	2.0	3.0	0.010	30				
1N3368	S			R*	900	2.0	3.0	0.010	30				
1N3369	S			R*	1000	2.5	3.0	0.025	30				
1N3370	S			R*	1200	2.5	3.0	0.025	30				
1N3371	S			R*	1500	2.5	3.0	0.025	30				
1N3372	S			R*	10	1.0	20	0.315	200				
1N3373	S			R*	25	1.0	20	0.315	200				
1N3374	S			R*	50	1.0	20	0.315	200				
1N3375	S			R*	100	1.0	20	0.315	200				
1N3376	S			R*	150	1.0	20	0.315	200				
1N3377	S			R*	200	1.0	20	0.315	200				
1N3378	S			R*	300	1.0	20	0.315	200				
1N3379	S			R*	400	1.0	20	0.315	200				
1N3380	S			R*	500	1.0	20	0.315	200				
1N3381	S			DS	15	1.0	500M	10*					
1N3382	S			DS	15	1.0	500M	10*					
1N3383	S			DS	50	1.0	500M	10*					
1N3384	S			DS	75	1.0	500M	15*					
1N3385	S			DS	100	1.0	500M	20*					
1N3386	S			DS	150	1.0	500M	20*					
1N3387	S			DS	200	1.0	500M	20*					
1N3388	S			DS	250	1.0	500M	25*					
1N3389	S			DS	300	1.0	500M	25*					
1N3390	S			DS	400	1.0	500M	25*					
1N3391	S			DS	500	1.0	500M	25*					
1N3392	S			DZ							1.5*	10	500M
1N3393	S	.5M1.8ZZS10		DZ							1.8*	10	500M
1N3394	S	.5M2.2ZZS10		DZ							2.2*	10	500M
1N3395	S	.5M2.7ZZS10		DZ							2.7*	10	500M
1N3396	S	.5M3.3ZZS10		DZ							3.3*	10	500M
1N3397	S	.5M3.9ZZS10		DZ							3.9*	10	500M
1N3398	S	.5M4.7ZZS10		DZ							4.7*	10	500M
1N3399	S	.5M5.6ZZS10		DZ							5.6*	10	500M
1N3400	S	.5M6.8ZZS10		DZ							6.8*	10	500M
1N3401	S	.5M8.2ZZS10		DZ							8.2*	10	500M
1N3402	S	.5M10ZZS10		DZ							10*	10	500M
1N3403	S	.5M12ZZS10		DZ							12*	10	500M
1N3404	S	.5M15AAS10		DZ							15*	10	500M
1N3405	S	.5M18ZZS10		DZ							18*	10	500M

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3406	S	.5M22ZZS10		DZ							22*	10	500M
1N3407	S	.5M27ZZS10		DZ							27*	10	500M
1N3408	S	.5M33ZZS10		DZ							33*	10	500M
1N3409	S	.5M39ZZS10		DZ							39*	10	500M
1N3410	S	.5M47ZZS10		DZ							47*	10	500M
1N3411	S	1N5234A	1N5221	DZ							6.2*	10	500M
1N3412	S	1N5235A	1N5221	DZ							6.8*	10	500M
1N3413	S	1N5236A	1N5221	DZ							7.5*	10	500M
1N3414	S	1N5237A	1N5221	DZ							8.2*	10	500M
1N3415	S	1N5240A	1N5221	DZ							10*	10	500M
1N3416	S	1N5242A	1N5221	DZ							12*	10	500M
1N3417	S	1N5245A	1N5221	DZ							15*	10	500M
1N3418	S	1N5248A	1N5221	DZ							18*	10	500M
1N3419	S	1N5251A	1N5221	DZ							22*	10	500M
1N3420	S	1N5254A	1N5221	DZ							27*	10	500M
1N3421	S	1N5256A	1N5221	DZ							30*	10	500M
1N3422	S	1N5257A	1N5221	DZ							33*	10	500M
1N3423	S	1N5259A	1N5221	DZ							39*	10	500M
1N3424	S	1N5261A	1N5221	DZ							47*	10	500M
1N3425	S	1N5263A	1N5221	DZ							56*	10	500M
1N3426	S	1N5266A	1N5222	DZ							68*	10	500M
1N3427	S	1N5268A	1N5221	DZ							82*	10	500M
1N3428	S	1N5271A	1N5221	DZ							100*	10	500M
1N3429	S	1N5273A	1N5221	DZ							120*	10	500M
1N3430	S	1N5276A	1N5221	DZ							150*	10	500M
1N3431	S	1N5279A	1N5221	DZ							180*	10	500M
1N3432	S	1N5281B	1N5221	DZ							220*	10	500M
1N3433	S	1N4738	1N4728	DZ							8.2*		2.0W
1N3434	S	1N4740	1N4728	DZ							10.0*		2.0W
1N3435	S	1N4742	1N4728	DZ							12.0*		2.0W
1N3436	S	1N4744	1N4728	DZ							15.0*		2.0W
1N3437	S	1N4746	1N4728	DZ							18.0*		2.0W
1N3438	S	1N4748	1N4728	DZ							22.0*		2.0W
1N3439	S	1N4750	1N4728	DZ							27.0*		2.0W
1N3440	S	1N4752	1N4728	DZ							33.0*		2.0W
1N3441	S	1N4754	1N4728	DZ							39.0*		2.0W
1N3442	S	1N4756	1N4728	DZ							47.0*		2.0W
1N3443	S	1N4735	1N4728	DZ							6.2*	10	2.0W
1N3444	S	1N4736	1N4728	DZ							6.8*	10	2.0W
1N3445	S	1N4738	1N4728	DZ							8.2*	10	2.0W
1N3446	S	1N4740	1N4728	DZ							10*	10	2.0W
1N3447	S	1N4742	1N4728	DZ							12*	10	2.0W
1N3448	S	1N4744	1N4728	DZ							15*	10	2.0W
1N3449	S	1N4746	1N4728	DZ							18*	10	2.0W
1N3450	S	1N4748	1N4728	DZ							22*	10	2.0W
1N3451	S	1N4750	1N4728	DZ							27*	10	2.0W
1N3452	S	1N4751	1N4728	DZ							30*	10	2.0W
1N3453	S	1N4752	1N4728	DZ							33*	10	2.0W
1N3454	S	1N4754	1N4728	DZ							39*	10	2.0W
1N3455	S	1N4756	1N4728	DZ							47*	10	2.0W
1N3456	S	1N4758	1N4728	DZ							56*	10	2.0W
1N3457	S	1N4760	1N4728	DZ							68*	10	2.0W
1N3458	S	1N4762	1N4728	DZ							82*	10	2.0W
1N3459	S	1N4764	1N4728	DZ							100*	10	2.0W
1N3460	S	1M120ZS10	1N4728	DZ							120*	10	2.0W
1N3461	S	1M150ZS10	1N4728	DZ							150*	10	2.0W
1N3462	S	1M180ZS10	1N4728	DZ							180*	10	2.0W
1N3463	S	1M200ZS5	1N4728	DZ							220*	10	2.0W
1N3464	S			R*	8500	30.0	0.1	0.001	2.0				
1N3465	G			DS	60	1.0	200M	20*					
1N3466	G			DS	40	1.0	200M	15*					
1N3467	G			DS	15	0.5	20M	15*	2.0				
1N3468	G			DS	15	0.5	20M	60*	2.0				
1N3469	G			DS	35	0.5	600M	15*					
1N3470	G			DS	35	0.5	600M	30*					
1N3471	S			DS	40	1.0	10M	20N	2.0				
1N3473	S			R*	200	1.4	0.75	0.5	20				
1N3474	S			R*	400	1.4	0.75	0.5	20				
1N3475	S			R*	600	1.4	0.75	0.5	20				
1N3476	S			R*	800	1.4	0.5	0.5	20				
1N3477	S	1N5221A	1N5221	DZ							2.2*	10	250M
1N3477A	S	1N5221B	1N5221	DZ							2.2*	5.0	250M
1N3478	S			DS	200	1.0	500M	10*					
1N3479	S			DS	400	1.0	500M	10*					
1N3480	S			DS	600	1.0	500M	10*					
1N3481	G	RF Power Switch: $P_{i(max)}$ = 10 mW, f = 9,000 MHz											
1N3482	G	RF Power Switch: $P_{i(max)}$ = 10 mW, f = 9,000 MHz											
1N3483	G			DS	8.0	0.6	10M	30*					
1N3484	G			DS	75	0.45	10M	4.0*					
1N3485	S			DS	175	1.0	10M	25N	0.05				
1N3486	S			R*	1000	2.0	0.4	0.05	10				
1N3487	S			R*	1200	2.0	0.4	0.05	10				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * / V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3488		Varactor Diode, see Table on Page 92											
1N3489 thru 1N3490		4-Layer Diodes, see Table on Page 102											
1N3491	S			R*	50	1.7	18	1.0	300				
1N3492	S			R*	100	1.7	18	1.0	300				
1N3493	S			R*	200	1.7	18	1.0	300				
1N3494	S			R*	300	1.7	18	1.0	300				
1N3495	S			R*	400	1.7	18	1.0	300				
1N3496	S	1N823 *	1N821	DR						0.005	6.5	0	75
1N3497	S	1N825 *	1N821	DR						0.002	6.5	0	75
1N3498	S	1N827 *	1N821	DR						0.001	6.5	0	75
1N3499	S	1N829 *	1N821	DR						0.0005	6.5	0	75
1N3500	S	1N821 *	1N821	DR						0.01	6.5	0	75
1N3501	S	MZ640 *	MZ600	DR							6.5	25	100
1N3502	S	MZ620 *	MZ600	DR							6.5	25	100
1N3503	S	MZ610 *	MZ600	DR							6.5	25	100
1N3504	S	MZ605 *	MZ600	DR							6.5	25	100
1N3506	S	1N5226B *	1N5221	DZ							3.3*	5.0	400M
1N3507	S	1N5227B *	1N5221	DZ							3.6*	5.0	400M
1N3508	S	1N5228B *	1N5221	DZ							3.9*	5.0	400M
1N3509	S	1N5229B *	1N5221	DZ							4.3*	5.0	400M
1N3510	S	1N5230B *	1N5221	DZ							4.7*	5.0	400M
1N3511	S	1N5231B *	1N5221	DZ							5.1*	5.0	400M
1N3512	S	1N5232B *	1N5221	DZ							5.6*	5.0	400M
1N3513	S	1N5234B *	1N5221	DZ							6.2*	5.0	400M
1N3514	S	1N5235B *	1N5221	DZ							6.8*	5.0	400M
1N3515	S	1N5236B *	1N5221	DZ							7.5*	5.0	400M
1N3516	S	1N5237B *	1N5221	DZ							8.2*	5.0	400M
1N3517	S	1N5239B *	1N5221	DZ							9.1*	5.0	400M
1N3518	S	1N5240B *	1N5221	DZ							10*	5.0	400M
1N3519	S	1N5241B *	1N5221	DZ							11*	5.0	400M
1N3520	S	1N5242B *	1N5221	DZ							12*	5.0	400M
1N3521	S	1N5243B *	1N5221	DZ							13*	5.0	400M
1N3522	S	1N5245B *	1N5221	DZ							15*	5.0	400M
1N3523	S	1N5246B *	1N5221	DZ							16*	5.0	400M
1N3524	S	1N5248B *	1N5221	DZ							18*	5.0	400M
1N3525	S	1N5250B *	1N5221	DZ							20*	5.0	400M
1N3526	S	1N5251B *	1N5221	DZ							22*	5.0	400M
1N3527	S	1N5252B *	1N5221	DZ							24*	5.0	400M
1N3528	S	1N5254B *	1N5221	DZ							27*	5.0	400M
1N3529	S	1N5256B *	1N5221	DZ							30*	5.0	400M
1N3530	S	1N5257B *	1N5221	DZ							33*	5.0	400M
1N3531	S	1N5258B *	1N5221	DZ							36*	5.0	400M
1N3532	S	1N5259B *	1N5221	DZ							39*	5.0	400M
1N3533	S	1N5260B *	1N5221	DZ							43*	5.0	400M
1N3534	S	1N5261B *	1N5221	DZ							47*	5.0	400M
1N3535	S			DS	200	0.549	100M						
1N3536	S			DS	70	0.65	1.0M	25N					
1N3537	S	1M12ZZS10		DZ							12*		1.0W
1N3538	S			DS	150		2.5M	2.0*					
1N3539	S	Backward Diode											
1N3539A	S	Backward Diode											
1N3540	S	Backward Diode											
1N3540A	S	Backward Diode											
1N3541	S	Backward Diode											
1N3541A	S	Backward Diode											
1N3542	S	Backward Diode											
1N3542A	S	Backward Diode											
1N3543	S	Backward Diode											
1N3543A	S	Backward Diode											
1N3544	S	1N4002	1N4001	R*	100	1.5	0.6	0.2	15				
1N3545	S	1N4003	1N4001	R*	200	1.5	0.6	0.2	15				
1N3546	S	1N4004	1N4001	R*	300	1.5	0.6	0.2	15				
1N3547	S	1N4004	1N4001	R*	400	1.5	0.6	0.2	15				
1N3548	S	1N4005	1N4001	R*	500	1.5	0.6	0.2	15				
1N3549	S	1N4005	1N4001	R*	600	1.5	0.6	0.2	15				
1N3550	S			DS	180	1.0	50M		1.5				
1N3551 thru 1N3552		Varactor Diodes, see Table on Page 92											
1N3553	S	1N821 *	1N821	DR						0.0001	6.3	-55	100
1N3554 thru		Varactor Diodes, see Table on Page 92											
1N3557													
1N3558	S	Matched Pair of 1N751A's, Zener Diode											
1N3559	G			DS	24	1.0	200M	20*					
1N3560 thru 1N3562		Tunnel Diodes, see Table on Page 98											
1N3563	S			R*	1000	1.2	0.4	0.2	40				
1N3564	G			DS	15	1.0	40M						
1N3565	S			DS	6.0	2.0	2.0A	25M					
1N3566	S			R*	800	2.25	1.0	0.5	20				

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3567	S			DS	50	1.0	100M	0.05*	2.0				
1N3568	S			DS	80	1.0	20M	1.0*	2.0				
1N3569	S	MR1121 *	MR1120	R*	100	1.3	3.5	0.4	35				
1N3570	S	MR1123 *	MR1120	R*	200	1.3	3.5	0.4	35				
1N3571	S	MR1123 *	MR1120	R*	300	1.3	3.5	0.4	35				
1N3572	S	MR1124 *	MR1120	R*	400	1.3	3.5	0.4	35				
1N3573	S	MR1125 *	MR1120	R*	500	1.3	3.5	0.4	35				
1N3574	S	MR1126 *	MR1120	R*	600	1.3	3.5	0.4	35				
1N3575	S			DS	60	0.74	1.0M	0.75N					
1N3576	S			DS	125	0.74	1.0M	0.75N					
1N3577	S			DS	175	0.74	1.0M	0.75N					
1N3578	S			DS	225	0.74	1.0M	0.75N					
1N3579	S			DS	275	0.74	1.0M	0.75N					
1N3580	S		1N2163	DR						0.01	12.28	0	75
1N3580A	S		1N2163	DR						0.01	12.28	-55	100
1N3580B	S		1N2163	DR						0.01	12.28	-55	150
1N3581	S		1N2163	DR						0.005	12.28	0	75
1N3581A	S		1N2163	DR						0.005	12.28	-55	100
1N3581B	S		1N2163	DR						0.005	12.28	-55	150
1N3582	S		1N2163	DR						0.002	12.28	0	75
1N3582A	S		1N2163	DR						0.002	12.28	-55	100
1N3582B	S		1N2163	DR						0.002	12.28	-55	150
1N3583	S		1N2163	DR						0.001	12.28	0	75
1N3583A	S		1N2163	DR						0.001	12.28	-55	100
1N3583B	S		1N2163	DR						0.001	12.28	-55	150
1N3584	S	1N945 *	1N941	DR						0.005	12.28	0	75
1N3584A	S	1N945A *	1N941	DR						0.005	12.28	-55	100
1N3584B	S	1N945B *	1N941	DR						0.005	12.28	-55	150
1N3585	S	MR1240SB	MR1240	R*	50	1.25	400	25	8000				
1N3586	S	MR1241SB	MR1240	R*	100	1.25	400	25	8000				
1N3587	S	MR1243SB	MR1240	R*	200	1.25	400	25	8000				
1N3588	S	MR1245SB	MR1240	R*	300	1.25	400	25	8000				
1N3589	S	MR1247SB	MR1240	R*	400	1.25	400	25	8000				
1N3590	S	MR1248SB	MR1240	R*	500	1.25	400	25	8000				
1N3591	S	MR1249SB	MR1240	R*	600	1.25	400	25	8000				
1N3592	G			DS	30	0.35	2.0M	4.0*	0.04				
1N3593	S			DS	40	1.0	10M	25N	10				
1N3594	S			DS	60	1.0	50M	0.1M	6.0				
1N3595	S			DS	125	1.0	200M	1.0M	3.0				
1N3596	S			DS	20	1.0	30M	0.1*	4.0				
1N3597	S			DS	150	1.2	400M	0.1*	0.3				
1N3598	S			DS	50	0.85	10M	0.1*	4.0				
1N3599	S			DS	150	1.0	100M	0.1*	50				
1N3600	S			DS	50	1.0	200M	100*	6.0				
1N3601	S			DS	75	1.0	10M	0.1*	5.0				
1N3602	S			DS	50	1.0	20M	0.1*	5.0				
1N3603	S			DS	30	1.0	30M	0.1*	5.0				
1N3604	S			DS	75	1.0	50M	0.05*	2.0				
1N3605	S			DS	40	0.55	0.1M	0.05*	2.0				
1N3606	S			DS	75	0.55	0.1M	0.05*	2.0				
1N3607	S			DS	75	1.0	50M	0.05*	2.0				
1N3608	S			DS	40	0.55	0.1M	0.05*	2.0				
1N3609	S			DS	75	0.55	0.1M	0.05*	2.0				
1N3611	S	1N4003	1N4001	DS	200	1.0	750M	10*					
1N3612	S	1N4004	1N4001	DS	400	1.0	750M	10*					
1N3613	S	1N4005	1N4001	DS	600	1.0	750M	10*					
1N3614	S	1N4006	1N4001	DS	800	1.0	750M	10*					
1N3615	S	MR1120	MR1120	R*	50	1.2	16	3.0	300				
1N3616	S	MR1121	MR1120	R*	100	1.2	16	2.5	300				
1N3617	S	MR1122	MR1120	R*	150	1.2	16	2.25	300				
1N3618	S	MR1122	MR1120	R*	200	1.2	16	2.0	300				
1N3619	S	MR1123	MR1120	R*	300	1.2	16	1.75	300				
1N3620	S	MR1124	MR1120	R*	400	1.2	16	1.5	300				
1N3621	S	MR1125	MR1120	R*	500	1.2	16	1.25	300				
1N3622	S	MR1126	MR1120	R*	600	1.2	16	1.0	300				
1N3623	S	MR1128	MR1120	R*	800	1.2	16	0.75	300				
1N3624	S	MR1130	MR1120	R*	1000	1.2	16	0.6	300				
1N3625	S			DS	225	1.0	40M	0.5*	0.5				
1N3626	G			DS	50	0.5	10M	1.0M	0.45				
1N3627 thru 1N3628		Varactor Diodes, see Table on Page 92											
1N3629	S			R*	100	1.0	0.75	0.01	30				
1N3630	S			R*	200	1.0	0.75	0.01	30				
1N3631	S			R*	300	1.0	0.75	0.01	30				
1N3632	S			R*	400	1.0	0.75	0.01	30				
1N3633	S			R*	500	1.0	0.75	0.01	30				
1N3634	S			R*	600	1.0	0.75	0.01	30				
1N3635	S			R*	700	1.0	0.75	0.01	30				
1N3636	S			R*	800	1.0	0.75	0.01	30				
1N3637	S			R*	900	1.0	0.75	0.01	30				
1N3638	S			R*	1000	1.0	0.75	0.01	30				

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3639	S	1N4003	1N4001	R*	200	1.2	0.75	0.2	40				
1N3640	S	1N4004	1N4001	R*	400	1.2	0.75	0.2	40				
1N3641	S	1N4005	1N4001	R*	600	1.2	0.75	0.2	40				
1N3642	S	1N4006	1N4001	R*	800	1.2	0.75	0.2	40				
1N3643	S			DS	1000	5.0	250M	5.0*					
1N3644	S			DS	1500	5.0	250M	5.0*					
1N3645	S			DS	1000	5.0	250M	5.0*					
1N3646	S			DS	2500	5.0	250M	5.0*					
1N3647	S			DS	3000	5.0	250M	5.0*					
1N3648	S			R*	10K	23	0.35	0.5	30				
1N3649	S	MR1128	MR1120	R*	800	1.1	1.0	0.005	25				
1N3650	S	MR1130	MR1120	R*	1000	1.1	1.0	0.005	25				
1N3653	S			DS	90	1.0	400M	25N	4.0				
1N3654	S			DS	90	1.0	50M	25N	4.0				
1N3655	S	Microwave S-band Mixer:			NF = 8.3 to 6.0 dB								
1N3655A	S	Microwave S-band Mixer:			NF = 8.3 to 6.0 dB								
1N3655B	S	Microwave S-band Mixer:			NF = 8.3 to 6.0 dB								
1N3656	S			DS	200	1.2	500M	0.01M					
1N3657	S			DS	400	1.2	500M	0.01M					
1N3658	S			DS	600	1.2	500M	0.01M					
1N3659	S			R*	50	1.4	25	5.0	400				
1N3660	S			R*	100	1.4	25	4.5	400				
1N3661	S			R*	200	1.4	25	4.0	400				
1N3662	S			R*	300	1.4	25	3.5	400				
1N3663	S			R*	400	1.4	25	3.0	400				
1N3664	S			R*	500	1.4	25	2.5	400				
1N3665	S			R*	600	1.4	25	2.0	400				
1N3666	G			DS	80	1.0	200M	25*	0.3				
1N3667	S			R*	500	1.2	1.5	1.2	30				
1N3668	S			DS	30	1.0	5.0M	0.1*	0.15				
1N3669	S			DS	70	1.1	400M	0.25*	0.2				
1N3670	S	MR1128	MR1120	R*	700	2.05	12	3.0	200				
1N3670A	S	MR1128	MR1120	R*	700	1.5	12	0.9	240				
1N3671	S	MR1128	MR1120	R*	800	2.05	12	2.0	200				
1N3671A	S	MR1128	MR1120	R*	800	1.3	12	0.8	240				
1N3672	S	MR1130	MR1120	R*	900	2.05	12	2.0	200				
1N3672A	S	MR1130	MR1120	R*	900	1.15	12	0.7	240				
1N3673	S	MR1130	MR1120	R*	1000	2.05	12	1.0	200				
1N3673A	S	MR1130	MR1120	R*	1000	1.0	12	0.6	240				
1N3675	S	1N4736 *	1N4728	DZ							6.8*	20	750M
1N3675A	S	1N4736 *	1N4728	DZ							6.8*	10	750M
1N3675B	S	1N4736A *	1N4728	DZ							6.8*	5.0	750M
1N3676	S	1N4737 *	1N4728	DZ							7.5*	20	750M
1N3676A	S	1N4737 *	1N4728	DZ							7.5*	10	750M
1N3676B	S	1N4737A *	1N4728	DZ							7.5*	5.0	750M
1N3677	S	1N4738 *	1N4728	DZ							8.2*	20	750M
1N3677A	S	1N4738 *	1N4728	DZ							8.2*	10	750M
1N3677B	S	1N4738A *	1N4728	DZ							8.2*	5.0	750M
1N3678	S	1N4739 *	1N4728	DZ							9.1*	20	750M
1N3678A	S	1N4739 *	1N4728	DZ							9.1*	10	750M
1N3678B	S	1N4739A *	1N4728	DZ							9.1*	5.0	750M
1N3679	S	1N4740 *	1N4728	DZ							10*	20	750M
1N3679A	S	1N4740 *	1N4728	DZ							10*	10	750M
1N3679B	S	1N4740A *	1N4728	DZ							10*	5.0	750M
1N3680	S	1N4741 *	1N4728	DZ							11*	20	750M
1N3680A	S	1N4741 *	1N4728	DZ							11*	10	750M
1N3680B	S	1N4741A *	1N4728	DZ							11*	5.0	750M
1N3681	S	1N4742 *	1N4728	DZ							12*	20	750M
1N3681A	S	1N4742 *	1N4728	DZ							12*	10	750M
1N3681B	S	1N4742A *	1N4728	DZ							12*	5.0	750M
1N3682	S	1N4743 *	1N4728	DZ							13*	20	750M
1N3682A	S	1N4743 *	1N4728	DZ							13*	10	750M
1N3682B	S	1N4743A *	1N4728	DZ							13*	5.0	750M
1N3683	S	1N4744 *	1N4728	DZ							15*	20	750M
1N3683A	S	1N4744 *	1N4728	DZ							15*	10	750M
1N3683B	S	1N4744A *	1N4728	DZ							15*	5.0	750M
1N3684	S	1N4745 *	1N4728	DZ							16*	20	750M
1N3684A	S	1N4745 *	1N4728	DZ							16*	10	750M
1N3684B	S	1N4745A *	1N4728	DZ							16*	5.0	750M
1N3685	S	1N4746 *	1N4728	DZ							18*	20	750M
1N3685A	S	1N4746 *	1N4728	DZ							18*	10	750M
1N3685B	S	1N4746A *	1N4728	DZ							18*	5.0	750M
1N3686	S	1N4747 *	1N4728	DZ							20*	20	750M
1N3686A	S	1N4747 *	1N4728	DZ							20*	10	750M
1N3686B	S	1N4747A *	1N4728	DZ							20*	5.0	750M
1N3687	S	1N4748 *	1N4728	DZ							22*	20	750M
1N3687A	S	1N4748 *	1N4728	DZ							22*	10	750M
1N3687B	S	1N4748A *	1N4728	DZ							22*	5.0	750M
1N3688	S	1N4749 *	1N4728	DZ							24*	20	750M
1N3688A	S	1N4749 *	1N4728	DZ							24*	10	750M
1N3688B	S	1N4749A *	1N4728	DZ							24*	5.0	750M
1N3689	S	1N4750 *	1N4728	DZ							27*	20	750M

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3689A	S	1N4750 *	1N4728	DZ							27*	10	750M
1N3689B	S	1N4750A *	1N4728	DZ							27*	5.0	750M
1N3690	S	1N4751 *	1N4728	DZ							30*	20	750M
1N3690A	S	1N4751 *	1N4728	DZ							30*	10	750M
1N3690B	S	1N4751A *	1N4728	DZ							30*	5.0	750M
1N3691	S	1N4752 *	1N4728	DZ							33*	20	750M
1N3691A	S	1N4752 *	1N4728	DZ							33*	10	750M
1N3691B	S	1N4752A *	1N4728	DZ							33*	5.0	750M
1N3692	S	1N4753 *	1N4728	DZ							36*	20	750M
1N3692A	S	1N4753 *	1N4728	DZ							36*	10	750M
1N3692B	S	1N4753A *	1N4728	DZ							36*	5.0	750M
1N3693	S	1N4754 *	1N4728	DZ							39*	20	750M
1N3693A	S	1N4754 *	1N4728	DZ							39*	10	750M
1N3693B	S	1N4754A *	1N4728	DZ							39*	5.0	750M
1N3694	S	1N4755 *	1N4728	DZ							43*	20	750M
1N3694A	S	1N4755 *	1N4728	DZ							43*	10	750M
1N3694B	S	1N4755A *	1N4728	DZ							43*	5.0	750M
1N3695	S	1N4756 *	1N4728	DZ							47*	20	750M
1N3695A	S	1N4756 *	1N4728	DZ							47*	10	750M
1N3695B	S	1N4756A *	1N4728	DZ							47*	5.0	750M
1N3696	S	1N4757 *	1N4728	DZ							51*	20	750M
1N3696A	S	1N4757 *	1N4728	DZ							51*	10	750M
1N3696B	S	1N4757A *	1N4728	DZ							51*	5.0	750M
1N3697	S	1N4758 *	1N4728	DZ							56*	20	750M
1N3697A	S	1N4758 *	1N4728	DZ							56*	10	750M
1N3697B	S	1N4758A *	1N4728	DZ							56*	5.0	750M
1N3698	S	1N4759 *	1N4728	DZ							62*	20	750M
1N3698A	S	1N4759 *	1N4728	DZ							62*	10	750M
1N3698B	S	1N4759A *	1N4728	DZ							62*	5.0	750M
1N3699	S	1N4760 *	1N4728	DZ							68*	20	750M
1N3699A	S	1N4760 *	1N4728	DZ							68*	10	750M
1N3699B	S	1N4760A *	1N4728	DZ							68*	5.0	750M
1N3700	S	1N4761 *	1N4728	DZ							75*	20	750M
1N3700A	S	1N4761 *	1N4728	DZ							75*	10	750M
1N3700B	S	1N4761A *	1N4728	DZ							75*	5.0	750M
1N3701	S	1N4762 *	1N4728	DZ							82*	20	750M
1N3701A	S	1N4762 *	1N4728	DZ							82*	10	750M
1N3701B	S	1N4762A *	1N4728	DZ							82*	5.0	750M
1N3702	S	1N4763 *	1N4728	DZ							91*	20	750M
1N3702A	S	1N4763 *	1N4728	DZ							91*	10	750M
1N3702B	S	1N4763A *	1N4728	DZ							91*	5.0	750M
1N3703	S	1N4764 *	1N4728	DZ							100*	20	750M
1N3703A	S	1N4764 *	1N4728	DZ							100*	10	750M
1N3703B	S	1N4764A *	1N4782	DZ							100*	5.0	750M
1N3704	S	1M110ZS10 *	1N4728	DZ							110*	20	750M
1N3704A	S	1M110ZS10 *	1N4728	DZ							110*	10	750M
1N3704B	S	1M110ZS5 *	1N4728	DZ							110*	5.0	750M
1N3705	S	1M120ZS10 *	1N4728	DZ							120*	20	750M
1N3705A	S	1M120ZS10 *	1N4728	DZ							120*	10	750M
1N3705B	S	1M120ZS5 *	1N4728	DZ							120*	5.0	750M
1N3706	S	1M130ZS10 *	1N4728	DZ							130*	20	750M
1N3706A	S	1M130ZS10 *	1N4728	DZ							130*	10	750M
1N3706B	S	1M130ZS5 *	1N4728	DZ							130*	5.0	750M
1N3707	S	1M150ZS10 *	1N4728	DZ							150*	20	750M
1N3707A	S	1M150ZS10 *	1N4728	DZ							150*	10	750M
1N3707B	S	1M150ZS5 *	1N4728	DZ							150*	5.0	750M
1N3708	S	1M160ZS10 *	1N4728	DZ							160*	20	750M
1N3708A	S	1M160ZS10 *	1N4728	DZ							160*	10	750M
1N3708B	S	1M160ZS5 *	1N4728	DZ							160*	5.0	750M
1N3709	S	1M180ZS10 *	1N4728	DZ							180*	20	750M
1N3709A	S	1M180ZS10 *	1N4728	DZ							180*	10	750M
1N3709B	S	1M180ZS5 *	1N4728	DZ							180*	5.0	750M
1N3710	S	1M200ZS10 *	1N4728	DZ							200*	20	750M
1N3710A	S	1M200ZS10 *	1N4728	DZ							200*	10	750M
1N3710B	S	1M200ZS5 *	1N4728	DZ							200*	5.0	750M
1N3711	S			R*	6000	11	0.15	0.025	5.0				
1N3712 thru 1N3721		Tunnel Diodes, see Table on Page 98											
1N3722	S			DS	50	1.0	20M	0.1*	10				
1N3723	S			R*	1000	2.2	0.75	0.005	12				
1N3724	S			R*	1200	2.2	0.75	0.005	12				
1N3725	S			R*	1400	2.2	0.75	0.005	12				
1N3726	S			R*	1600	2.2	0.75	0.005	12				
1N3727	S			R*	1800	2.2	0.75	0.005	12				
1N3728	S			DS	550	1.2	400M	0.1*					
1N3729	S			DS	600	1.0	5.0M	0.1*	0.5				
1N3730	S			DS	80	1.0	750M	0.1*	15				
1N3731	S			DS	80	1.0	100M	5.0*	3.0				
1N3732	S	1N4733A	1N4728	DZ							5.1*	5.0	1.0W
1N3733	S	Microwave S-band Mixer											
1N3734	S	Photosensitive Device; BV = 100 V, Sensitivity = 0.05 μA/fc											

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3735	S	MR1231SB	MR1230	R*	100	1.3	250	16	4500				
1N3736	S	MR1233SB	MR1230	R*	200	1.3	250	16	4500				
1N3737	S	MR1235SB	MR1230	R*	300	1.3	250	16	4500				
1N3738	S	MR1237SB	MR1230	R*	400	1.3	250	16	4500				
1N3739	S	MR1238SB	MR1230	R*	500	1.3	250	13	4500				
1N3740	S	MR1239SB	MR1230	R*	600	1.3	250	12	4500				
1N3741	S			R*	800	1.3	250	9.0	4500				
1N3742	S			R*	1000	1.3	250	7.0	4500				
1N3743	S			R*	1200	1.3	250	7.0	4500				
1N3744	S			R*	1400	1.3	250	7.0	4500				
1N3745	S	Microwave X-band Mixer; NF = 9.5 dB											
1N3746	S	Microwave X-band Mixer; NF = 8.5 dB											
1N3747	S	Microwave X-band Mixer; NF = 7.5 dB											
1N3748	S			R*	200	1.5	0.5		20				
1N3749	S			R*	400	1.5	0.5		20				
1N3750	S			R*	600	1.5	0.5		20				
1N3751	S			R*	800	1.5	0.5		20				
1N3752	S			R*	1000	1.5	0.5		20				
1N3753	G			DS	55	1.0	150M	5.0*					
1N3754	S			R*	100	1.2	0.15	0.3	15				
1N3755	S			R*	200	1.2	0.15	0.3	15				
1N3756	S			R*	400	1.2	0.15	0.3	15				
1N3757	S			R*	200	1.0	1.0		30				
1N3758	S			R*	400	1.0	1.0		30				
1N3759	S			R*	600	1.0	1.0		30				
1N3760	S			R*	800	1.0	1.0		30				
1N3761	S			R*	1000	1.0	1.0		30				
1N3762	S			R*	5300	12	0.065	0.005	15				
1N3763	S	1N2767A		DR						0.002	20	-55	150
1N3764	S			R*	3000	6.5	0.2	0.1	8.0				
1N3765	S			R*	700	1.8	35	5.0	400				
1N3766	S			R*	800	1.8	35	4.0	400				
1N3767	S			R*	900	1.8	35	3.0	400				
1N3768	S			R*	1000	1.8	35	2.0	400				
1N3769	G			DS	90	0.5	25M	5.0*					
1N3770		Varactor Diode, see Table on Page 92											
1N3771 thru 1N3772		4-Layer Diodes, see Table on Page 102											
1N3773	G			DS	25	0.35	2.0M	4.0*	40				
1N3774	S			DZ							1.15*	2.0	0.34W
1N3775	S			R*	1500	2.2	3.3	0.1	15				
1N3776	S			DZ							10*		6.0W
1N3777	S			DS	40	1.1	10M	0.1*	4.0				
1N3778	S	Microwave C-X-band Detector											
1N3779	S	1N821A	1N821	DR						0.015	6.7	-55	25
1N3780	S	1N821A	1N821	DR						0.001	6.7	-55	25
1N3781	S	1N823A	1N821	DR						0.005	6.7	-55	25
1N3782	S	1N825A	1N821	DR						0.002	6.7	-55	25
1N3783	S	1N827A	1N821	DR						0.001	6.7	-55	25
1N3784	S	1N829A	1N821	DR						0.0005	6.7	-55	25
1N3785	S		1N3785	DZ							6.8*	20	1.5W
1N3785A	S		1N3785	DZ							6.8*	10	1.5W
1N3785B	S		1N3785	DZ							6.8*	5.0	1.5W
1N3786	S		1N3785	DZ							7.5*	20	1.5W
1N3786A	S		1N3785	DZ							7.5*	10	1.5W
1N3786B	S		1N3785	DZ							7.5*	5.0	1.5W
1N3787	S		1N3785	DZ							8.2*	20	1.5W
1N3787A	S		1N3785	DZ							8.2*	10	1.5W
1N3787B	S		1N3785	DZ							8.2*	5.0	1.5W
1N3788	S		1N3785	DZ							9.1*	20	1.5W
1N3788A	S		1N3785	DZ							9.1*	10	1.5W
1N3788B	S		1N3785	DZ							9.1*	5.0	1.5W
1N3789	S		1N3785	DZ							10*	20	1.5W
1N3789A	S		1N3785	DZ							10*	10	1.5W
1N3789B	S		1N3785	DZ							10*	5.0	1.5W
1N3790	S		1N3785	DZ							11*	20	1.5W
1N3790A	S		1N3785	DZ							11*	10	1.5W
1N3790B	S		1N3785	DZ							11*	5.0	1.5W
1N3791	S		1N3785	DZ							12*	20	1.5W
1N3791A	S		1N3785	DZ							12*	10	1.5W
1N3791B	S		1N3785	DZ							12*	5.0	1.5W
1N3792	S		1N3785	DZ							13*	20	1.5W
1N3792A	S		1N3785	DZ							13*	10	1.5W
1N3792B	S		1N3785	DZ							13*	5.0	1.5W
1N3793	S		1N3785	DZ							15*	20	1.5W
1N3793A	S		1N3785	DZ							15*	10	1.5W
1N3793B	S		1N3785	DZ							15*	5.0	1.5W
1N3794	S		1N3785	DZ							16*	20	1.5W
1N3794A	S		1N3785	DZ							16*	10	1.5W
1N3794B	S		1N3785	DZ							16*	5.0	1.5W
1N3795	S		1N3785	DZ							18*	20	1.5W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3795A	S		1N3785	DZ							18*	10	1.5W
1N3795B	S		1N3785	DZ							18*	5.0	1.5W
1N3796	S		1N3785	DZ							20*	20	1.5W
1N3796A	S		1N3785	DZ							20*	10	1.5W
1N3796B	S		1N3785	DZ							20*	5.0	1.5W
1N3797	S		1N3785	DZ							22*	20	1.5W
1N3797A	S		1N3785	DZ							22*	10	1.5W
1N3797B	S		1N3785	DZ							22*	5.0	1.5W
1N3798	S		1N3785	DZ							24*	20	1.5W
1N3798A	S		1N3785	DZ							24*	10	1.5W
1N3798B	S		1N3785	DZ							24*	5.0	1.5W
1N3799	S		1N3785	DZ							27*	20	1.5W
1N3799A	S		1N3785	DZ							27*	10	1.5W
1N3799B	S		1N3785	DZ							27*	5.0	1.5W
1N3800	S		1N3785	DZ							30*	20	1.5W
1N3800A	S		1N3785	DZ							30*	10	1.5W
1N3800B	S		1N3785	DZ							30*	5.0	1.5W
1N3801	S		1N3785	DZ							33*	20	1.5W
1N3801A	S		1N3785	DZ							33*	10	1.5W
1N3801B	S		1N3785	DZ							33*	5.0	1.5W
1N3802	S		1N3785	DZ							36*	20	1.5W
1N3802A	S		1N3785	DZ							36*	10	1.5W
1N3802B	S		1N3785	DZ							36*	5.0	1.5W
1N3803	S		1N3785	DZ							39*	20	1.5W
1N3803A	S		1N3785	DZ							39*	10	1.5W
1N3803B	S		1N3785	DZ							39*	5.0	1.5W
1N3804	S		1N3785	DZ							43*	20	1.5W
1N3804A	S		1N3785	DZ							43*	10	1.5W
1N3804B	S		1N3785	DZ							43*	5.0	1.5W
1N3805	S		1N3785	DZ							47*	20	1.5W
1N3805A	S		1N3785	DZ							47*	10	1.5W
1N3805B	S		1N3785	DZ							47*	5.0	1.5W
1N3806	S		1N3785	DZ							51*	20	1.5W
1N3806A	S		1N3785	DZ							51*	10	1.5W
1N3806B	S		1N3785	DZ							51*	5.0	1.5W
1N3807	S		1N3785	DZ							56*	20	1.5W
1N3807A	S		1N3785	DZ							56*	10	1.5W
1N3807B	S		1N3785	DZ							56*	5.0	1.5W
1N3808	S		1N3785	DZ							62*	20	1.5W
1N3808A	S		1N3785	DZ							62*	10	1.5W
1N3808B	S		1N3785	DZ							62*	5.0	1.5W
1N3809	S		1N3785	DZ							68*	20	1.5W
1N3809A	S		1N3785	DZ							68*	10	1.5W
1N3809B	S		1N3785	DZ							68*	5.0	1.5W
1N3810	S		1N3785	DZ							75*	20	1.5W
1N3810A	S		1N3785	DZ							75*	10	1.5W
1N3810B	S		1N3785	DZ							75*	5.0	1.5W
1N3811	S		1N3785	DZ							82*	20	1.5W
1N3811A	S		1N3785	DZ							82*	10	1.5W
1N3811B	S		1N3785	DZ							82*	5.0	1.5W
1N3812	S		1N3785	DZ							91*	20	1.5W
1N3812A	S		1N3785	DZ							91*	10	1.5W
1N3812B	S		1N3785	DZ							91*	5.0	1.5W
1N3813	S		1N3785	DZ							100*	20	1.5W
1N3813A	S		1N3785	DZ							100*	10	1.5W
1N3813B	S		1N3785	DZ							100*	5.0	1.5W
1N3814	S		1N3785	DZ							110*	20	1.5W
1N3814A	S		1N3785	DZ							110*	10	1.5W
1N3814B	S		1N3785	DZ							110*	5.0	1.5W
1N3815	S		1N3785	DZ							120*	20	1.5W
1N3815A	S		1N3785	DZ							120*	10	1.5W
1N3815B	S		1N3785	DZ							120*	5.0	1.5W
1N3816	S		1N3785	DZ							130*	20	1.5W
1N3816A	S		1N3785	DZ							130*	10	1.5W
1N3816B	S		1N3785	DZ							130*	5.0	1.5W
1N3817	S		1N3785	DZ							150*	20	1.5W
1N3817A	S		1N3785	DZ							150*	10	1.5W
1N3817B	S		1N3785	DZ							150*	5.0	1.5W
1N3818	S		1N3785	DZ							160*	20	1.5W
1N3818A	S		1N3785	DZ							160*	10	1.5W
1N3818B	S		1N3785	DZ							160*	5.0	1.5W
1N3819	S		1N3785	DZ							180*	20	1.5W
1N3819A	S		1N3785	DZ							180*	10	1.5W
1N3819B	S		1N3785	DZ							180*	5.0	1.5W
1N3820	S		1N3785	DZ							200*	20	1.5W
1N3820A	S		1N3785	DZ							200*	10	1.5W
1N3820B	S		1N3785	DZ							200*	5.0	1.5W
1N3821	S		1N3821	DZ							3.3*	10	1.0W
1N3821A	S		1N3821	DZ							3.3*	5.0	1.0W
1N3822	S		1N3821	DZ							3.6*	10	1.0W
1N3822A	S		1N3821	DZ							3.6*	5.0	1.0W
1N3823	S		1N3821	DZ							3.9*	10	1.0W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * / V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3823A	S		1N3821	DZ							3.9*	5.0	1.0W
1N3824	S		1N3821	DZ							4.3*	10	1.0W
1N3824A	S		1N3821	DZ							4.3*	5.0	1.0W
1N3825	S		1N3821	DZ							4.7*	10	1.0W
1N3825A	S		1N3821	DZ							4.7*	5.0	1.0W
1N3826	S		1N3821	DZ							5.1*	10	1.0W
1N3826A	S		1N3821	DZ							5.1*	5.0	1.0W
1N3827	S		1N3821	DZ							5.6*	10	1.0W
1N3827A	S		1N3821	DZ							5.6*	5.0	1.0W
1N3828	S		1N3821	DZ							6.2*	10	1.0W
1N3828A	S		1N3821	DZ							6.2*	5.0	1.0W
1N3829	S		1N3821	DZ							6.8*	10	1.0W
1N3829A	S		1N3821	DZ							6.8*	5.0	1.0W
1N3830	S		1N3821	DZ							7.5*	10	1.0W
1N3830A	S		1N3821	DZ							7.5*	5.0	1.0W
1N3831 thru 1N3846		4-Layer Diodes, see Table on Page 102											
1N3847 thru 1N3860		Tunnel Diodes, see Table on Page 98											
1N3861	G	Tunnel Rectifier											
1N3862	G	Tunnel Rectifier											
1N3863	G	Tunnel Rectifier											
1N3864	S			DS	125	1.5	200M	1.0N	0.9				
1N3865	G			DS	80		100M	15*	0.5				
1N3866	S			R*	200	1.5	1.0	0.05	25				
1N3867	S			R*	400	1.5	1.0	0.05	25				
1N3868	S			R*	600	1.5	1.0	0.05	25				
1N3869	S			R*	1000	3.0	0.5	0.05	10				
1N3870	S			R*	1500	3.0	0.5	0.05	10				
1N3871	S			R*	2500	6.0	0.25	0.05	5.0				
1N3872	S			DS	90	1.0	150M	0.1*	15				
1N3873	S			DS	50	1.14	0.2A	0.1*	4.0				
1N3874	S			R*	50	1.5	6.0	3.0	75				
1N3875	S			R*	100	1.5	6.0	3.0	75				
1N3876	S			R*	200	1.5	6.0	3.0	75				
1N3877	S			R*	300	1.5	6.0	3.0	75				
1N3878	S			R*	400	1.5	6.0	3.0	75				
1N3879	S		1N4933	R*	50	1.5	6.0	3.0	75				
1N3880	S		1N4933	R*	150	1.5	6.0	3.0	75				
1N3881	S		1N4933	R*	200	1.5	6.0	3.0	75				
1N3882	S		1N4933	R*	300	1.5	6.0	3.0	75				
1N3883	S		1N4933	R*	400	1.5	6.0	3.0	75				
1N3884	S			R*	50	1.5	12	3.0	150				
1N3885	S			R*	100	1.5	12	3.0	150				
1N3886	S			R*	200	1.5	12	3.0	150				
1N3887	S			R*	300	1.5	12	3.0	150				
1N3888	S			R*	400	1.5	12	3.0	150				
1N3889	S		1N4933	R*	50	1.5	12	3.0	150				
1N3890	S		1N4933	R*	100	1.5	12	3.0	150				
1N3891	S		1N4933	R*	200	1.5	12	3.0	150				
1N3892	S		1N4933	R*	300	1.5	12	3.0	150				
1N3893	S		1N4933	R*	400	1.5	12	3.0	150				
1N3894	S			DS	400	1.0	400M	0.2*					
1N3895	S			DS	350	1.0	200M	0.5*					
1N3896	S			DZ							0.77*	5.0	250M
1N3897	S			DZ							1.5*	5.0	250M
1N3898	S	1N5221B	1N5221	DZ							2.1*	5.0	250M
1N3899	S		1N4933	R*	50	1.5	20	6.0	225				
1N3900	S		1N4933	R*	100	1.5	20	6.0	225				
1N3901	S		1N4933	R*	200	1.5	20	6.0	225				
1N3902	S		1N4933	R*	300	1.5	20	6.0	225				
1N3903	S		1N4933	R*	400	1.5	20	6.0	225				
1N3904	S			R*	50	1.5	20	6.0	225				
1N3905	S			R*	100	1.5	20	6.0	225				
1N3906	S			R*	200	1.5	20	6.0	225				
1N3907	S			R*	300	1.5	20	6.0	225				
1N3908	S			R*	400	1.5	20	6.0	225				
1N3909	S		1N4933	R*	50	1.5	30	10	300				
1N3910	S		1N4933	R*	100	1.5	30	10	300				
1N3911	S		1N4933	R*	200	1.5	30	10	300				
1N3912	S		1N4933	R*	300	1.5	30	10	300				
1N3913	S		1N4933	R*	400	1.5	30	10	300				
1N3914	S			R*	50	1.5	30	10	300				
1N3915	S			R*	100	1.5	30	10	300				
1N3916	S			R*	200	1.5	30	10	300				
1N3917	S			R*	300	1.5	30	10	300				
1N3918	S			R*	400	1.5	30	10	300				
1N3919	S			R*	1000	2.0	5.0	0.5	100				
1N3920	S			R*	1500	2.0	5.0	0.5	100				
1N3921	S			R*	2000	2.0	5.0	0.5	100				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3922	S			R*	2500	2.0	5.0	0.5	100				
1N3923	S			R*	3000	2.0	5.0	0.5	100				
1N3924	S			R*	1000	2.0	10	0.5	100				
1N3925	S			R*	1500	2.0	10	0.5	100				
1N3926	S			R*	2000	2.0	10	0.5	100				
1N3927	S			R*	2500	2.0	10	0.5	100				
1N3928	S			R*	3000	2.0	10	0.5	100				
1N3929	S			DS	1000	2.0	1.0A	10*					
1N3930	S			DS	1500	2.0	1.0A	10*					
1N3931	S			DS	2000	2.0	1.0A	10*					
1N3932	S			DS	1500	2.0	1.0A	10*					
1N3933	S			DS	3000	2.0	1.0A	10*					
1N3934	S			R*	1200	2.5	1.0	0.4	50				
1N3935													
thru		4-Layer Diodes, see Table on Page 102											
1N3937													
1N3938	S			R*	200	1.1	2.0	0.4	30				
1N3939	S			R*	400	1.1	2.0	0.2	30				
1N3940	S			R*	600	1.1	2.0	0.2	30				
1N3941	S			R*	800	1.5	2.0	0.2	30				
1N3942	S			R*	1000	1.5	2.0	0.2	30				
1N3943	S			DS	3.0	2.5	300M	100*					
1N3944	G			DS	15	0.75	10M	2.5*	12				
1N3945													
thru		Varactor Diodes, see Table on Page 92											
1N3947													
1N3948		Tunnel Diode, see Table on Page 98											
1N3949	S	1N2984B	1N2970	DZ							20*	5.0	10W
1N3950	S	1N3796B	1N3785	DZ							20*	5.0	1.5W
1N3951	S	1.5M25Z5		DZ							25*	5.0	1.5W
1N3952	S			DS	130	0.74	10M	25N					
1N3953	G			DS	40	0.5	35M	50*	300				
1N3954	S			DS	50	1.0	200M	0.1*	4.0				
1N3955	S			R*	100	1.3	70	15	1200				
1N3956	S			DS	40	0.55	100*	0.05*	2.0				
1N3957	S			DS	1000	1.0	400M	10*					
1N3958	S	1N3880	1N4933	R*	100	1.3	3.5	0.4	35				
1N3959	S	1N3881	1N4933	R*	200	1.3	3.5	0.4	35				
1N3960	S	1N3882	1N4933	R*	300	1.3	3.5	0.4	35				
1N3961	S	1N3883	1N4933	R*	400	1.3	3.5	0.4	35				
1N3962	S	MR1366	1N4933	R*	500	1.3	3.5	0.4	35				
1N3963	S	MR1366	1N4933	R*	600	1.3	3.5	0.4	35				
1N3964	S			R*	200	1.6	22	1.0	200				
1N3965	S			R*	400	1.6	22	1.0	200				
1N3966	S			R*	600	1.6	22	1.0	200				
1N3967	S			R*	800	1.6	22	1.0	200				
1N3968	S			R*	200	1.6	50	2.0	600				
1N3969	S			R*	400	1.6	50	2.0	600				
1N3970	S			R*	600	1.6	50	2.0	600				
1N3971	S			R*	800	1.6	50	2.0	600				
1N3972	S			R*	200	1.5	104	5.0	1500				
1N3973	S			R*	400	1.5	104	5.0	1500				
1N3974	S			R*	600	1.5	104	5.0	1500				
1N3975	S			R*	800	1.5	104	5.0	1500				
1N3976	S			R*	200	1.5	250	10	4000				
1N3977	S			R*	400	1.5	250	10	4000				
1N3978	S			R*	600	1.5	250	10	4000				
1N3979	S			R*	800	1.5	250	10	4000				
1N3981	S			DS	200	1.0	900M	0.01M					
1N3982	S			DS	400	1.0	900M	0.01M					
1N3983	S			DS	600	1.0	900M	0.01M					
1N3984	S	1N3997A	1N3993	DZ							5.5*	5.0	10W
1N3985	S	1N3998A	1N3993	DZ							6.0*	5.0	10W
1N3986	S	1N3998A	1N3993	DZ							6.2*	5.0	10W
1N3987	S			R*	700	1.4	6.0	0.9	150				
1N3988	S	MR1128	MR1120	R*	800	1.4	6.0	0.8	150				
1N3989	S	MR1130	MR1120	R*	900	1.4	6.0	0.7	150				
1N3990	S	MR1130	MR1120	R*	1000	1.4	6.0	0.6	150				
1N3991	G			DS	35	0.55	30M	1.0M	1.0				
1N3992	S			DS	4000	5.0	250M	5.0*					
1N3993	S		1N3993	DZ							3.9*	10	10W
1N3993A	S		1N3993	DZ							3.9*	5.0	10W
1N3994	S		1N3993	DZ							4.3*	10	10W
1N3994A	S		1N3993	DZ							4.3*	5.0	10W
1N3995	S		1N3993	DZ							4.7*	10	10W
1N3995A	S		1N3993	DZ							4.7*	5.0	10W
1N3996	S		1N3993	DZ							5.1*	10	10W
1N3996A	S		1N3993	DZ							5.1*	5.0	10W
1N3997	S		1N3993	DZ							5.6*	10	10W
1N3997A	S		1N3993	DZ							5.6*	5.0	10W
1N3998	S		1N3993	DZ							6.2*	10	10W
1N3998A	S		1N3993	DZ							6.2*	5.0	10W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N3999	S		1N3993	DZ							6.8*	10	10W
1N3999A	S		1N3993	DZ							6.8*	5.0	10W
1N4000	S		1N3993	DZ							7.5*	10	10W
1N4000A	S		1N3993	DZ							7.5*	5.0	10W
1N4001	S		1N4001	R*	50	1.6	1.0	0.03	30				
1N4002	S		1N4001	R*	100	1.6	1.0	0.03	30				
1N4003	S		1N4001	R*	200	1.6	1.0	0.03	30				
1N4004	S		1N4001	R*	400	1.6	1.0	0.03	30				
1N4005	S		1N4001	R*	600	1.6	1.0	0.03	30				
1N4006	S		1N4001	R*	800	1.6	1.0	0.03	30				
1N4007	S		1N4001	R*	1000	1.6	1.0	0.03	30				
1N4008	G			DS	12	0.5	10M	0.1M	70				
1N4009	S			DS	25	1.0	30M	0.1M	4.0				
1N4010	S	1N829	1N821	DR						0.0005	6.2	25	100
1N4011	S			R*	1000	1.1	0.5	0.2	30				
1N4012	S			R*	700	1.3	12	1.0	200				
1N4013	S			R*	800	1.3	12	1.0	200				
1N4014	S			R*	900	1.3	12	1.0	200				
1N4015	S			R*	1000	1.3	12	1.0	200				
1N4016	S	1N2972	1N2970	DZ							8.2*	20	5.0W
1N4016A	S	1N2972A	1N2970	DZ							8.2*	10	5.0W
1N4016B	S	1N2972B	1N2970	DZ							8.2*	5.0	5.0W
1N4017	S	1N2973	1N2970	DZ							9.1*	20	5.0W
1N4017A	S	1N2973A	1N2970	DZ							9.1*	10	5.0W
1N4017B	S	1N2973B	1N2970	DZ							9.1*	5.0	5.0W
1N4018	S	1N2974	1N2970	DZ							10*	20	5.0W
1N4018A	S	1N2974A	1N2970	DZ							10*	10	5.0W
1N4018B	S	1N2974B	1N2970	DZ							10*	5.0	5.0W
1N4019	S	1N2975	1N2970	DZ							11*	20	5.0W
1N4019A	S	1N2975A	1N2970	DZ							11*	10	5.0W
1N4019B	S	1N2975B	1N2970	DZ							11*	5.0	5.0W
1N4020	S	1N2976	1N2970	DZ							12*	20	5.0W
1N4020A	S	1N2976A	1N2970	DZ							12*	10	5.0W
1N4020B	S	1N2976B	1N2970	DZ							12*	5.0	5.0W
1N4021	S	1N2977	1N2970	DZ							13*	20	5.0W
1N4021A	S	1N2977A	1N2970	DZ							13*	10	5.0W
1N4021B	S	1N2977B	1N2970	DZ							13*	5.0	5.0W
1N4022	S	1N2979	1N2970	DZ							15*	20	5.0W
1N4022A	S	1N2979A	1N2970	DZ							15*	10	5.0W
1N4022B	S	1N2979B	1N2970	DZ							15*	5.0	5.0W
1N4023	S	1N2980	1N2970	DZ							16*	20	5.0W
1N4023A	S	1N2980A	1N2970	DZ							16*	10	5.0W
1N4023B	S	1N2980B	1N2970	DZ							16*	5.0	5.0W
1N4024	S	1N2982	1N2970	DZ							18*	20	5.0W
1N4024A	S	1N2982A	1N2970	DZ							18*	10	5.0W
1N4024B	S	1N2982B	1N2970	DZ							18*	5.0	5.0W
1N4025	S	1N2984	1N2970	DZ							20*	20	5.0W
1N4025A	S	1N2984A	1N2970	DZ							20*	10	5.0W
1N4025B	S	1N2984B	1N2970	DZ							20*	5.0	5.0W
1N4026	S	1N2985	1N2970	DZ							22*	20	5.0W
1N4026A	S	1N2985A	1N2970	DZ							22*	10	5.0W
1N4026B	S	1N2985B	1N2970	DZ							22*	5.0	5.0W
1N4027	S	1N2986	1N2970	DZ							24*	20	5.0W
1N4027A	S	1N2986A	1N2970	DZ							24*	10	5.0W
1N4027B	S	1N2986B	1N2970	DZ							24*	5.0	5.0W
1N4028	S	1N2988	1N2970	DZ							27*	20	5.0W
1N4028A	S	1N2988A	1N2970	DZ							27*	10	5.0W
1N4028B	S	1N2988B	1N2970	DZ							27*	5.0	5.0W
1N4029	S	1N2989	1N2970	DZ							30*	20	5.0W
1N4029A	S	1N2989A	1N2970	DZ							30*	10	5.0W
1N4029B	S	1N2989B	1N2970	DZ							30*	5.0	5.0W
1N4030	S	1N2990	1N2970	DZ							33*	20	5.0W
1N4030A	S	1N2990A	1N2970	DZ							33*	10	5.0W
1N4030B	S	1N2990B	1N2970	DZ							33*	5.0	5.0W
1N4031	S	1N2991	1N2970	DZ							36*	20	5.0W
1N4031A	S	1N2991A	1N2970	DZ							36*	10	5.0W
1N4031B	S	1N2992B	1N2970	DZ							36*	5.0	5.0W
1N4032	S	1N2992	1N2970	DZ							39*	20	5.0W
1N4032A	S	1N2992A	1N2970	DZ							39*	10	5.0W
1N4032B	S	1N2992B	1N2970	DZ							39*	5.0	5.0W
1N4033	S	1N2993	1N2970	DZ							43*	20	5.0W
1N4033A	S	1N2993A	1N2970	DZ							43*	10	5.0W
1N4033B	S	1N2993B	1N2970	DZ							43*	5.0	5.0W
1N4034	S	1N2995	1N2970	DZ							47*	20	5.0W
1N4034A	S	1N2995A	1N2970	DZ							47*	10	5.0W
1N4034B	S	1N2995B	1N2970	DZ							47*	5.0	5.0W
1N4035	S	1N2997	1N2970	DZ							51*	20	5.0W
1N4035A	S	1N2997A	1N2970	DZ							51*	10	5.0W
1N4035B	S	1N2997B	1N2970	DZ							51*	5.0	5.0W
1N4036	S	1N2999	1N2970	DZ							56*	20	5.0W
1N4036A	S	1N2999A	1N2970	DZ							56*	10	5.0W
1N4036B	S	1N2999B	1N2970	DZ							56*	5.0	5.0W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4037	S	1N3000	1N2970	DZ							62*	20	5.0W
1N4037A	S	1N3000A	1N2970	DZ							62*	10	5.0W
1N4037B	S	1N3000B	1N2970	DZ							62*	5.0	5.0W
1N4038	S	1N3001	1N2970	DZ							68*	20	5.0W
1N4038A	S	1N3001A	1N2970	DZ							68*	10	5.0W
1N4038B	S	1N3001B	1N2970	DZ							68*	5.0	5.0W
1N4039	S	1N3002	1N2970	DZ							75*	20	5.0W
1N4039A	S	1N3002A	1N2970	DZ							75*	10	5.0W
1N4039B	S	1N3002B	1N2970	DZ							75*	5.0	5.0W
1N4040	S	1N3003	1N2970	DZ							82*	20	5.0W
1N4040A	S	1N3003A	1N2970	DZ							82*	10	5.0W
1N4040B	S	1N3003B	1N2970	DZ							82*	5.0	5.0W
1N4041	S	1N3004	1N2970	DZ							91*	20	5.0W
1N4041A	S	1N3004A	1N2970	DZ							91*	10	5.0W
1N4041B	S	1N3004B	1N2970	DZ							91*	5.0	5.0W
1N4042	S	1N3005	1N2970	DZ							100*	20	5.0W
1N4042A	S	1N3005A	1N2970	DZ							100*	10	5.0W
1N4042B	S	1N3005B	1N2970	DZ							100*	5.0	5.0W
1N4043	S			DS	25	1.0	275	0.1*	2.0				
1N4044	S	MR1230SB	MR1230	R*	50	1.35	275	15	5000				
1N4045	S	MR1231SB	MR1230	R*	100	1.35	275	15	5000				
1N4046	S	MR1232SB	MR1230	R*	150	1.35	275	15	5000				
1N4047	S	MR1233SB	MR1230	R*	200	1.35	275	15	5000				
1N4048	S	MR1234SB	MR1230	R*	250	1.35	275	15	5000				
1N4049	S	MR1235SB	MR1230	R*	300	1.35	275	15	5000				
1N4050	S	MR1237SB	MR1230	R*	400	1.35	275	15	5000				
1N4051	S	MR1238SB	MR1230	R*	500	1.35	275	15	5000				
1N4052	S	MR1239SB	MR1230	R*	600	1.35	275	15	5000				
1N4053	S			R*	700	1.35	275	15	5000				
1N4054	S			R*	800	1.35	275	15	5000				
1N4055	S			R*	900	1.35	275	15	5000				
1N4056	S			R*	1000	1.35	275	15	5000				
1N4057	S		1N429	DR						0.005	12.4	-55	100
1N4057A	S		1N429	DR						0.002	12.4	-55	100
1N4058	S		1N429	DR						0.005	14.6	-55	100
1N4058A	S		1N429	DR						0.002	14.6	-55	100
1N4059	S		1N429	DR						0.005	16.8	-55	100
1N4059A	S		1N429	DR						0.002	16.8	-55	100
1N4060	S		1N429	DR						0.005	18.5	-55	100
1N4060A	S		1N429	DR						0.002	18.5	-55	100
1N4061	S		1N429	DR						0.005	21	-55	100
1N4061A	S		1N429	DR						0.002	21	-55	100
1N4062	S		1N429	DR						0.005	23	-55	100
1N4062A	S		1N429	DR						0.002	23	-55	100
1N4063	S		1N429	DR						0.005	27	-55	100
1N4063A	S		1N429	DR						0.002	27	-55	100
1N4064	S		1N429	DR						0.005	30	-55	100
1N4064A	S		1N429	DR						0.002	30	-55	100
1N4065	S		1N429	DR						0.005	33	-55	100
1N4065A	S		1N429	DR						0.002	33	-55	100
1N4066	S		1N429	DR						0.005	37	-55	100
1N4066A	S		1N429	DR						0.002	37	-55	100
1N4067	S		1N429	DR						5.0	43	-55	100
1N4067A	S		1N429	DR						2.0	43	-55	100
1N4068	S		1N429	DR						5.0	47	-55	100
1N4068A	S		1N429	DR						2.0	47	-55	100
1N4069	S		1N429	DR						5.0	51	-55	100
1N4069A	S		1N429	DR						2.0	51	-55	100
1N4070	S		1N429	DR						5.0	56	-55	100
1N4070A	S		1N429	DR						2.0	56	-55	100
1N4071	S		1N429	DR						5.0	62	-55	100
1N4071A	S		1N429	DR						2.0	62	-55	100
1N4072	S		1N429	DR						5.0	68	-55	100
1N4072A	S		1N429	DR						2.0	68	-55	100
1N4073	S		1N429	DR						5.0	75	-55	100
1N4073A	S		1N429	DR						2.0	75	-55	100
1N4074	S		1N429	DR						5.0	82	-55	100
1N4074A	S		1N429	DR						2.0	82	-55	100
1N4075	S		1N429	DR						0.005	87	-55	100
1N4075A	S		1N429	DR						0.002	87	-55	100
1N4076	S		1N429	DR						0.005	91	-55	100
1N4076A	S		1N429	DR						0.002	91	-55	100
1N4077	S		1N429	DR						0.002	100	-55	100
1N4077A	S		1N429	DR						0.002	100	-55	100
1N4078	S		1N429	DR						0.005	105	-55	100
1N4078A	S		1N429	DR						0.002	105	-55	100
1N4079	S		1N429	DR						0.005	110	-55	100
1N4079A	S		1N429	DR						0.002	110	-55	100
1N4080	S		1N429	DR						0.005	120	-55	100
1N4080A	S		1N429	DR						0.002	120	-55	100
1N4081	S		1N429	DR						0.005	130	-55	100
1N4081A	S		1N429	DR						0.002	130	-55	100

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4082	S		1N429	DR						0.005	140	-55	100
1N4082A	S		1N429	DR						0.002	140	-55	100
1N4083	S		1N429	DR						0.005	150	-55	100
1N4083A	S		1N429	DR						0.002	150	-55	100
1N4084	S		1N429	DR						0.005	175	-55	100
1N4084A	S		1N429	DR						0.002	175	-55	100
1N4085	S		1N429	DR						0.005	200	-55	100
1N4085A	S		1N429	DR						0.002	200	-55	100
1N4086	S			DS	70	1.0	200M	0.25M	200				
1N4087	S			DS	50	0.975	30M	90N	2.5				
1N4088	G			DS	30	1.0	100M	0.2M					
1N4089	S			R*	400	1.2	400	0.2	75				
1N4090	G	Backward Diode											
1N4091		Varactor Diode, see Table on Page 92											
1N4092	S			DS		1.0	5.0M	1.0*					
1N4093	S			DS	50	1.0	5.0M	1.0					
1N4094	S	1N2624B	1N2620	DR							9.6		
1N4095	S	1N5231A	1N5221	DZ							5.0*	10	275M
1N4096	S	1N4763A	1N4728	DZ							90*	5.0	3.0W
1N4097	S	1N4764A	1N4728	DZ							100*	5.0	3.0W
1N4098	S	1M150ZS5	1N4728	DZ							150*	5.0	3.0W
1N4099	S		1N4099	DZ						6.46	7.14		250M
1N4100	S		1N4099	DZ						7.125	7.875		250M
1N4101	S		1N4099	DZ						7.79	8.61		250M
1N4102	S		1N4099	DZ						8.265	9.135		250M
1N4103	S		1N4099	DZ						8.645	9.555		250M
1N4104	S		1N4099	DZ						9.5	10.5		250M
1N4105	S		1N4099	DZ						10.45	11.55		250M
1N4106	S		1N4099	DZ						11.4	12.6		250M
1N4107	S		1N4099	DZ						12.35	13.65		250M
1N4108	S		1N4099	DZ						13.3	14.7		250M
1N4109	S		1N4099	DZ						14.25	15.75		250M
1N4110	S		1N4099	DZ						15.2	16.8		250M
1N4111	S		1N4099	DZ						16.15	17.85		250M
1N4112	S		1N4099	DZ						17.1	18.9		250M
1N4113	S		1N4099	DZ						18.05	19.95		250M
1N4114	S		1N4099	DZ						19	21		250M
1N4115	S		1N4099	DZ						20.9	23.1		250M
1N4116	S		1N4099	DZ						22.8	25.2		250M
1N4117	S		1N4099	DZ						23.75	26.25		250M
1N4118	S		1N4099	DZ						25.65	28.35		250M
1N4119	S		1N4099	DZ						26.6	29.4		250M
1N4120	S		1N4099	DZ						28.5	31.5		250M
1N4121	S		1N4099	DZ						31.35	34.65		250M
1N4122	S		1N4099	DZ						34.2	37.8		250M
1N4123	S		1N4099	DZ						37.05	40.95		250M
1N4124	S		1N4099	DZ						40.85	45.15		250M
1N4125	S		1N4099	DZ						44.65	49.35		250M
1N4126	S		1N4099	DZ						48.45	53.55		250M
1N4127	S		1N4099	DZ						53.2	58.8		250M
1N4128	S		1N4099	DZ						57	63		250M
1N4129	S		1N4099	DZ						58.9	65.1		250M
1N4130	S		1N4099	DZ						64.6	71.4		250M
1N4131	S		1N4099	DZ						71.25	78.75		250M
1N4132	S		1N4099	DZ						77.9	86.1		250M
1N4133	S		1N4099	DZ						82.65	91.35		250M
1N4134	S		1N4099	DZ						86.45	95.55		250M
1N4135	S		1N4099	DZ						95	105		250M
1N4136	S			R*	200	1.6	70	16	750				
1N4137	S			R*	400	1.6	70	12	750				
1N4138	S			R*	600	1.6	70	8.0	750				
1N4139	S	1N4719	1N4719	R*	50	1.0	3.0	0.1	300				
1N4140	S	1N4720	1N4719	R*	100	1.0	3.0	0.1	300				
1N4141	S	1N4721	1N4719	R*	200	1.0	3.0	0.1	300				
1N4142	S	1N4722	1N4719	R*	400	1.0	3.0	0.1	300				
1N4143	S	1N4723	1N4719	R*	600	1.0	3.0	0.1	300				
1N4144	S	1N4724	1N4719	R*	800	1.0	3.0	0.1	300				
1N4145	S	1N4725	1N4719	R*	1000	1.0	3.0	0.1	300				
1N4146	S			R*	1200	1.0	3.0	0.1	300				
1N4147	S			DS	30	1.0	30M	0.1*	10				
1N4148	S			DS	75	1.0	10M	25N	4.0				
1N4149	S			DS	75	1.0	10M	25N	4.0				
1N4150	S			DS	50	1.0	200M	0.1*	6.0				
1N4151	S			DS	50	1.0	50M	50N	2.0				
1N4152	S			DS	30	0.88	20M	50N	2.0				
1N4153	S			DS	50	0.88	20M	50N	2.0				
1N4154	S			DS	25	1.0	30M	0.1*	4.0				
1N4155	S			DS	400	1.0	100M	0.1*	10				
1N4156	S			DS	20	1.84	0.1A	50N					
1N4157	S			DS	20	2.66	0.1A	50N					
1N4158	S	1N4736	1N4728	DZ							6.8*	20	1.0W
1N4158A	S	1N4736	1N4728	DZ							6.8*	10	1.0W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4158B	S	1N4736A	1N4728	DZ							6.8*	5.0	1.0W
1N4159	S	1N4737	1N4728	DZ							7.5*	20	1.0W
1N4159A	S	1N4737	1N4728	DZ							7.5*	10	1.0W
1N4159B	S	1N4737A	1N4728	DZ							7.5*	5.0	1.0W
1N4160	S	1N4738	1N4728	DZ							8.2*	20	1.0W
1N4160A	S	1N4738	1N4728	DZ							8.2*	10	1.0W
1N4160B	S	1N4738A	1N4728	DZ							8.2*	5.0	1.0W
1N4161	S	1N4739	1N4728	DZ							9.1*	20	1.0W
1N4161A	S	1N4739	1N4728	DZ							9.1*	10	1.0W
1N4161B	S	1N4739A	1N4728	DZ							9.1*	5.0	1.0W
1N4162	S	1N4740	1N4728	DZ							10*	20	1.0W
1N4162A	S	1N4740	1N4728	DZ							10*	10	1.0W
1N4162B	S	1N4740A	1N4728	DZ							10*	5.0	1.0W
1N4163	S	1N4741	1N4728	DZ							11*	20	1.0W
1N4163A	S	1N4741	1N4728	DZ							11*	10	1.0W
1N4163B	S	1N4741A	1N4728	DZ							11*	5.0	1.0W
1N4164	S	1N4742	1N4728	DZ							12*	20	1.0W
1N4164A	S	1N4742	1N4728	DZ							12*	10	1.0W
1N4164B	S	1N4742A	1N4728	DZ							12*	5.0	1.0W
1N4165	S	1N4743	1N4728	DZ							13*	20	1.0W
1N4165A	S	1N4743	1N4728	DZ							13*	10	1.0W
1N4165B	S	1N4743A	1N4728	DZ							13*	5.0	1.0W
1N4166	S	1N4744	1N4728	DZ							15*	20	1.0W
1N4166A	S	1N4744	1N4728	DZ							15*	10	1.0W
1N4166B	S	1N4744A	1N4728	DZ							15*	5.0	1.0W
1N4167	S	1N4745	1N4728	DZ							16*	20	1.0W
1N4167A	S	1N4745	1N4728	DZ							16*	10	1.0W
1N4167B	S	1N4745A	1N4728	DZ							16*	5.0	1.0W
1N4168	S	1N4746	1N4728	DZ							18*	20	1.0W
1N4168A	S	1N4746	1N4728	DZ							18*	10	1.0W
1N4168B	S	1N4746A	1N4728	DZ							18*	5.0	1.0W
1N4169	S	1N4747	1N4728	DZ							20*	20	1.0W
1N4169A	S	1N4747	1N4728	DZ							20*	10	1.0W
1N4169B	S	1N4747A	1N4728	DZ							20*	5.0	1.0W
1N4170	S	1N4748	1N4728	DZ							22*	20	1.0W
1N4170A	S	1N4748	1N4728	DZ							22*	10	1.0W
1N4170B	S	1N4748A	1N4728	DZ							22*	5.0	1.0W
1N4171	S	1N4749	1N4728	DZ							24*	20	1.0W
1N4171A	S	1N4749	1N4728	DZ							24*	10	1.0W
1N4171B	S	1N4749A	1N4728	DZ							24*	5.0	1.0W
1N4172	S	1N4750	1N4728	DZ							27*	20	1.0W
1N4172A	S	1N4750	1N4728	DZ							27*	10	1.0W
1N4172B	S	1N4750A	1N4728	DZ							27*	5.0	1.0W
1N4173	S	1N4751	1N4728	DZ							30*	20	1.0W
1N4173A	S	1N4751	1N4728	DZ							30*	10	1.0W
1N4173B	S	1N4751A	1N4728	DZ							30*	5.0	1.0W
1N4174	S	1N4752	1N4728	DZ							33*	20	1.0W
1N4174A	S	1N4752	1N4728	DZ							33*	10	1.0W
1N4174B	S	1N4752A	1N4728	DZ							33*	5.0	1.0W
1N4175	S	1N4753	1N4728	DZ							36*	20	1.0W
1N4175A	S	1N4753	1N4728	DZ							36*	10	1.0W
1N4175B	S	1N4753A	1N4728	DZ							36*	5.0	1.0W
1N4176	S	1N4754	1N4728	DZ							39*	20	1.0W
1N4176A	S	1N4754	1N4728	DZ							39*	10	1.0W
1N4176B	S	1N4754A	1N4728	DZ							39*	5.0	1.0W
1N4177	S	1N4755	1N4728	DZ							43*	20	1.0W
1N4177A	S	1N4755	1N4728	DZ							43*	10	1.0W
1N4177B	S	1N4755A	1N4728	DZ							43*	5.0	1.0W
1N4178	S	1N4756	1N4728	DZ							47*	20	1.0W
1N4178A	S	1N4756	1N4728	DZ							47*	10	1.0W
1N4178B	S	1N4756A	1N4728	DZ							47*	5.0	1.0W
1N4179	S	1N4757	1N4728	DZ							51*	20	1.0W
1N4179A	S	1N4757	1N4728	DZ							51*	10	1.0W
1N4179B	S	1N4757A	1N4728	DZ							51*	5.0	1.0W
1N4180	S	1N4758	1N4728	DZ							56*	20	1.0W
1N4180A	S	1N4758	1N4728	DZ							56*	10	1.0W
1N4180B	S	1N4758A	1N4728	DZ							56*	5.0	1.0W
1N4181	S	1N4759	1N4728	DZ							62*	20	1.0W
1N4181A	S	1N4759	1N4728	DZ							62*	10	1.0W
1N4181B	S	1N4759A	1N4728	DZ							62*	5.0	1.0W
1N4182	S	1N4760	1N4728	DZ							68*	20	1.0W
1N4182A	S	1N4760	1N4728	DZ							68*	10	1.0W
1N4182B	S	1N4760A	1N4728	DZ							68*	5.0	1.0W
1N4183	S	1N4761	1N4728	DZ							75*	20	1.0W
1N4183A	S	1N4761	1N4728	DZ							75*	10	1.0W
1N4183B	S	1N4761A	1N4728	DZ							75*	5.0	1.0W
1N4184	S	1N4762	1N4728	DZ							82*	20	1.0W
1N4184A	S	1N4762	1N4728	DZ							82*	10	1.0W
1N4184B	S	1N4762A	1N4728	DZ							82*	5.0	1.0W
1N4185	S	1N4763	1N4728	DZ							91*	20	1.0W
1N4185A	S	1N4763	1N4728	DZ							91*	10	1.0W
1N4185B	S	1N4763A	1N4728	DZ							91*	5.0	1.0W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4186	S	1N4764	1N4728	DZ							100*	20	1.0W
1N4186A	S	1N4764	1N4728	DZ							100*	10	1.0W
1N4186B	S	1N4764A	1N4728	DZ							100*	5.0	1.0W
1N4187	S	1M110ZS10	1N4728	DZ							110*	20	1.0W
1N4187A	S	1M110ZS10	1N4728	DZ							110*	10	1.0W
1N4187B	S	1M110ZS5	1N4728	DZ							110*	5.0	1.0W
1N4188	S	1M120ZS10	1N4728	DZ							120*	20	1.0W
1N4188A	S	1M120ZS10	1N4728	DZ							120*	10	1.0W
1N4188B	S	1M120ZS5	1N4728	DZ							120*	5.0	1.0W
1N4189	S	1M130ZS10	1N4728	DZ							130*	20	1.0W
1N4189A	S	1M130ZS10	1N4728	DZ							130*	10	1.0W
1N4189B	S	1M130ZS5	1N4728	DZ							130*	5.0	1.0W
1N4190	S	1M150ZS10	1N4728	DZ							150*	20	1.0W
1N4190A	S	1M150ZS10	1N4728	DZ							150*	10	1.0W
1N4190B	S	1M150ZS5	1N4728	DZ							150*	5.0	1.0W
1N4191	S	1M160ZS10	1N4728	DZ							160*	20	1.0W
1N4191A	S	1M160ZS10	1N4728	DZ							160*	10	1.0W
1N4191B	S	1M160ZS5	1N4728	DZ							160*	5.0	1.0W
1N4192	S	1M180ZS10	1N4728	DZ							180*	20	1.0W
1N4192A	S	1M180ZS10	1N4728	DZ							180*	10	1.0W
1N4192B	S	1M180ZS5	1N4728	DZ							180*	5.0	1.0W
1N4193	S	1M200ZS10	1N4728	DZ							200*	20	1.0W
1N4193A	S	1M200ZS10	1N4728	DZ							200*	10	1.0W
1N4193B	S	1M200ZS5	1N4728	DZ							200*	5.0	1.0W
1N4194	S	1N2970	1N2970	DZ							6.8*	20	10W
1N4194A	S	1N2970A	1N2970	DZ							6.8*	10	10W
1N4194B	S	1N2970B	1N2970	DZ							6.8*	5.0	10W
1N4195	S	1N2971	1N2970	DZ							7.5*	20	10W
1N4195A	S	1N2971A	1N2970	DZ							7.5*	10	10W
1N4195B	S	1N2971B	1N2970	DZ							7.5*	5.0	10W
1N4196	S	1N2972	1N2970	DZ							8.2*	20	10W
1N4196A	S	1N2972A	1N2970	DZ							8.2*	10	10W
1N4196B	S	1N2972B	1N2970	DZ							8.2*	5.0	10W
1N4197	S	1N2973	1N2970	DZ							9.1*	20	10W
1N4197A	S	1N2973A	1N2970	DZ							9.1*	10	10W
1N4197B	S	1N2973B	1N2970	DZ							9.1*	5.0	10W
1N4198	S	1N2974	1N2970	DZ							10*	20	10W
1N4198A	S	1N2974A	1N2970	DZ							10*	10	10W
1N4198B	S	1N2974B	1N2970	DZ							10*	5.0	10W
1N4199	S	1N2975	1N2970	DZ							11*	20	10W
1N4199A	S	1N2975A	1N2970	DZ							11*	10	10W
1N4199B	S	1N2975B	1N2970	DZ							11*	5.0	10W
1N4200	S	1N2976	1N2970	DZ							12*	20	10W
1N4200A	S	1N2976A	1N2970	DZ							12*	10	10W
1N4200B	S	1N2976B	1N2970	DZ							12*	5.0	10W
1N4201	S	1N2977	1N2970	DZ							13*	20	10W
1N4201A	S	1N2977A	1N2970	DZ							13*	10	10W
1N4201B	S	1N2977B	1N2970	DZ							13*	5.0	10W
1N4202	S	1N2978	1N2970	DZ							14*	20	10W
1N4202A	S	1N2978A	1N2970	DZ							14*	10	10W
1N4202B	S	1N2978B	1N2970	DZ							14*	5.0	10W
1N4203	S	1N2979	1N2970	DZ							15*	20	10W
1N4203A	S	1N2979A	1N2970	DZ							15*	10	10W
1N4203B	S	1N2979B	1N2970	DZ							15*	5.0	10W
1N4204	S	1N2980	1N2970	DZ							16*	20	10W
1N4204A	S	1N2980A	1N2970	DZ							16*	10	10W
1N4204B	S	1N2980B	1N2970	DZ							16*	5.0	10W
1N4205	S	1N2981	1N2970	DZ							17*	20	10W
1N4205A	S	1N2981A	1N2970	DZ							17*	10	10W
1N4205B	S	1N2981B	1N2970	DZ							17*	5.0	10W
1N4206	S	1N2982	1N2970	DZ							18*	20	10W
1N4206A	S	1N2982A	1N2970	DZ							18*	10	10W
1N4206B	S	1N2982B	1N2970	DZ							18*	5.0	10W
1N4207	S	1N2983	1N2970	DZ							19*	20	10W
1N4207A	S	1N2983A	1N2970	DZ							19*	10	10W
1N4207B	S	1N2983B	1N2970	DZ							19*	5.0	10W
1N4208	S	1N2984	1N2970	DZ							20*	20	10W
1N4208A	S	1N2984A	1N2970	DZ							20*	10	10W
1N4208B	S	1N2984B	1N2970	DZ							20*	5.0	10W
1N4209	S	1N2985	1N2970	DZ							22*	20	10W
1N4209A	S	1N2985A	1N2970	DZ							22*	10	10W
1N4209B	S	1N2985B	1N2970	DZ							22*	5.0	10W
1N4210	S	1N2986	1N2970	DZ							24*	20	10W
1N4210A	S	1N2986A	1N2970	DZ							24*	10	10W
1N4210B	S	1N2986B	1N2970	DZ							24*	5.0	10W
1N4211	S	1N2987	1N2970	DZ							25*	20	10W
1N4211A	S	1N2987A	1N2970	DZ							25*	10	10W
1N4211B	S	1N2987B	1N2970	DZ							25*	5.0	10W
1N4212	S	1N2988	1N2970	DZ							27*	20	10W
1N4212A	S	1N2988A	1N2970	DZ							27*	10	10W
1N4212B	S	1N2988B	1N2970	DZ							27*	5.0	10W
1N4213	S	1N2989	1N2970	DZ							30*	20	10W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4213A	S	1N2989A	1N2970	DZ							30*	10	10W
1N4213B	S	1N2989B	1N2970	DZ							30*	5.0	10W
1N4214	S	1N2990	1N2970	DZ							33*	20	10W
1N4214A	S	1N2990A	1N2970	DZ							33*	10	10W
1N4214B	S	1N2990B	1N2970	DZ							33*	5.0	10W
1N4215	S	1N2991	1N2970	DZ							36*	20	10W
1N4215A	S	1N2991A	1N2970	DZ							36*	10	10W
1N4215B	S	1N2991B	1N2970	DZ							36*	5.0	10W
1N4216	S	1N2992	1N2970	DZ							39*	20	10W
1N4216A	S	1N2992A	1N2970	DZ							39*	10	10W
1N4216B	S	1N2992B	1N2970	DZ							39*	5.0	10W
1N4217	S	1N2993	1N2970	DZ							43*	20	10W
1N4217A	S	1N2993A	1N2970	DZ							43*	10	10W
1N4217B	S	1N2993B	1N2970	DZ							43*	5.0	10W
1N4218	S	1N2994	1N2970	DZ							45*	20	10W
1N4218A	S	1N2994A	1N2970	DZ							45*	10	10W
1N4218B	S	1N2994B	1N2970	DZ							45*	5.0	10W
1N4219	S	1N2995	1N2970	DZ							47*	20	10W
1N4219A	S	1N2995A	1N2970	DZ							47*	10	10W
1N4219B	S	1N2995B	1N2970	DZ							47*	5.0	10W
1N4220	S	1N2996	1N2970	DZ							50*	20	10W
1N4220A	S	1N2996A	1N2970	DZ							50*	10	10W
1N4220B	S	1N2996B	1N2970	DZ							50*	5.0	10W
1N4221	S	1N2997	1N2970	DZ							51*	20	10W
1N4221A	S	1N2997A	1N2970	DZ							51*	10	10W
1N4221B	S	1N2997B	1N2970	DZ							51*	5.0	10W
1N4222	S	1N2998	1N2970	DZ							52*	20	10W
1N4222A	S	1N2998A	1N2970	DZ							52*	10	10W
1N4222B	S	1N2998B	1N2970	DZ							52*	5.0	10W
1N4223	S	1N2999	1N2970	DZ							56*	20	10W
1N4223A	S	1N2999A	1N2970	DZ							56*	10	10W
1N4223B	S	1N2999B	1N2970	DZ							56*	5.0	10W
1N4224	S	1N3000	1N2970	DZ							62*	20	10W
1N4224A	S	1N3000A	1N2970	DZ							62*	10	10W
1N4224B	S	1N3000B	1N2970	DZ							62*	5.0	10W
1N4225	S	1N3001	1N2970	DZ							68*	20	10W
1N4225A	S	1N3001A	1N2970	DZ							68*	10	10W
1N4225B	S	1N3001B	1N2970	DZ							68*	5.0	10W
1N4226	S	1N3002	1N2970	DZ							75*	20	10W
1N4226A	S	1N3002A	1N2970	DZ							75*	10	10W
1N4226B	S	1N3002B	1N2970	DZ							75*	5.0	10W
1N4227	S	1N3003	1N2970	DZ							82*	20	10W
1N4227A	S	1N3003A	1N2970	DZ							82*	10	10W
1N4227B	S	1N3003B	1N2970	DZ							82*	5.0	10W
1N4228	S	1N3004	1N2970	DZ							91*	20	10W
1N4228A	S	1N3004A	1N2970	DZ							91*	10	10W
1N4228B	S	1N3004B	1N2970	DZ							91*	5.0	10W
1N4229	S	1N3005	1N2970	DZ							100*	20	10W
1N4229A	S	1N3005A	1N2970	DZ							100*	10	10W
1N4229B	S	1N3005B	1N2970	DZ							100*	5.0	10W
1N4230	S	1N3006	1N2970	DZ							105*	20	10W
1N4230A	S	1N3006A	1N2970	DZ							105*	10	10W
1N4230B	S	1N3006B	1N2970	DZ							105*	5.0	10W
1N4231	S	1N3007	1N2970	DZ							110*	20	10W
1N4231A	S	1N3007A	1N2970	DZ							110*	10	10W
1N4231B	S	1N3007B	1N2970	DZ							110*	5.0	10W
1N4232	S	1N3008	1N2970	DZ							120*	20	10W
1N4232A	S	1N3008A	1N2970	DZ							120*	10	10W
1N4232B	S	1N3008B	1N2970	DZ							120*	5.0	10W
1N4233	S	1N3009	1N2970	DZ							130*	20	10W
1N4233A	S	1N3009A	1N2970	DZ							130*	10	10W
1N4233B	S	1N3009B	1N2970	DZ							130*	5.0	10W
1N4234	S	1N3010	1N2970	DZ							140*	20	10W
1N4234A	S	1N3010A	1N2970	DZ							140*	10	10W
1N4234B	S	1N3010B	1N2970	DZ							140*	5.0	10W
1N4235	S	1N3011	1N2970	DZ							150*	20	10W
1N4235A	S	1N3011A	1N2970	DZ							150*	10	10W
1N4235B	S	1N3011B	1N2970	DZ							150*	5.0	10W
1N4236	S	1N3012	1N2970	DZ							160*	20	10W
1N4236A	S	1N3012A	1N2970	DZ							160*	10	10W
1N4236B	S	1N3012B	1N2970	DZ							160*	5.0	10W
1N4237	S	1N3013	1N2970	DZ							175*	20	10W
1N4237A	S	1N3013A	1N2970	DZ							175*	10	10W
1N4237B	S	1N3013B	1N2970	DZ							175*	5.0	10W
1N4238	S	1N3014	1N2970	DZ							180*	20	10W
1N4238A	S	1N3014A	1N2970	DZ							180*	10	10W
1N4238B	S	1N3014B	1N2970	DZ							180*	5.0	10W
1N4239	S	1N3015	1N2970	DZ							200*	20	10W
1N4239A	S	1N3015A	1N2970	DZ							200*	10	10W
1N4239B	S	1N3015B	1N2970	DZ							200*	5.0	10W
1N4240	S	10M5.0AZ2		DZ						4.9	5.1	2.0	10W
1N4241	S	10M6.0AZ1		DZ						5.9	6.1	2.0	10W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4242	S			DS	40	1.0	20M	0.1N	2.0				
1N4243	S			DS	40	1.0	10M	0.1N	2.0				
1N4244	S			DS	10	1.0	20M	0.1*	0.75				
1N4245	S	1N4003	1N4001	R*	200	1.64	1.0	0.05	25				
1N4246	S	1N4004	1N4001	R*	400	1.64	1.0	0.05	25				
1N4247	S	1N4005	1N4001	R*	600	1.64	1.0	0.05	25				
1N4248	S	1N4006	1N4001	R*	800	1.64	1.0	0.05	25				
1N4249	S	1N4007	1N4001	R*	1000	1.64	1.0	0.05	25				
1N4250	S	1N4006	1N4001	R*	800		0.5	0.05	10				
1N4251	S	1N4007	1N4001	R*	1000		0.5	0.05	10				
1N4252	S			R*	1200		0.5	0.05	10				
1N4253	S			R*	1500		0.5	0.05	10				
1N4254	S	MR991A	MR990A	R*	1500	4.8	0.25	0.05	6.25				
1N4255	S	MR992A	MR990A	R*	2000	4.8	0.25	0.05	6.25				
1N4256	S	MR993A	MR990A	R*	2500	4.8	0.25	0.05	6.25				
1N4257	S	MR994A	MR990A	R*	3000	4.8	0.25	0.05	6.25				
1N4258	S	1N2970	1N2970	DZ							6.8*	20	10W
1N4258A	S	1N2970A	1N2970	DZ							6.8*	10	10W
1N4258B	S	1N2970B	1N2970	DZ							6.8*	5.0	10W
1N4259	S	1N2971	1N2970	DZ							7.5*	20	10W
1N4259A	S	1N2971A	1N2970	DZ							7.5*	10	10W
1N4259B	S	1N2971B	1N2970	DZ							7.5*	5.0	10W
1N4260	S	1N2972	1N2970	DZ							8.2*	20	10W
1N4260A	S	1N2972A	1N2970	DZ							8.2*	10	10W
1N4260B	S	1N2972B	1N2970	DZ							8.2*	5.0	10W
1N4261	S	1N2973	1N2970	DZ							9.1*	20	10W
1N4261A	S	1N2973A	1N2970	DZ							9.1*	10	10W
1N4261B	S	1N2973B	1N2970	DZ							9.1*	5.0	10W
1N4262	S	1N2974	1N2970	DZ							10*	20	10W
1N4262A	S	1N2974A	1N2970	DZ							10*	10	10W
1N4262B	S	1N2974B	1N2970	DZ							10*	5.0	10W
1N4263	S	1N2975	1N2970	DZ							11*	20	10W
1N4263A	S	1N2975A	1N2970	DZ							11*	10	10W
1N4263B	S	1N2975B	1N2970	DZ							11*	5.0	10W
1N4264	S	1N2976	1N2970	DZ							12*	20	10W
1N4264A	S	1N2976A	1N2970	DZ							12*	10	10W
1N4264B	S	1N2976B	1N2970	DZ							12*	5.0	10W
1N4265	S	1N2977	1N2970	DZ							13*	20	10W
1N4265A	S	1N2977A	1N2970	DZ							13*	10	10W
1N4265B	S	1N2977B	1N2970	DZ							13*	5.0	10W
1N4266	S	1N2979	1N2970	DZ							15*	20	10W
1N4266A	S	1N2979A	1N2970	DZ							15*	10	10W
1N4266B	S	1N2979B	1N2970	DZ							15*	5.0	10W
1N4267	S	1N2980	1N2970	DZ							16*	20	10W
1N4267A	S	1N2980A	1N2970	DZ							16*	10	10W
1N4267B	S	1N2980B	1N2970	DZ							16*	5.0	10W
1N4268	S	1N2982	1N2970	DZ							18*	20	10W
1N4268A	S	1N2982A	1N2970	DZ							18*	10	10W
1N4268B	S	1N2982B	1N2970	DZ							18*	5.0	10W
1N4269	S	1N2984	1N2970	DZ							20*	20	10W
1N4269A	S	1N2984A	1N2970	DZ							20*	10	10W
1N4269B	S	1N2984B	1N2970	DZ							20*	5.0	10W
1N4270	S	1N2985	1N2979	DZ							22*	20	10W
1N4270A	S	1N2985A	1N2970	DZ							22*	10	10W
1N4270B	S	1N2985B	1N2970	DZ							22*	5.0	10W
1N4271	S	1N2986	1N2970	DZ							24*	20	10W
1N4271A	S	1N2986A	1N2970	DZ							24*	10	10W
1N4271B	S	1N2986B	1N2970	DZ							24*	5.0	10W
1N4272	S	1N2988	1N2970	DZ							27*	20	10W
1N4272A	S	1N2988A	1N2970	DZ							27*	10	10W
1N4272B	S	1N2988B	1N2970	DZ							27*	5.0	10W
1N4273	S	1N2989	1N2970	DZ							30*	20	10W
1N4273A	S	1N2989A	1N2970	DZ							30*	10	10W
1N4273B	S	1N2989B	1N2970	DZ							30*	5.0	10W
1N4274	S	1N2990	1N2970	DZ							33*	20	10W
1N4274A	S	1N2990A	1N2970	DZ							33*	10	10W
1N4274B	S	1N2990B	1N2970	DZ							33*	5.0	10W
1N4275	S	1N2991	1N2970	DZ							36*	20	10W
1N4275A	S	1N2991A	1N2970	DZ							36*	10	10W
1N4275B	S	1N2991B	1N2970	DZ							36*	5.0	10W
1N4276	S	1N2992	1N2970	DZ							39*	20	10W
1N4276A	S	1N2992A	1N2970	DZ							39*	10	10W
1N4276B	S	1N2992B	1N2970	DZ							39*	5.0	10W
1N4277	S	1N2993	1N2970	DZ							43*	20	10W
1N4277A	S	1N2993A	1N2970	DZ							43*	10	10W
1N4277B	S	1N2993B	1N2970	DZ							43*	5.0	10W
1N4278	S	1N2995	1N2970	DZ							47*	20	10W
1N4278A	S	1N2995A	1N2970	DZ							47*	10	10W
1N4278B	S	1N2995B	1N2970	DZ							47*	5.0	10W
1N4279	S	1N2997	1N2970	DZ							51*	20	10W
1N4279A	S	1N2997A	1N2970	DZ							51*	10	10W
1N4279B	S	1N2997B	1N2970	DZ							51*	5.0	10W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4280	S	1N2999	1N2970	DZ							56*	20	10W
1N4280A	S	1N2999A	1N2970	DZ							56*	10	10W
1N4280B	S	1N2999B	1N2970	DZ							56*	5.0	10W
1N4281	S	1N3000	1N2970	DZ							62*	20	10W
1N4281A	S	1N3000A	1N2970	DZ							62*	10	10W
1N4281B	S	1N3000B	1N2970	DZ							62*	5.0	10W
1N4282	S	1N3001	1N2970	DZ							68*	20	10W
1N4282A	S	1N3001A	1N2970	DZ							68*	10	10W
1N4282B	S	1N3001B	1N2970	DZ							68*	5.0	10W
1N4283	S	1N3002	1N2970	DZ							75*	20	10W
1N4283A	S	1N3002A	1N2970	DZ							75*	10	10W
1N4283B	S	1N3002B	1N2970	DZ							75*	5.0	10W
1N4284	S	1N3003	1N2970	DZ							82*	20	10W
1N4284A	S	1N3003A	1N2970	DZ							82*	10	10W
1N4284B	S	1N3003B	1N2970	DZ							82*	5.0	10W
1N4285	S	1N3004	1N2970	DZ							91*	20	10W
1N4285A	S	1N3004A	1N2970	DZ							91*	10	10W
1N4285B	S	1N3004B	1N2970	DZ							91*	5.0	10W
1N4286	S	1N3005	1N2970	DZ							100*	20	10W
1N4286A	S	1N3005A	1N2970	DZ							100*	10	10W
1N4286B	S	1N3005B	1N2970	DZ							100*	5.0	10W
1N4287	S	1N3007	1N2970	DZ							110*	20	10W
1N4287A	S	1N3007A	1N2970	DZ							110*	10	10W
1N4287B	S	1N3007B	1N2970	DZ							110*	5.0	10W
1N4288	S	1N3008	1N2970	DZ							120*	20	10W
1N4288A	S	1N3008A	1N2970	DZ							120*	10	10W
1N4288B	S	1N3008B	1N2970	DZ							120*	5.0	10W
1N4289	S	1N3009	1N2970	DZ							130*	20	10W
1N4289A	S	1N3009A	1N2970	DZ							130*	10	10W
1N4289B	S	1N3009B	1N2970	DZ							130*	5.0	10W
1N4290	S	1N3011	1N2970	DZ							150*	20	10W
1N4290A	S	1N3011A	1N2970	DZ							150*	10	10W
1N4290B	S	1N3011B	1N2970	DZ							150*	5.0	10W
1N4291	S	1N3012	1N2970	DZ							160*	20	10W
1N4291A	S	1N3012A	1N2970	DZ							160*	10	10W
1N4291B	S	1N3012B	1N2970	DZ							160*	5.0	10W
1N4292	S	1N3014	1N2970	DZ							180*	20	10W
1N4292A	S	1N3014A	1N2970	DZ							180*	10	10W
1N4292B	S	1N3014B	1N2970	DZ							180*	5.0	10W
1N4293	S	1N3015	1N2970	DZ							200*	20	10W
1N4293A	S	1N3015A	1N2970	DZ							200*	10	10W
1N4293B	S	1N3015B	1N2970	DZ							200*	5.0	10W
1N4294	S	Microwave S-band Mixer											
1N4295	S			DR						0.012	10	-55	150
1N4295A	S			DR						0.012	10	-55	150
1N4296	S			DR						0.0005	9.3*	-55	150
1N4296A	S			DR						0.0005	9.3*	-55	150
1N4297	S			DR						0.01	8.8	0	75
1N4297A	S			DR						0.01	8.8	-55	100
1N4297B	S			DR						0.01	8.8	-55	150
1N4298	S			DR						0.005	8.8	0	75
1N4298A	S			DR						0.005	8.8	-55	100
1N4298B	S			DR						0.005	8.8	-55	150
1N4299	S			DR						0.01	11.3	0	75
1N4299A	S			DR						0.01	11.3	-55	100
1N4299B	S			DR						0.01	11.3	-55	150
1N4300	S			DR						0.005	11.3	0	75
1N4300A	S			DR						0.005	11.3	-55	100
1N4300B	S			DR						0.005	11.3	-55	150
1N4301	S			DR						0.01	8.8	0	75
1N4301A	S			DR						0.01	8.8	-55	100
1N4301B	S			DR						0.01	8.8	-55	150
1N4302	S			DR						0.005	8.8	0	75
1N4302A	S			DR						0.005	8.8	-55	100
1N4302B	S			DR						0.005	8.8	-55	150
1N4303	S			DR						0.01	11.3	0	75
1N4303A	S			DR						0.01	11.3	-55	100
1N4303B	S			DR						0.01	11.3	-55	150
1N4304	S			DR						0.005	11.3	0	75
1N4304A	S			DR						0.005	11.3	-55	100
1N4304B	S			DR						0.005	11.3	-55	150
1N4305				DS	75	0.575	0.25M	0.1*	2.0				
1N4306	S			DS	50	1.0	50M	50N	2.0				
1N4307	S			DS	50	1.0	50M	50N	2.0				
1N4308	S			DS	80	1.0	200M	0.1*	2.0				
1N4309	S			DS	40	1.0	400M	0.1*	2.0				
1N4310	S			DS	60	1.0	400M	0.1*	2.0				
1N4311	S			DS	80	1.0	300M	0.1*	2.0				
1N4312	S			DS	120	1.0	200M	0.1*	2.0				
1N4313	S			DS	80	1.0	100M	0.1*	4.0				
1N4314	S			DS	80	1.0	200M	0.1*	2.0				
1N4315	S			DS	40	1.0	400M	0.1*	2.0				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	ZENER DIODES V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (μs)	REFERENCE DIODES TC %/°C	V_Z	T (min) °C	T (max) °C
1N4316	S			DS	60	1.0	400M	0.1*	2.0				
1N4317	S			DS	80	1.0	300M	0.1*	2.0				
1N4318	S			DS	120	1.0	200M	0.1*	2.0				
1N4319	S			DS	80	1.0	100M	0.1*	4.0				
1N4320	S			DS	640			1.0*					
1N4321	S	1M50ZS10	1N4728	DZ							50*	10	3.0W
1N4322	S			DS	50	1.0	0.2A	0.1*	6.0				
1N4323	S	1N4736	1N4728	DZ							6.8*	20	1.0W
1N4323A	S	1N4736	1N4728	DZ							6.8*	10	1.0W
1N4323B	S	1N4736A	1N4728	DZ							6.8*	5.0	1.0W
1N4324	S	1N4737	1N4728	DZ							7.5*	20	1.0W
1N4324A	S	1N4737	1N4728	DZ							7.5*	10	1.0W
1N4324B	S	1N4737A	1N4728	DZ							7.5*	5.0	1.0W
1N4325	S	1N4738	1N4728	DZ							8.2*	20	1.0W
1N4325A	S	1N4738	1N4728	DZ							8.2*	10	1.0W
1N4325B	S	1N4738A	1N4728	DZ							8.2*	5.0	1.0W
1N4326	S	1N4739	1N4728	DZ							9.1*	20	1.0W
1N4326A	S	1N4739	1N4728	DZ							9.1*	10	1.0W
1N4326B	S	1N4739A	1N4782	DZ							9.1*	5.0	1.0W
1N4327	S	1N4740	1N4728	DZ							10*	20	1.0W
1N4327A	S	1N4740	1N4728	DZ							10*	10	1.0W
1N4327B	S	1N4740A	1N4728	DZ							10*	5.0	1.0W
1N4328	S	1N4741	1N4728	DZ							11*	20	1.0W
1N4328A	S	1N4741	1N4728	DZ							11*	10	1.0W
1N4328B	S	1N4741A	1N4728	DZ							11*	5.0	1.0W
1N4329	S	1N4742	1N4728	DZ							12*	20	1.0W
1N4329A	S	1N4742	1N4728	DZ							12*	10	1.0W
1N4329B	S	1N4742A	1N4728	DZ							12*	5.0	1.0W
1N4330	S	1N4743	1N4728	DZ							13*	20	1.0W
1N4330A	S	1N4743	1N4728	DZ							13*	10	1.0W
1N4330B	S	1N4743A	1N4728	DZ							13*	5.0	1.0W
1N4331	S	1N4744	1N4728	DZ							15*	20	1.0W
1N4331A	S	1N4744	1N4728	DZ							15*	10	1.0W
1N4331B	S	1N4744A	1N4728	DZ							15*	5.0	1.0W
1N4332	S	1N4745	1N4728	DZ							16*	20	1.0W
1N4332A	S	1N4745	1N4728	DZ							16*	10	1.0W
1N4332B	S	1N4745A	1N4728	DZ							16*	5.0	1.0W
1N4333	S	1N4746	1N4728	DZ							18*	20	1.0W
1N4333A	S	1N4746	1N4728	DZ							18*	10	1.0W
1N4333B	S	1N4746A	1N4728	DZ							18*	5.0	1.0W
1N4334	S	1N4747	1N4728	DZ							20*	20	1.0W
1N4334A	S	1N4747	1N4728	DZ							20*	10	1.0W
1N4334B	S	1N4747A	1N4728	DZ							20*	5.0	1.0W
1N4335	S	1N4748	1N4728	DZ							22*	20	1.0W
1N4335A	S	1N4748	1N4728	DZ							22*	10	1.0W
1N4335B	S	1N4748A	1N4728	DZ							22*	5.0	1.0W
1N4336	S	1N4749	1N4728	DZ							24*	20	1.0W
1N4336A	S	1N4749	1N4728	DZ							24*	10	1.0W
1N4336B	S	1N4749A	1N4728	DZ							24*	5.0	1.0W
1N4337	S	1N4750	1N4728	DZ							27*	20	1.0W
1N4337A	S	1N4750	1N4728	DZ							27*	10	1.0W
1N4337B	S	1N4750A	1N4728	DZ							27*	5.0	1.0W
1N4338	S	1N4751	1N4728	DZ							30*	20	1.0W
1N4338A	S	1N4751	1N4728	DZ							30*	10	1.0W
1N4338B	S	1N4751A	1N4728	DZ							30*	5.0	1.0W
1N4339	S	1N4752	1N4728	DZ							33*	20	1.0W
1N4339A	S	1N4752	1N4728	DZ							33*	10	1.0W
1N4339B	S	1N4752A	1N4728	DZ							33*	5.0	1.0W
1N4340	S	1N4753	1N4728	DZ							36*	20	1.0W
1N4340A	S	1N4753	1N4728	DZ							36*	10	1.0W
1N4340B	S	1N4753A	1N4728	DZ							36*	5.0	1.0W
1N4341	S	1N4754	1N4728	DZ							39*	20	1.0W
1N4341A	S	1N4754	1N4728	DZ							39*	10	1.0W
1N4341B	S	1N4754A	1N4728	DZ							39*	5.0	1.0W
1N4342	S	1N4755	1N4728	DZ							43*	20	1.0W
1N4342A	S	1N4755	1N4728	DZ							43*	10	1.0W
1N4342B	S	1N4755A	1N4728	DZ							43*	5.0	1.0W
1N4343	S	1N4756	1N4728	DZ							47*	20	1.0W
1N4343A	S	1N4756	1N4728	DZ							47*	10	1.0W
1N4343B	S	1N4756A	1N4728	DZ							47*	5.0	1.0W
1N4344	S	1N4757	1N4728	DZ							51*	20	1.0W
1N4344A	S	1N4757	1N4728	DZ							51*	10	1.0W
1N4344B	S	1N4757A	1N4728	DZ							51*	5.0	1.0W
1N4345	S	1N4758	1N4728	DZ							56*	20	1.0W
1N4345A	S	1N4758	1N4728	DZ							56*	10	1.0W
1N4345B	S	1N4758A	1N4728	DZ							56*	5.0	1.0W
1N4346	S	1N4759	1N4728	DZ							62*	20	1.0W
1N4346A	S	1N4759	1N4728	DZ							62*	10	1.0W
1N4346B	S	1N4759A	1N4728	DZ							62*	5.0	1.0W
1N4347	S	1N4760	1N4728	DZ							68*	20	1.0W
1N4347A	S	1N4760	1N4728	DZ							68*	10	1.0W
1N4347B	S	1N4760A	1N4728	DZ							68*	5.0	1.0W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4348	S	1N4761	1N4728	DZ							75*	20	1.0W
1N4348A	S	1N4761	1N4728	DZ							75*	10	1.0W
1N4348B	S	1N4761A	1N4728	DZ							75*	5.0	1.0W
1N4349	S	1N4762	1N4728	DZ							82*	20	1.0W
1N4349A	S	1N4762	1N4728	DZ							82*	10	1.0W
1N4349B	S	1N4762A	1N4728	DZ							82*	5.0	1.0W
1N4350	S	1N4763	1N4728	DZ							91*	20	1.0W
1N4350A	S	1N4763	1N4728	DZ							91*	10	1.0W
1N4350B	S	1N4763A	1N4728	DZ							91*	5.0	1.0W
1N4351	S	1N4764	1N4728	DZ							100*	20	1.0W
1N4351A	S	1N4764	1N4728	DZ							100*	10	1.0W
1N4351B	S	1N4764A	1N4728	DZ							100*	5.0	1.0W
1N4352	S	1M110ZS10	1N4728	DZ							110*	20	1.0W
1N4352A	S	1M110ZS10	1N4728	DZ							110*	10	1.0W
1N4352B	S	1M110ZS5	1N4728	DZ							110*	5.0	1.0W
1N4353	S	1M120ZS10	1N4728	DZ							120*	20	1.0W
1N4353A	S	1M120ZS10	1N4728	DZ							120*	10	1.0W
1N4343B	S	1M120ZS5	1N4728	DZ							120*	5.0	1.0W
1N4354	S	1M130ZS10	1N4728	DZ							130*	20	1.0W
1N4354A	S	1M130ZS10	1N4728	DZ							130*	10	1.0W
1N4354B	S	1M130ZS5	1N4728	DZ							130*	5.0	1.0W
1N4355	S	1M150ZS10	1N4728	DZ							150*	20	1.0W
1N4355A	S	1M150ZS10	1N4728	DZ							150*	10	1.0W
1N4355B	S	1M150ZS5	1N4728	DZ							150*	5.0	1.0W
1N4356	S	1M160ZS10	1N4728	DZ							160*	20	1.0W
1N4356A	S	1M160ZS10	1N4728	DZ							160*	10	1.0W
1N4356B	S	1M160ZS5	1N4728	DZ							160*	5.0	1.0W
1N4357	S	1M180ZS10	1N4728	DZ							180*	20	1.0W
1N4357A	S	1M180ZS10	1N4728	DZ							180*	10	1.0W
1N4357B	S	1M180ZS5	1N4728	DZ							180*	5.0	1.0W
1N4358	S	1M200ZS10	1N4728	DZ							200*	20	1.0W
1N4358A	S	1M200ZS10	1N4728	DZ							200*	10	1.0W
1N4358B	S	1M200ZS5	1N4728	DZ							200*	5.0	1.0W
1N4359	S			DS	200								
1N4360	S	1N4370A*	1N746	DZ						2.28	2.52	5.0	0.25W
1N4361	S	1N4007	1N4001	R*	900	1.3	0.5	0.5	20				
1N4362	S			DS	100	0.9	0.1A	10N					
1N4363	S			DS	120	1.0	0.2A	0.1*	40				
1N4364	S	1N4002	1N4001	R*	100	1.5	0.75	0.1	20				
1N4365	S	1N4003	1N4001	R*	200	1.5	0.75	0.1	20				
1N4366	S	1N4004	1N4001	R*	300	1.5	0.75	0.1	20				
1N4367	S	1N4004	1N4001	R*	400	1.5	0.75	0.1	20				
1N4368	S	1N4005	1N4001	R*	500	1.5	0.75	0.1	20				
1N4369	S	1N4005	1N4001	R*	600	1.5	0.75	0.1	20				
1N4370	S		1N746	DZ							2.4*	10	0.4W
1N4370A	S		1N746	DZ							2.4*	5.0	0.4W
1N4371	S		1N746	DZ							2.7*	10	0.4W
1N4371A	S		1N746	DZ							2.7*	5.0	0.4W
1N4372	S		1N746	DZ							3.0*	10	0.4W
1N4372A	S		1N746	DZ							3.0*	5.0	0.4W
1N4373	S			DS	80	1.0	10M	5.0*	4.0				
1N4374	S	MR991A	MR990A	R*	1500	1.75	0.75	0.1	15				
1N4375	S			DS	50	1.0	20M	10N	6.0				
1N4376	S			DS	10	1.1	50M	0.1*	0.75				
1N4377	S			R*	25K	30	0.75	0.1	50				
1N4378	S	Photosensitive Device; $I_{(dark)}$ = 10 nA, Sensitivity = 9.0 mA @ V_{CE} = 5.0 V, H = 9.0 mW/cm^2											
1N4379	S	Microwave S-band Detector											
1N4380	S			DS	50	1.4	570M	50N	1.8				
1N4381	G			DS	25	0.35	2.0M	0.1M	0.1				
1N4382	S			DS	55	1.0	0.3A	0.1*	6.5				
1N4383	S	1N4003	1N4001	R*	200	1.3	1.0	0.275	50				
1N4384	S	1N4004	1N4001	R*	400	1.3	1.0	0.25	50				
1N4385	S	1N4005	1N4001	R*	600	1.3	1.0	0.225	50				
1N4386 thru 1N4388		Varactor Diodes, see Table on Page 92											
1N4389	S			DS	5.0	1.0	2.0M	0.1M					
1N4390	S			DS	20	1.0	5.0M	0.2*	0.5				
1N4391	S			DS	20	1.0	2.0M	0.2*	0.5				
1N4392	S			DS	15	1.0	2.0M	1.0*	0.5				
1N4393, A,B thru 1N4399, A,B		Tunnel Diodes, see Table on Page 98											
1N4400	S	1N4736	1N4728	DZ							6.8*	20	1.0W
1N4401	S	1N4737	1N4728	DZ							7.5*	20	1.0W
1N4402	S	1N4738	1N4728	DZ							8.2*	20	1.0W
1N4403	S	1N4739	1N4728	DZ							9.1*	20	1.0W
1N4404	S	1N4740	1N4728	DZ							10*	20	1.0W
1N4405	S	1N4741	1N4728	DZ							11*	20	1.0W

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4406	S	1N4742	1N4728	DZ							12*	20	1.0W
1N4407	S	1N4743	1N4728	DZ							13*	20	1.0W
1N4408	S	1N4744	1N4728	DZ							15*	20	1.0W
1N4409	S	1N4745	1N4728	DZ							16*	20	1.0W
1N4410	S	1N4746	1N4728	DZ							18*	20	1.0W
1N4411	S	1N4747	1N4728	DZ							20*	20	1.0W
1N4412	S	1N4748	1N4728	DZ							22*	20	1.0W
1N4413	S	1N4749	1N4728	DZ							24*	20	1.0W
1N4414	S	1N4750	1N4728	DZ							27*	20	1.0W
1N4415	S	1N4751	1N4728	DZ							30*	20	1.0W
1N4416	S	1N4752	1N4728	DZ							33*	20	1.0W
1N4417	S	1N4753	1N4728	DZ							36*	20	1.0W
1N4418	S	1N4754	1N4728	DZ							39*	20	1.0W
1N4419	S	1N4755	1N4728	DZ							43*	20	1.0W
1N4420	S	1N4756	1N4728	DZ							47*	20	1.0W
1N4421	S	1N4757	1N4728	DZ							51*	20	1.0W
1N4422	S	1N4758	1N4728	DZ							56*	20	1.0W
1N4423	S	1N4759	1N4728	DZ							62*	20	1.0W
1N4424	S	1N4760	1N4728	DZ							68*	20	1.0W
1N4425	S	1N4761	1N4728	DZ							75*	20	1.0W
1N4426	S	1N4762	1N4728	DZ							82*	20	1.0W
1N4427	S	1N4763	1N4728	DZ							91*	20	1.0W
1N4428	S	1N4764	1N4728	DZ							100*	20	1.0W
1N4429	S	1M110ZS10	1N4728	DZ							110*	20	1.0W
1N4430	S	1M120ZS10	1N4728	DZ							120*	20	1.0W
1N4431	S	1M130ZS10	1N4728	DZ							130*	20	1.0W
1N4432	S	1M150ZS10	1N4728	DZ							150*	20	1.0W
1N4433	S	1M160ZS10	1N4728	DZ							160*	20	1.0W
1N4434	S	1M180ZS10	1N4728	DZ							180*	20	1.0W
1N4435	S	1M200ZS10	1N4728	DZ							200*	20	1.0W
1N4436	S			R*	200	1.2	10	1.0	100				
1N4437	S			R*	400	1.2	10	1.0	100				
1N4438	S			R*	600	1.0	10	1.0	100				
1N4439	S			R*	800	1.2	10	1.0	100				
1N4440	S			R*	1000	1.2	10	1.0	100				
1N4441	S			R*	1500	4.0	0.025	0.001	3.0				
1N4442	S			DS	30	1.0	0.1A	1.0N	1.0				
1N4443	S			DS	50	1.0	0.1A	2.0N	0.6				
1N4444	S			DS	50	1.0	0.1A	50N	7.0				
1N4445	S			DS	100	1.0	0.1A	50N	4.0				
1N4446	S			DS	75	1.0	20M	25N	4.0				
1N4447	S			DS	75	1.0	20M	25N	4.0				
1N4448	S			DS	75	0.72	5.0M	25N	4.0				
1N4449	S			DS	75	0.73	5.0M	25N	4.0				
1N4450	S			DS	30	0.92	0.1A	50N	4.0				
1N4451	S			DS	30	0.875	0.1A	50N	10				
1N4452	S			DS	30	1.2	1.0A	50N	50				
1N4453	S			DS	20	0.92	0.1A	50N					
1N4454	S			DS	75	1.0	10M	0.1*	2.0				
1N4455	S			DS	50	0.7	5.0M	0.1*					
1N4456	S			DS	35	1.0	0.15A	0.2*	1.5				
1N4457	S			DS	50	1.0	0.2A	0.2*	1.5				
1N4458	S			R*	800	1.5	5.0	0.5	150				
1N4459	S			R*	1000	1.5	5.0	0.5	150				
1N4460	S	1N4735A	1N4728	DZ							6.2*	5.0	1.5W
1N4461	S	1N4736A	1N4728	DZ							6.8*	5.0	1.5W
1N4462	S	1N4737A	1N4728	DZ							7.5*	5.0	1.5W
1N4463	S	1N4738A	1N4728	DZ							8.2*	5.0	1.5W
1N4464	S	1N4739A	1N4728	DZ							9.1*	5.0	1.5W
1N4465	S	1N4740A	1N4728	DZ							10*	5.0	1.5W
1N4466	S	1N4741A	1N4728	DZ							11*	5.0	1.5W
1N4467	S	1N4742A	1N4728	DZ							12*	5.0	1.5W
1N4468	S	1N4743A	1N4728	DZ							13*	5.0	1.5W
1N4469	S	1N4744A	1N4728	DZ							15*	5.0	1.5W
1N4470	S	1N4745A	1N4728	DZ							16*	5.0	1.5W
1N4471	S	1N4746A	1N4728	DZ							18*	5.0	1.5W
1N4472	S	1N4747A	1N4728	DZ							20*	5.0	1.5W
1N4473	S	1N4748A	1N4728	DZ							22*	5.0	1.5W
1N4474	S	1N4749A	1N4728	DZ							24*	5.0	1.5W
1N4475	S	1N4750A	1N4728	DZ							27*	5.0	1.5W
1N4476	S	1N4751A	1N4728	DZ							30*	5.0	1.5W
1N4477	S	1N4752A	1N4728	DZ							33*	5.0	1.5W
1N4478	S	1N4753A	1N4728	DZ							36*	5.0	1.5W
1N4479	S	1N4754A	1N4728	DZ							39*	5.0	1.5W
1N4480	S	1N4755A	1N4728	DZ							43*	5.0	1.5W
1N4481	S	1N4756A	1N4728	DZ							47*	5.0	1.5W
1N4482	S	1N4757A	1N4728	DZ							51*	5.0	1.5W
1N4483	S	1N4758A	1N4728	DZ							56*	5.0	1.5W
1N4484	S	1N4759A	1N4728	DZ							62*	5.0	1.5W
1N4485	S	1N4760A	1N4728	DZ							68*	5.0	1.5W
1N4486	S	1N4761A	1N4728	DZ							75*	5.0	1.5W
1N4487	S	1N4762A	1N4728	DZ							82*	5.0	1.5W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4488	S	1N4763A	1N4728	DZ							91*	5.0	1.5W
1N4489	S	1N4764A	1N4728	DZ							100*	5.0	1.5W
1N4490	S	1M110ZS5	1N4728	DZ							110*	5.0	1.5W
1N4491	S	1M120ZS5	1N4728	DZ							120*	5.0	1.5W
1N4492	S	1M130ZS5	1N4728	DZ							130*	5.0	1.5W
1N4493	S	1M150ZS5	1N4728	DZ							150*	5.0	1.5W
1N4494	S	1M160ZS5	1N4728	DZ							160*	5.0	1.5W
1N4495	S	1M180ZS5	1N4728	DZ							180*	5.0	1.5W
1N4496	S	1M200ZS5	1N4728	DZ							200*	5.0	1.5W
1N4497	S			R*	1600	3.0	0.75	0.1	35				
1N4498	S			R*	3000	5.0	0.75	0.1	35				
1N4499	S	1N4735A	1N4728	DZ							6.2*	5.0	1.0W
1N4500	S			DS	80	1.0	0.3A	0.1*	4.0				
1N4501	S			DR						0.01	7.4	-55	100
1N4502	G			DS	20	0.3	3.0M	10*					
1N4503	S	1N4752	1N4728	DZ							33*	10	3.0W
1N4504	S	1N5388A	1N5333	DZ							200*	10	3.0W
1N4505	S			R*	6000	8.5	0.1	0.1	20				
1N4506	S			R*	200	1.4	12	2.5	240				
1N4507	S			R*	400	1.4	12	2.5	240				
1N4508	S			R*	600	1.4	12	2.5	240				
1N4509	S			R*	800	1.4	12	2.0	240				
1N4510	S			R*	1000	1.4	12	1:75	240				
1N4511	S			R*	1200	1.4	12	1.5	240				
1N4512	S			DS	10	0.777	5.0M	10N					
1N4513	S			R*	2000	4.5	0.25	0.1	20				
1N4514	S			R*	800	1.0	1.1	0.1	50				
1N4517	S			R*	200	1.2	2.0	0.1	100				
1N4523	G			DS	15	1.0	0.1A	30*	8.0				
1N4524	G			DS	10	0.65	10M	12*	3.0				
1N4525	S			R*	200	1.4	35	3.5	500				
1N4526	S			R*	400	1.4	35	3.5	500				
1N4527	S			R*	600	1.4	35	3.5	500				
1N4528	S			R*	800	1.4	35	3.0	500				
1N4529	S			R*	1000	1.4	35	2.5	500				
1N4530	S			R*	1200	1.4	35	2.0	500				
1N4531	S			DS	75	1.0	10M	25N	4.0				
1N4532	S			DS	75	1.0	10M	0.1*	2.0				
1N4533	S			DS	40	0.88	20M	50N	2.0				
1N4534	S			DS	50	0.88	20M	50N	2.0				
1N4535	S	.5M3.4ZZS5		DZ							3.45*	5.0	0.5W
1N4536	S			DS	25	1.0	30M	0.1*	2.0				
1N4537	S			R*	1500	1.85	3.0	0.3	15				
1N4538	S			R*	2000	1.85	3.0	0.3	15				
1N4539	S			R*	2500	1.85	3.0	0.3	15				
1N4540	S			R*	3000	1.85	3.0	0.3	15				
1N4541	S			DS	225	1.0	0.4A	20N					
1N4542	S			DS	400	1.0	0.4A	20N					
1N4543	S			DS	600	1.0	0.4A	20N					
1N4544	S			DS	800	1.0	0.4A	20N					
1N4545	S			DS	1000	1.0	400M	0.02*					
1N4546	S			R*	25K	30	1.0	0.1	50				
1N4547	S			DS	25	1.0	25M	10N					
1N4548	S			DS	25	1.0	30M	0.1*	4.0				
1N4549	S		1N2804	DZ							3.9*	20	50W
1N4549A	S		1N2804	DZ							3.9*	10	50W
1N4549B	S		1N2804	DZ							3.9*	5.0	50W
1N4550	S		1N2804	DZ							4.3*	20	50W
1N4550A	S		1N2804	DZ							4.3*	10	50W
1N4550B	S		1N2804	DZ							4.3*	5.0	50W
1N4551	S		1N2804	DZ							4.7*	20	50W
1N4551A	S		1N2804	DZ							4.7*	10	50W
1N4551B	S		1N2804	DZ							4.7*	5.0	50W
1N4552	S		1N2804	DZ							5.1*	20	50W
1N4552A	S		1N2804	DZ							5.1*	10	50W
1N4552B	S		1N2804	DZ							5.1*	5.0	50W
1N4553	S		1N2804	DZ							5.6*	20	50W
1N4553A	S		1N2804	DZ							5.6*	10	50W
1N4553B	S		1N2804	DZ							5.6*	5.0	50W
1N4554	S		1N2804	DZ							6.2*	20	50W
1N4554A	S		1N2804	DZ							6.2*	10	50W
1N4554B	S		1N2804	DZ							6.2*	5.0	50W
1N4555	S		1N2804	DZ							6.8*	20	50W
1N4555A	S		1N2804	DZ							6.8*	10	50W
1N4555B	S		1N2804	DZ							6.8*	5.0	50W
1N4556	S		1N2804	DZ							7.5*	20	50W
1N4556A	S		1N2804	DZ							7.5*	10	50W
1N4556B	S		1N2804	DZ							7.5*	5.0	50W
1N4557	S		1N2804	DZ							3.9*	20	50W
1N4557A	S		1N2804	DZ							3.9*	10	50W
1N4557B	S		1N2804	DZ							3.9*	5.0	50W
1N4558	S		1N2804	DZ							4.3*	20	50W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * / V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4558A	S		1N2804	DZ							4.3*	10	50W
1N4558B	S		1N2804	DZ							4.3*	5.0	50W
1N4559	S		1N2804	DZ							4.7*	20	50W
1N4559A	S		1N2804	DZ							4.7*	10	50W
1N4559B	S		1N2804	DZ							4.7*	5.0	50W
1N4560	S		1N2804	DZ							5.1*	20	50W
1N4560A	S		1N2804	DZ							5.1*	10	50W
1N4560B	S		1N2804	DZ							5.1*	5.0	50W
1N4561	S		1N2804	DZ							5.6*	20	50W
1N4561A	S		1N2804	DZ							5.6*	10	50W
1N4561B	S		1N2804	DZ							5.6*	5.0	50W
1N4562	S		1N2804	DZ							6.2*	20	50W
1N4562A	S		1N2804	DZ							6.2*	10	50W
1N4562B	S		1N2804	DZ							6.2*	5.0	50W
1N4563	S		1N2804	DZ							6.8*	20	50W
1N4563A	S		1N2804	DZ							6.8*	10	50W
1N4563B	S		1N2804	DZ							6.8*	5.0	50W
1N4564	S		1N2804	DZ							7.5*	20	50W
1N4564A	S		1N2804	DZ							7.5*	10	50W
1N4564B	S		1N2804	DZ							7.5*	5.0	50W
1N4565	S		1N4549	DR						0.01	6.4	0	75
1N4565A	S		1N4549	DR						0.01	6.4	-55	100
1N4566	S		1N4549	DR						0.005	6.4	0	75
1N4566A	S		1N4549	DR						0.005	6.4	-55	100
1N4567	S		1N4549	DR						0.002	6.4	0	75
1N4567A	S		1N4549	DR						0.002	6.4	-55	100
1N4568	S		1N4549	DR						0.001	6.4	0	75
1N4568A	S		1N4549	DR						0.001	6.4	-55	100
1N4569	S		1N4549	DR						0.0005	6.4	0	75
1N4569A	S		1N4549	DR						0.0005	6.4	-55	100
1N4570	S		1N4549	DR						0.01	6.4	0	75
1N4570A	S		1N4549	DR						0.01	6.4	-55	100
1N4571	S		1N4549	DR						0.005	6.4	0	75
1N4571A	S		1N4549	DR						0.005	6.4	-55	100
1N4572	S		1N4549	DR						0.002	6.4	0	75
1N4572A	S		1N4549	DR						0.002	6.4	-55	100
1N4573	S		1N4549	DR						0.001	6.4	0	75
1N4573A	S		1N4549	DR						0.001	6.4	-55	100
1N4574	S		1N4549	DR						0.0005	6.4	0	75
1N4574A	S		1N4549	DR						0.0005	6.4	-55	100
1N4575	S			DR						0.01	6.4	0	75
1N4575A	S			DR						0.01	6.4	-55	100
1N4576	S			DR						0.005	6.4	0	75
1N4576A	S			DR						0.005	6.4	-55	100
1N4577	S			DR						0.002	6.4	0	75
1N4577A	S			DR						0.002	6.4	-55	100
1N4578	S			DR						0.001	6.4	0	75
1N4578A	S			DR						0.001	6.4	-55	100
1N4579	S			DR						0.0005	6.4	0	75
1N4579A	S			DR						0.0005	6.4	-55	100
1N4580	S			DR						0.01	6.4	0	75
1N4580A	S			DR						0.01	6.4	-55	100
1N4581	S			DR						0.005	6.4	0	75
1N4581A	S			DR						0.005	6.4	-55	100
1N4582	S			DR						0.002	6.4	0	75
1N4582A	S			DR						0.002	6.4	-55	100
1N4583	S			DR						0.0001	6.4	0	75
1N4583A	S			DR						0.0001	6.4	-55	100
1N4584	S			DR						0.0005	6.4	0	75
1N4584A	S			DR						0.0005	6.4	-55	100
1N4585	S			R*	800	1.3	1.0	0.2	50				
1N4586	S			R*	1000	1.3	1.0	0.2	50				
1N4587	S	MR1221SB	MR1220	R*	100	1.35	150	9.5	3000				
1N4588	S	MR1223SB	MR1220	R*	200	1.35	150	9.5	3000				
1N4589	S	MR1225SB	MR1220	R*	300	1.35	150	9.0	3000				
1N4590	S	MR1227SB	MR1220	R*	400	1.35	150	9.0	3000				
1N4591	S	MR1228SB	MR1220	R*	500	1.35	150	8.0	3000				
1N4592	S	MR1229SB	MR1220	R*	600	1.35	150	6.5	3000				
1N4593	S			R*	800	1.35	150	5.5	3000				
1N4594	S			R*	1000	1.35	150	4.5	3000				
1N4595	S			R*	1200	1.35	150	4.0	3000				
1N4596	S			R*	1400	1.35	150	3.5	3000				
1N4597	S			R*	5000	5.0	0.025		1.0				
1N4598 thru 1N4599		Varactor Diodes, see Table on Page 92											
1N4600	S	Microwave Mixer: f = 13,300 MHz, NF = 9.5 dB											
1N4601	S	Microwave Mixer: f = 13,300 MHz, NF = 8.8 dB											
1N4602	S	Microwave Mixer: f = 13,300 MHz, NF = 8.0 dB											
1N4603	S	Microwave Mixer: f = 16,000 MHz, NF = 9.5 dB											
1N4604	S	Microwave Mixer: f = 16,000 MHz, NF = 8.8 dB											
1N4605	S	Microwave Mixer: f = 16,000 MHz, NF = 8.0 dB											

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4606	S			DS	70	1.0	0.2A	0.25*	6.0				
1N4607	S			DS	70	0.95	250M	0.25*	10				
1N4608	S			DS	70	0.96	350M	0.25*	10				
1N4609	S	Varactor Diode, see Table on Page 92											
1N4610	S			DS	55	1.1	0.3A	0.1*	2.0				
1N4611	S	1N4576A *	1N4549	DR						0.005	6.6	-50	100
1N4611A	S	1N4577A *	1N4549	DR						0.002	6.6	-50	100
1N4611B	S	1N4578A *	1N4549	DR						0.001	6.6	-50	100
1N4611C	S	1N4579A *	1N4549	DR						0.0005	6.6	-50	100
1N4612	S	1N4581A *	1N4549	DR						0.005	6.6	-50	100
1N4612A	S	1N4582A *	1N4549	DR						0.002	6.6	-50	100
1N4612B	S	1N4583A *	1N4549	DR						0.001	6.6	-50	100
1N4612C	S	1N4584A *	1N4549	DR						0.0005	6.6	-50	100
1N4613	S	1N4581A *	1N4549	DR						0.005	6.6	-50	100
1N4613A	S	1N4582A *	1N4549	DR						0.002	6.6	-50	100
1N4613B	S	1N4583A *	1N4549	DR						0.001	6.6	-50	100
1N4613C	S	1N4584A *	1N4549	DR						0.0005	6.6	-50	100
1N4614	S	MZ4614	1N4099	DZ							1.8*		0.25W
1N4615	S	MZ4615	1N4099	DZ							2.0*		0.25W
1N4616	S	MZ4616	1N4099	DZ							2.2*		0.25W
1N4617	S	MZ4617	1N4099	DZ							2.4*		0.25W
1N4618	S	MZ4618	1N4099	DZ							2.7*		0.25W
1N4619	S	MZ4619	1N4099	DZ							3.0*		0.25W
1N4620	S	MZ4620	1N4099	DZ							3.3*		0.25W
1N4621	S	MZ4621	1N4099	DZ							3.6*		0.25W
1N4622	S	MZ4622	1N4099	DZ							3.9*		0.25W
1N4623	S	MZ4623	1N4099	DZ							4.3*		0.25W
1N4624	S	MZ4624	1N4099	DZ							4.7*		0.25W
1N4625	S	MZ4625	1N4099	DZ							5.1*		0.25W
1N4626	S	MZ4626	1N4099	DZ							5.6*		0.25W
1N4627	S	MZ4627	1N4099	DZ							6.2*		0.25W
1N4628	S	1N4736A	1N4728	DZ							6.8*		0.6W
1N4629	S	1N4737A	1N4728	DZ							7.5*		0.6W
1N4630	S	1N4738A	1N4728	DZ							8.2*		0.6W
1N4631	S	1N4739A	1N4728	DZ							9.1*		0.6W
1N4632	S	1N4740A	1N4728	DZ							10*		0.6W
1N4633	S	1N4741A	1N4728	DZ							11*		0.6W
1N4634	S	1N4742A	1N4728	DZ							12*		0.6W
1N4635	S	1N4743A	1N4728	DZ							13*		0.6W
1N4636	S	1N4744A	1N4728	DZ							15*		0.6W
1N4637	S	1N4745A	1N4728	DZ							16*		0.6W
1N4638	S	1N4746A	1N4728	DZ							18*		0.6W
1N4639	S	1N4747A	1N4728	DZ							20*		0.6W
1N4640	S	1N4748A	1N4728	DZ							22*		0.6W
1N4641	S	1N4749A	1N4728	DZ							24*		0.6W
1N4642	S	1N4750A	1N4728	DZ							27*		0.6W
1N4643	S	1N4751A	1N4728	DZ							30*		0.6W
1N4644	S	1N4752A	1N4728	DZ							33*		0.6W
1N4645	S	1N4753A	1N4728	DZ							36*		0.6W
1N4646	S	1N4754A	1N4728	DZ							39*		0.6W
1N4647	S	1N4755A	1N4728	DZ							43*		0.6W
1N4648	S	1N4756A	1N4728	DZ							47*		0.6W
1N4649	S	1N4728A	1N4728	DZ							3.3*		1.0W
1N4650	S	1N4729A	1N4728	DZ							3.6*		1.0W
1N4651	S	1N4730A	1N4728	DZ							3.9*		1.0W
1N4652	S	1N4731A	1N4728	DZ							4.3*		1.0W
1N4653	S	1N4732A	1N4728	DZ							4.7*		1.0W
1N4654	S	1N4733A	1N4728	DZ							5.1*		1.0W
1N4655	S	1N4734A	1N4728	DZ							5.6*		1.0W
1N4656	S	1N4735A	1N4728	DZ							6.2*		1.0W
1N4657	S	1N4736A	1N4728	DZ							6.8*		1.0W
1N4658	S	1N4737A	1N4728	DZ							7.5*		1.0W
1N4659	S	1N4738A	1N4728	DZ							8.2*		1.0W
1N4660	S	1N4739A	1N4728	DZ							9.1*		1.0W
1N4661	S	1N4740A	1N4728	DZ							10*		1.0W
1N4662	S	1N4741A	1N4728	DZ							11*		1.0W
1N4663	S	1N4742A	1N4728	DZ							12*		1.0W
1N4664	S	1N4743A	1N4728	DZ							13*		1.0W
1N4665	S	1N4744A	1N4728	DZ							15*		1.0W
1N4666	S	1N4745A	1N4728	DZ							16*		1.0W
1N4667	S	1N4746A	1N4728	DZ							18*		1.0W
1N4668	S	1N4747A	1N4728	DZ							20*		1.0W
1N4669	S	1N4748A	1N4728	DZ							22*		1.0W
1N4670	S	1N4749A	1N4728	DZ							24*		1.0W
1N4671	S	1N4750A	1N4728	DZ							27*		1.0W
1N4672	S	1N4751A	1N4728	DZ							30*		1.0W
1N4673	S	1N4752A	1N4728	DZ							33*		1.0W
1N4674	S	1N4753A	1N4728	DZ							36*		1.0W
1N4675	S	1N4754A	1N4728	DZ							39*		1.0W
1N4676	S	1N4755A	1N4728	DZ							43*		1.0W
1N4677	S	1N4756A	1N4728	DZ							47*		1.0W

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F (Amps)	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4678	S	MZ4678		DZ						1.710	1.890		250
1N4679	S	MZ4679		DZ						1.900	2.100		250
1N4680	S	MZ4680		DZ						2.090	2.310		250
1N4681	S	MZ4681		DZ						2.280	2.520		250
1N4682	S	MZ4682		DZ						2.565	2.835		250
1N4683	S	MZ4683		DZ						2.850	3.150		250
1N4684	S	MZ4684		DZ						3.135	3.465		250
1N4685	S	MZ4685		DZ						3.420	3.780		250
1N4686	S	MZ4686		DZ						3.705	4.095		250
1N4687	S	MZ4687		DZ						4.085	4.515		250
1N4688	S	MZ4688		DZ						4.465	4.935		250
1N4689	S	MZ4689		DZ						4.845	5.355		250
1N4690	S	MZ4690		DZ						5.320	5.880		250
1N4691	S	MZ4691		DZ						5.890	6.510		250
1N4692	S	MZ4692		DZ						6.460	7.140		250
1N4693	S	MZ4693		DZ						7.125	7.875		250
1N4694	S	MZ4694		DZ						7.790	8.610		250
1N4695	S	MZ4695		DZ						8.265	9.135		250
1N4696	S	MZ4696		DZ						8.645	9.555		250
1N4697	S	MZ4697		DZ						9.500	10.50		250
1N4698	S	MZ4698		DZ						10.45	11.55		250
1N4699	S	MZ4699		DZ						11.40	12.60		250
1N4700	S	MZ4700		DZ						12.35	13.65		250
1N4701	S	MZ4701		DZ						13.30	14.70		250
1N4702	S	MZ4702		DZ						14.25	15.75		250
1N4703	S	MZ4703		DZ						15.20	16.80		250
1N4704	S	MZ4704		DZ						16.15	17.85		250
1N4705	S	MZ4705		DZ						17.10	18.90		250
1N4706	S	MZ4706		DZ						18.05	19.95		250
1N4707	S	MZ4707		DZ						19.00	21.00		250
1N4708	S	MZ4708		DZ						20.90	23.10		250
1N4709	S	MZ4709		DZ						22.80	25.20		250
1N4710	S	MZ4710		DZ						23.75	26.25		250
1N4711	S	MZ4711		DZ						25.65	28.35		250
1N4712	S	MZ4712		DZ						26.60	29.40		250
1N4713	S	MZ4713		DZ						28.50	31.50		250
1N4714	S	MZ4714		DZ						31.35	34.65		250
1N4715	S	MZ4715		DZ						34.20	37.80		250
1N4716	S	MZ4716		DZ						37.05	40.95		250
1N4717	S	MZ4717		DZ						40.85	45.15		250
1N4718	S			DS	50	1.2	0.75A	50*	180				
1N4719	S			R*	50	1.0	3.0	1.5	300				
1N4720	S			R*	100	1.0	3.0	1.5	300				
1N4721	S			R*	200	1.0	3.0	1.5	300				
1N4722	S			R*	400	1.0	3.0	1.5	300				
1N4723	S			R*	600	1.0	3.0	1.5	300				
1N4724	S			R*	800	1.0	3.0	1.5	300				
1N4725	S			R*	1000	1.0	3.0	1.5	300				
1N4726	S			DS	20	0.85	10M	0.1*					
1N4727	S			DS	20	0.85	10M	0.1*					
1N4728	S		1N4728	DZ							3.3*	10	1.0W
1N4728A	S		1N4728	DZ							3.3*	5.0	1.0W
1N4729	S		1N4728	DZ							3.6*	10	1.0W
1N4729A	S		1N4728	DZ							3.6*	5.0	1.0W
1N4730	S		1N4728	DZ							3.9*	10	1.0W
1N4730A	S		1N4728	DZ							3.9*	5.0	1.0W
1N4731	S		1N4728	DZ							4.3*	10	1.0W
1N4731A	S		1N4728	DZ							4.3*	5.0	1.0W
1N4732	S		1N4728	DZ							4.7*	10	1.0W
1N4732A	S		1N4728	DZ							4.7*	5.0	1.0W
1N4733	S		1N4728	DZ							5.1*	10	1.0W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4733A	S		1N4728	DZ							5.1*	5.0	1.0W
1N4734	S		1N4728	DZ							5.6*	10	1.0W
1N4734A	S		1N4728	DZ							5.6*	5.0	1.0W
1N4735	S		1N4728	DZ							6.2*	10	1.0W
1N4735A	S		1N4728	DZ							6.2*	5.0	1.0W
1N4736	S		1N4728	DZ							6.8*	10	1.0W
1N4736A	S		1N4728	DZ							6.8*	5.0	1.0W
1N4737	S		1N4728	DZ							7.5*	10	1.0W
1N4737A	S		1N4728	DZ							7.5*	5.0	1.0W
1N4738	S		1N4728	DZ							8.2*	10	1.0W
1N4738A	S		1N4728	DZ							8.2*	5.0	1.0W
1N4739	S		1N4728	DZ							9.1*	10	1.0W
1N4739A	S		1N4728	DZ							9.1*	5.0	1.0W
1N4740	S		1N4728	DZ							10*	10	1.0W
1N4740A	S		1N4728	DZ							10*	5.0	1.0W
1N4741	S		1N4728	DZ							11*	10	1.0W
1N4741A	S		1N4728	DZ							11*	5.0	1.0W
1N4742	S		1N4728	DZ							12*	10	1.0W
1N4742A	S		1N4728	DZ							12*	5.0	1.0W
1N4743	S		1N4728	DZ							13*	10	1.0W
1N4743A	S		1N4728	DZ							13*	5.0	1.0W
1N4744	S		1N4728	DZ							15*	10	1.0W
1N4744A	S		1N4728	DZ							15*	5.0	1.0W
1N4745	S		1N4728	DZ							16*	10	1.0W
1N4745A	S		1N4728	DZ							16*	5.0	1.0W
1N4746	S		1N4728	DZ							18*	10	1.0W
1N4746A	S		1N4728	DZ							18*	5.0	1.0W
1N4747	S		1N4728	DZ							20*	10	1.0W
1N4747A	S		1N4728	DZ							20*	5.0	1.0W
1N4748	S		1N4728	DZ							22*	10	1.0W
1N4748A	S		1N4728	DZ							22*	5.0	1.0W
1N4749	S		1N4728	DZ							24*	10	1.0W
1N4749A	S		1N4728	DZ							24*	5.0	1.0W
1N4750	S		1N4728	DZ							27*	10	1.0W
1N4750A	S		1N4728	DZ							27*	5.0	1.0W
1N4751	S		1N4728	DZ							30*	10	1.0W
1N4751A	S		1N4728	DZ							30*	5.0	1.0W
1N4752	S		1N4728	DZ							33*	10	1.0W
1N4752A	S		1N4728	DZ							33*	5.0	1.0W
1N4753	S		1N4728	DZ							36*	10	1.0W
1N4753A	S		1N4728	DZ							36*	5.0	1.0W
1N4754	S		1N4728	DZ							39*	10	1.0W
1N4754A	S		1N4728	DZ							39*	5.0	1.0W
1N4755	S		1N4728	DZ							43*	10	1.0W
1N4755A	S		1N4728	DZ							43*	5.0	1.0W
1N4756	S		1N4728	DZ							47*	10	1.0W
1N4756A	S		1N4728	DZ							47*	5.0	1.0W
1N4757	S		1N4728	DZ							51*	10	1.0W
1N4757A	S		1N4728	DZ							51*	5.0	1.0W
1N4758	S		1N4728	DZ							56*	10	1.0W
1N4758A	S		1N4728	DZ							56*	5.0	1.0W
1N4759	S		1N4728	DZ							62*	10	1.0W
1N4759A	S		1N4728	DZ							62*	5.0	1.0W
1N4760	S		1N4728	DZ							68*	10	1.0W
1N4760A	S		1N4728	DZ							68*	5.0	1.0W
1N4761	S		1N4728	DZ							75*	10	1.0W
1N4761A	S		1N4728	DZ							75*	5.0	1.0W
1N4762	S		1N4728	DZ							82*	10	1.0W
1N4762A	S		1N4728	DZ							82*	5.0	1.0W
1N4763	S		1N4728	DZ							91*	10	1.0W
1N4763A	S		1N4728	DZ							91*	5.0	1.0W
1N4764	S		1N4728	DZ							100*	10	1.0W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4764A	S		1N4728	DZ							100*	5.0	1.0W
1N4765	S		1N4549	DR						0.01	9.1	0	75
1N4765A	S		1N4549	DR						0.01	9.1	-55	100
1N4766	S		1N4549	DR						0.005	9.1	0	75
1N4766A	S		1N4549	DR						0.005	9.1	-55	100
1N4767	S		1N4549	DR						0.002	9.1	0	75
1N4767A	S		1N4549	DR						0.002	9.1	-55	100
1N4768	S		1N4549	DR						0.001	9.1	0	75
1N4768A	S		1N4549	DR						0.001	9.1	-55	100
1N4769	S		1N4549	DR						0.0005	9.1	0	75
1N4769A	S		1N4549	DR						0.0005	9.1	-55	100
1N4770	S		1N4549	DR						0.01	9.1	0	75
1N4770A	S		1N4549	DR						0.01	9.1	-55	100
1N4771	S		1N4549	DR						0.005	9.1	0	75
1N4771A	S		1N4549	DR						0.005	9.1	-55	100
1N4772	S		1N4549	DR						0.002	9.1	0	75
1N4772A	S		1N4549	DR						0.002	9.1	-55	100
1N4773	S		1N4549	DR						0.001	9.1	0	75
1N4773A	S		1N4549	DR						0.001	9.1	-55	100
1N4774	S		1N4549	DR						0.0005	9.1	0	75
1N4774A	S		1N4549	DR						0.0005	9.1	-55	100
1N4775	S		1N4549	DR						0.01	8.5	0	75
1N4775A	S		1N4549	DR						0.01	8.5	-55	100
1N4776	S		1N4549	DR						0.005	8.5	0	75
1N4776A	S		1N4549	DR						0.005	8.5	-55	100
1N4777	S		1N4549	DR						0.002	8.5	0	75
1N4777A	S		1N4549	DR						0.002	8.5	-55	100
1N4778	S		1N4549	DR						0.001	8.5	0	75
1N4778A	S		1N4549	DR						0.001	8.5	-55	100
1N4779	S		1N4549	DR						0.0005	8.5	0	75
1N4779A	S		1N4549	DR						0.0005	8.5	-55	100
1N4780	S		1N4549	DR						0.01	8.5	0	75
1N4780A	S		1N4549	DR						0.01	8.5	-55	100
1N4781	S		1N4549	DR						0.005	8.5	0	75
1N4781A	S		1N4549	DR						0.005	8.5	-55	100
1N4782	S		1N4549	DR						0.002	8.5	0	75
1N4782A	S		1N4549	DR						0.002	8.5	-55	100
1N4783	S		1N4549	DR						0.001	8.5	0	75
1N4783A	S		1N4549	DR						0.001	8.5	-55	100
1N4784	S		1N4549	DR						0.0005	8.5	0	75
1N4784A	S		1N4549	DR						0.0005	8.5	-55	100
1N4786 thru 1N4815		Varactor Diodes, see Table on Page 92											
1N4816	S	1N4001	1N4001	R*	50	1.3	1.5	0.25	50				
1N4817	S	1N4002	1N4001	R*	100	1.3	1.5	0.25	50				
1N4818	S	1N4003	1N4001	R*	200	1.3	1.5	0.25	50				
1N4819	S	1N4004	1N4001	R*	300	1.3	1.5	0.25	50				
1N4820	S	1N4004	1N4001	R*	400	1.3	1.5	0.25	50				
1N4821	S	1N4005	1N4001	R*	500	1.3	1.5	0.25	50				
1N4822	S	1N4005	1N4001	R*	600	1.3	1.5	0.25	50				
1N4823	S			R*	100	1.25	1.0	1.0	35				
1N4824	S			R*	200	1.25	1.0	1.0	35				
1N4825	S			R*	400	1.25	1.0	1.0	35				
1N4826	S			R*	600	1.25	1.0	1.0	35				
1N4827	G			DS	30	1.0	40M	15*	0.2				
1N4828	S			DS	20	1.1	0.1A	0.1*					
1N4829	S			DS	20	1.87	0.1A	0.1*					
1N4830	S			DS	20	2.69	0.1A	0.1*					
1N4831	S	1N4739	1N4728	DZ							9.1*	20	1.2W
1N4831A	S	1N4739	1N4728	DZ							9.1*	10	1.2W
1N4831B	S	1N4739A	1N4728	DZ							9.1*	5.0	1.2W
1N4832	S	1N4740	1N4728	DZ							10*	20	1.2W
1N4832A	S	1N4740	1N4728	DZ							10*	10	1.2W
1N4832B	S	1N4740A	1N4728	DZ							10*	5.0	1.2W
1N4833	S	1N4741	1N4728	DZ							11*	20	1.2W
1N4833A	S	1N4741	1N4728	DZ							11*	10	1.2W
1N4833B	S	1N4741A	1N4728	DZ							11*	5.0	1.2W
1N4834	S	1N4742	1N4728	DZ							12*	20	1.2W
1N4834A	S	1N4742	1N4728	DZ							12*	10	1.2W
1N4834B	S	1N4742A	1N4728	DZ							12*	5.0	1.2W
1N4835	S	1N4743	1N4728	DZ							13*	20	1.2W
1N4835A	S	1N4743	1N4728	DZ							13*	10	1.2W
1N4835B	S	1N4743A	1N4728	DZ							13*	5.0	1.2W
1N4836	S	1N4744	1N4728	DZ							15*	20	1.2W
1N4836A	S	1N4744	1N4728	DZ							15*	10	1.2W
1N4836B	S	1N4744A	1N4728	DZ							15*	5.0	1.2W
1N4837	S	1N4745	1N4728	DZ							16*	20	1.2W
1N4837A	S	1N4745	1N4728	DZ							16*	10	1.2W
1N4837B	S	1N4745A	1N4728	DZ							16*	5.0	1.2W
1N4838	S	1N4746	1N4728	DZ							18*	20	1.2W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4838A	S	1N4746	1N4728	DZ							18*	10	1.2W
1N4838B	S	1N4746A	1N4728	DZ							18*	5.0	1.2W
1N4839	S	1N4747	1N4728	DZ							20*	20	1.2W
1N4839A	S	1N4747	1N4728	DZ							20*	10	1.2W
1N4839B	S	1N4747A	1N4728	DZ							20*	5.0	1.2W
1N4840	S	1N4748	1N4728	DZ							22*	20	1.2W
1N4840A	S	1N4748	1N4728	DZ							22*	10	1.2W
1N4840B	S	1N4748A	1N4728	DZ							22*	5.0	1.2W
1N4841	S	1N4749	1N4728	DZ							24*	20	1.2W
1N4841A	S	1N4749	1N4728	DZ							24*	10	1.2W
1N4841B	S	1N4749A	1N4728	DZ							24*	5.0	1.2W
1N4842	S	1N4750	1N4728	DZ							27*	20	1.2W
1N4842A	S	1N4750	1N4728	DZ							27*	10	1.2W
1N4842B	S	1N4750A	1N4728	DZ							27*	5.0	1.2W
1N4843	S	1N4751	1N4728	DZ							30*	20	1.2W
1N4843A	S	1N4751	1N4728	DZ							30*	10	1.2W
1N4843B	S	1N4751A	1N4728	DZ							30*	5.0	1.2W
1N4844	S	1N4752	1N4728	DZ							33*	20	1.2W
1N4844A	S	1N4752	1N4728	DZ							33*	10	1.2W
1N4844B	S	1N4752A	1N4728	DZ							33*	5.0	1.2W
1N4845	S	1N4753	1N4728	DZ							36*	20	1.2W
1N4845A	S	1N4753	1N4728	DZ							36*	10	1.2W
1N4845B	S	1N4753A	1N4728	DZ							36*	5.0	1.2W
1N4846	S	1N4754	1N4728	DZ							39*	20	1.2W
1N4846A	S	1N4754	1N4728	DZ							39*	10	1.2W
1N4846B	S	1N4754A	1N4728	DZ							39*	5.0	1.2W
1N4847	S	1N4755	1N4728	DZ							43*	20	1.2W
1N4847A	S	1N4755	1N4728	DZ							43*	10	1.2W
1N4847B	S	1N4755A	1N4728	DZ							43*	5.0	1.2W
1N4848	S	1N4756	1N4728	DZ							47*	20	1.2W
1N4848A	S	1N4756	1N4728	DZ							47*	10	1.2W
1N4848B	S	1N4756A	1N4728	DZ							47*	5.0	1.2W
1N4849	S	1N4757	1N4728	DZ							51*	20	1.2W
1N4849A	S	1N4757	1N4728	DZ							51*	10	1.2W
1N4849B	S	1N4757A	1N4728	DZ							51*	5.0	1.2W
1N4850	S	1N4758	1N4728	DZ							56*	20	1.2W
1N4850A	S	1N4758	1N4728	DZ							56*	10	1.2W
1N4850B	S	1N4758A	1N4728	DZ							56*	5.0	1.2W
1N4851	S	1N4759	1N4728	DZ							62*	20	1.2W
1N4851A	S	1N4759	1N4728	DZ							62*	10	1.2W
1N4851B	S	1N4759A	1N4728	DZ							62*	5.0	1.2W
1N4852	S	1N4760	1N4728	DZ							68*	20	1.2W
1N4852A	S	1N4760	1N4728	DZ							68*	10	1.2W
1N4852B	S	1N4760A	1N4728	DZ							68*	5.0	1.2W
1N4853	S	1N4761	1N4728	DZ							75*	20	1.2W
1N4853A	S	1N4761	1N4728	DZ							75*	10	1.2W
1N4853B	S	1N4761A	1N4728	DZ							75*	5.0	1.2W
1N4854	S	1N4762	1N4728	DZ							82*	20	1.2W
1N4854A	S	1N4762	1N4728	DZ							82*	10	1.2W
1N4854B	S	1N4762A	1N4728	DZ							82*	5.0	1.2W
1N4855	S	1N4763	1N4728	DZ							91*	20	1.2W
1N4855A	S	1N4763	1N4728	DZ							91*	10	1.2W
1N4855B	S	1N5763A	1N4728	DZ							91*	5.0	1.2W
1N4856	S	1N5764	1N4728	DZ							100*	20	1.2W
1N4856A	S	1N5764	1N4728	DZ							100*	10	1.2W
1N4856B	S	1N5764A	1N4728	DZ							100*	5.0	1.2W
1N4857	S	1M110ZS10	1N4728	DZ							110*	20	1.2W
1N4857A	S	1M110ZS10	1N4728	DZ							110*	10	1.2W
1N4857B	S	1M110ZS5	1N4728	DZ							110*	5.0	1.2W
1N4858	S	1M120ZS10	1N4728	DZ							120*	20	1.2W
1N4858A	S	1M120ZS10	1N4728	DZ							120*	10	1.2W
1N4858B	S	1M120ZS5	1N4728	DZ							120*	5.0	1.2W
1N4859	S	1M130ZS10	1N4728	DZ							130*	20	1.2W
1N4859A	S	1M130ZS10	1N4728	DZ							130*	10	1.2W
1N4859B	S	1M130ZS5	1N4728	DZ							130*	5.0	1.2W
1N4860	S	1M150ZS10	1N4728	DZ							150*	20	1.2W
1N4860A	S	1M150ZS10	1N4728	DZ							150*	10	1.2W
1N4860B	S	1M150ZS5	1N4728	DZ							150*	5.0	1.2W
1N4861	S			DS	50	1.2	0.1A	2.0N	1.0				
1N4862	S			DS	50	1.1	0.1A	5.0N	1.0				
1N4863	S			DS	50	1.2	0.1A	50N	7.0				
1N4864	S			DS	80	1.1	0.1A	0.1*	9.0				
1N4865	S			R*	1500	2.4	1.25	0.6	150				
1N4866	S			R*	2500	3.6	1.25	0.6	150				
1N4867	S			R*	3000	4.8	1.25	0.6	150				
1N4868	S			R*	5000	8.4	1.25	0.6	150				
1N4869	S			R*	7500	12	1.25	0.6	150				
1N4870	S			R*	10K	16	1.25	0.6	150				
1N4871	S			R*	12K	18	1.25	0.6	150				
1N4872	S			R*	15K	23	1.25	0.6	150				
1N4873	S			R*	20K	30	1.25	0.6	150				
1N4874	S			R*	25K	38	1.25	0.6	150				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS V_R (volts) SIGNAL DIODES PRV (volts)	RECTIFIERS V_F (volts) SIGNAL DIODES V_F (volts) @	RECTIFIERS I_O (Amps) SIGNAL DIODES I_F	RECTIFIERS I_R (mA) SIGNAL DIODES I_R	RECTIFIERS I_{surge} (Amps) SIGNAL DIODES t_{rr} (µs)	ZENER DIODES V_Z (min) REFERENCE DIODES TC %/°C	ZENER DIODES V_Z (nom) * / V_Z (max) REFERENCE DIODES V_Z	ZENER DIODES Tol V_Z % REFERENCE DIODES T (min) °C	ZENER DIODES P_D REFERENCE DIODES T (max) °C
1N4875	S			R*	30K	46	1.25	0.6	150				
1N4876	S			R*	40K	60	1.25	0.6	150				
1N4877	S			R*	50K	76	1.25	0.6	150				
1N4878	S			R*	100	1.3	100	5.0	1500				
1N4879	S	MR1221SB	MR1220	R*	100	1.3	160	10	2200				
1N4880	S			R*	100	1.2	250	10	4000				
1N4881	S	1N4747	1N4728	DZ							20*	10	3.0W
1N4882	S	1N4753	1N4728	DZ							36*	10	3.0W
1N4883	S	1N4742A	1N4728	DZ							12*	5.0	3.0W
1N4884	S	1N4747A	1N4728	DZ							20*	5.0	3.0W
1N4885 thru		Varactor Diodes, see Table on Page 92											
1N4886													
1N4887	S			R*	75K	115	1.25	0.6	150				
1N4888	S			DS	12	1.0	20M	50N					
1N4889	S	1N3000B	1N2970	DZ							62*	5.0	5.0W
1N4890	S	MZ640 *	MZ600	DR						0.001	6.35	25	100
1N4890A	S	MZ640 *	MZ600	DR						0.001	6.35	-55	100
1N4891	S	MZ640 *	MZ600	DR						0.0005	6.35	25	100
1N4891A	S	MZ640 *	MZ600	DR						0.0005	6.35	-55	100
1N4892	S	MZ620 *	MZ600	DR						0.001	6.35	25	100
1N4892A	S	MZ620 *	MZ600	DR						0.001	6.35	-55	100
1N4893	S	MZ620 *	MZ600	DR						0.0005	6.35	25	100
1N4893A	S	MZ620 *	MZ600	DR						0.0005	6.35	-55	100
1N4894	S	MZ610 *	MZ600	DR						0.001	6.35	25	100
1N4894A	S	MZ610 *	MZ600	DR						0.001	6.35	-55	100
1N4895	S	MZ610 *	MZ600	DR						0.0005	6.35	25	100
1N4895A	S	MZ610 *	MZ600	DR						0.0005	6.35	-55	100
1N4896	S		1N4765	DR						0.01	12.8	25	100
1N4896A	S		1N4765	DR						0.01	12.8	-55	100
1N4897	S		1N4765	DR						0.005	12.8	25	100
1N4897A	S		1N4765	DR						0.005	12.8	-55	100
1N4898	S		1N4765	DR						0.002	12.8	25	100
1N4898A	S		1N4765	DR						0.002	12.8	-55	100
1N4899	S		1N4765	DR						0.001	12.8	25	100
1N4899A	S		1N4765	DR						0.001	12.8	-55	100
1N4900	S		1N4765	DR						0.01	12.8	25	100
1N4900A	S		1N4765	DR						0.01	12.8	-55	100
1N4901	S		1N4765	DR						0.005	12.8	25	100
1N4901A	S		1N4765	DR						0.005	12.8	-55	100
1N4902	S		1N4765	DR						0.002	12.8	25	100
1N4902A	S		1N4765	DR						0.002	12.8	-55	100
1N4903	S		1N4765	DR						0.001	12.8	25	100
1N4903A	S		1N4765	DR						0.001	12.8	-55	100
1N4904	S		1N4765	DR						0.01	12.8	25	100
1N4904A	S		1N4765	DR						0.01	12.8	-55	100
1N4905	S		1N4765	DR						0.005	12.8	25	100
1N4905A	S		1N4765	DR						0.005	12.8	-55	100
1N4906	S		1N4765	DR						0.002	12.8	25	100
1N4906A	S		1N4765	DR						0.002	12.8	-55	100
1N4907	S		1N4765	DR						0.001	12.8	25	100
1N4907A	S		1N4765	DR						0.001	12.8	-55	100
1N4908	S		1N4765	DR						0.01	12.8	25	100
1N4908A	S		1N4765	DR						0.01	12.8	-55	100
1N4909	S		1N4765	DR						0.005	12.8	25	100
1N4909A	S		1N4765	DR						0.005	12.8	-55	100
1N4910	S		1N4765	DR						0.002	12.8	25	100
1N4910A	S		1N4765	DR						0.002	12.8	-55	100
1N4911	S		1N4765	DR						0.001	12.8	25	100
1N4911A	S		1N4765	DR						0.001	12.8	-55	100
1N4912	S		1N4765	DR						0.01	12.8	25	100
1N4912A	S		1N4765	DR						0.01	12.8	-55	100
1N4913	S		1N4765	DR						0.005	12.8	25	100
1N4913A	S		1N4765	DR						0.005	12.8	-55	100
1N4914	S		1N4765	DR						0.002	12.8	25	100
1N4914A	S		1N4765	DR						0.002	12.8	-55	100
1N4915	S		1N4765	DR						0.001	12.8	25	100
1N4915A	S		1N4765	DR						0.001	12.8	-55	100
1N4916	S		1N4765	DR						0.01	19.2	25	100
1N4916A	S		1N4765	DR						0.01	19.2	-55	100
1N4917	S		1N4765	DR						0.005	19.2	25	100
1N4917A	S		1N4765	DR						0.005	19.2	-55	100
1N4918	S		1N4765	DR						0.002	19.2	25	100
1N4918A	S		1N4765	DR						0.002	19.2	-55	100
1N4919	S		1N4765	DR						0.01	19.2	25	100
1N4919A	S		1N4765	DR						0.01	19.2	-55	100
1N4920	S		1N4765	DR						0.005	19.2	25	100
1N4920A	S		1N4765	DR						0.005	19.2	-55	100
1N4921	S		1N4765	DR						0.002	19.2	25	100
1N4921A	S		1N4765	DR						0.002	19.2	-55	100
1N4922	S		1N4765	DR						0.01	19.2	25	100
1N4922A	S		1N4765	DR						0.01	19.2	-55	100

Replacement * denotes exact device type replacement available on request.

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4923	S		1N4765	DR						0.005	19.2	25	100
1N4923A	S		1N4765	DR						0.005	19.2	-55	100
1N4924	S		1N4765	DR						0.002	19.2	25	100
1N4924A	S		1N4765	DR						0.002	19.2	-55	100
1N4925	S		1N4765	DR						0.01	19.2	25	100
1N4925A	S		1N4765	DR						0.01	19.2	-55	100
1N4926	S		1N4765	DR						0.005	19.2	25	100
1N4926A	S		1N4765	DR						0.005	19.2	-55	100
1N4927	S		1N4765	DR						0.002	19.2	25	100
1N4927A	S		1N4765	DR						0.002	19.2	-55	100
1N4928	S		1N4765	DR						0.001	19.2	25	100
1N4928A	S		1N4765	DR						0.001	19.2	-55	100
1N4929	S		1N4765	DR						0.01	19.2	25	100
1N4929A	S		1N4765	DR						0.01	19.2	-55	100
1N4930	S		1N4765	DR						0.005	19.2	25	100
1N4930A	S		1N4765	DR						0.005	19.2	-55	100
1N4931	S		1N4765	DR						0.002	19.2	25	100
1N4931A	S		1N4765	DR						0.002	19.2	-55	100
1N4932	S		1N4765	DR						0.001	19.2	25	100
1N4932A	S		1N4765	DR						0.001	19.2	-55	100
1N4933	S		1N4933	R*	50	1.2	1.0	0.3	30				
1N4934	S		1N4933	R*	100	1.2	1.0	0.3	30				
1N4935	S		1N4933	R*	200	1.2	1.0	0.3	30				
1N4936	S		1N4933	R*	400	1.2	1.0	0.3	30				
1N4937	S		1N4933	R*	600	1.2	1.0	0.3	30				
1N4938	S			DS	200	1.0	0.1A	0.1*	50				
1N4939	G	Microwave Ka-band Mixer, NF = 10.5 dB											
1N4940	G	Microwave Ka-band Mixer, f = 9,375 MHz, NF = 6.5 dB											
1N4941		Varactor Diode, see Table on Page 92											
1N4942	S			DS	200	2.5	2.0	0.5M	0.15				
1N4943	S			DS	300	2.5	2.0	0.5M	0.15				
1N4944	S			DS	400	2.5	2.0	0.5M	0.15				
1N4945	S			DS	500	2.5	2.0	0.5M	0.15				
1N4946	S			DS	600	2.5	2.0	0.5M	0.15				
1N4947	S			DS	800	2.5	2.0	0.5M	0.25				
1N4948	S			DS	1000	2.5	2.0	0.5M	0.5				
1N4950	S			DS	25	0.53	1.0M	0.1M					
1N4951	S			DS	20	0.85	1.0M	0.1*					
1N4952	S			DS	50	0.85	1.0M	0.1*					
1N4954	S	1N5342B	1N5333	DZ							6.8*	5.0	3.0W
1N4955	S	1N5343B	1N5333	DZ							7.5*	5.0	3.0W
1N4956	S	1N5344B	1N5333	DZ							8.2*	5.0	3.0W
1N4957	S	1N5346B	1N5333	DZ							9.1*	5.0	3.0W
1N4958	S	1N5347B	1N5333	DZ							10*	5.0	3.0W
1N4959	S	1N5348B	1N5333	DZ							11*	5.0	3.0W
1N4960	S	1N5349B	1N5333	DZ							12*	5.0	3.0W
1N4961	S	1N5350B	1N5333	DZ							13*	5.0	3.0W
1N4962	S	1N5352B	1N5333	DZ							15*	5.0	3.0W
1N4963	S	1N5353B	1N5333	DZ							16*	5.0	3.0W
1N4964	S	1N5355B	1N5333	DZ							18*	5.0	3.0W
1N4965	S	1N5357B	1N5333	DZ							20*	5.0	3.0W
1N4966	S	1N5358B	1N5333	DZ							22*	5.0	3.0W
1N4967	S	1N5359B	1N5333	DZ							24*	5.0	3.0W
1N4968	S	1N5361B	1N5333	DZ							27*	5.0	3.0W
1N4969	S	1N5363B	1N5333	DZ							30*	5.0	3.0W
1N4970	S	1N5364B	1N5333	DZ							33*	5.0	3.0W
1N4971	S	1N5365B	1N5333	DZ							36*	5.0	3.0W
1N4972	S	1N5366B	1N5333	DZ							39*	5.0	3.0W
1N4973	S	1N5367B	1N5333	DZ							43*	5.0	3.0W
1N4974	S	1N5368B	1N5333	DZ							47*	5.0	3.0W
1N4975	S	1N5369B	1N5333	DZ							51*	5.0	3.0W
1N4976	S	1N5370B	1N5333	DZ							56*	5.0	3.0W
1N4977	S	1N5372B	1N5333	DZ							62*	5.0	3.0W
1N4978	S	1N5373B	1N5333	DZ							68*	5.0	3.0W
1N4979	S	1N5374B	1N5333	DZ							75*	5.0	3.0W
1N4980	S	1N5375B	1N5333	DZ							82*	5.0	3.0W
1N4981	S	1N5377B	1N5333	DZ							91*	5.0	3.0W
1N4982	S	1N5378B	1N5333	DZ							100*	5.0	3.0W
1N4983	S	1N5379B	1N5333	DZ							110*	5.0	3.0W
1N4984	S	1N5380B	1N5333	DZ							120*	5.0	3.0W
1N4985	S	1N5381B	1N5333	DZ							130*	5.0	3.0W
1N4986	S	1N5383B	1N5333	DZ							150*	5.0	3.0W
1N4987	S	1N5384B	1N5333	DZ							160*	5.0	3.0W
1N4988	S	1N5386B	1N5333	DZ							180*	5.0	3.0W
1N4989	S	1N5388B	1N5333	DZ							200*	5.0	3.0W
1N4990	S	5M110ZSB5		DZ							220*	5.0	3.0W
1N4991	S	5M180ZSB5		DZ							240*	5.0	3.0W
1N4992	S	5M135ZSB5		DZ							270*	5.0	3.0W
1N4993	S	5M150ZSB5		DZ							300*	5.0	3.0W
1N4994	S	5M165ZSB5		DZ							330*	5.0	3.0W
1N4995	S	5M180ZSB5		DZ							360*	5.0	3.0W
1N4996	S	5M195ZSB5		DZ							390*	5.0	3.0W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N4997	S		1N4719	R*	50	1.0	3.0	2.0	300				
1N4998	S		1N4719	R*	100	1.0	3.0	2.0	300				
1N4999	S		1N4719	R*	200	1.0	3.0	2.0	300				
1N5000	S		1N4719	R*	400	1.0	3.0	2.0	300				
1N5001	S		1N4719	R*	600	1.0	3.0	1.0	300				
1N5002	S		1N4719	R*	800	1.0	3.0	1.0	300				
1N5003	S		1N4719	R*	1000	1.0	3.0	1.0	300				
1N5004	S			R*	100	1.3	1.0	1.0	35				
1N5005	S			R*	200	1.3	1.0	1.0	35				
1N5006	S			R*	400	1.3	1.0	1.0	35				
1N5007	S			R*	600	1.3	1.0	1.0	35				
1N5008	S	1N4728	1N4728	DZ							3.3*	10	2.5W
1N5008A	S	1N4728A	1N4728	DZ							3.3*	5.0	2.5W
1N5009	S	1N4729	1N4728	DZ							3.6*	10	2.5W
1N5009A	S	1N4729A	1N4728	DZ							3.6*	5.0	2.5W
1N5010	S	1N4730	1N4728	DZ							3.9*	10	2.5W
1N5010A	S	1N4730A	1N4728	DZ							3.9*	5.0	2.5W
1N5011	S	1N4731	1N4728	DZ							4.3*	10	2.5W
1N5011A	S	1N4731A	1N4728	DZ							4.3*	5.0	2.5W
1N5012	S	1N4732	1N4728	DZ							4.7*	10	2.5W
1N5012A	S	1N4732A	1N4728	DZ							4.7*	5.0	2.5W
1N5013	S	1N4733	1N4728	DZ							5.1*	10	2.5W
1N5013A	S	1N4733A	1N4728	DZ							5.1*	5.0	2.5W
1N5014	S	1N4734	1N4728	DZ							5.6*	10	2.5W
1N5014A	S	1N4734A	1N4728	DZ							5.6*	5.0	2.5W
1N5015	S	1N4735	1N4728	DZ							6.2*	10	2.5W
1N5015A	S	1N4735A	1N4728	DZ							6.2*	5.0	2.5W
1N5016	S	1N4736	1N4728	DZ							6.8*	10	2.5W
1N5016A	S	1N4736A	1N4728	DZ							6.8*	5.0	2.5W
1N5017	S	1N4737	1N4728	DZ							7.5*	10	2.5W
1N5017A	S	1N4737A	1N4728	DZ							7.5*	5.0	2.5W
1N5018	S	1N4738	1N4728	DZ							8.2*	10	2.5W
1N5018A	S	1N4738A	1N4728	DZ							8.2*	5.0	2.5W
1N5019	S	1N4739	1N4728	DZ							9.1*	10	2.5W
1N5019A	S	1N4739A	1N4728	DZ							9.1*	5.0	2.5W
1N5020	S	1N4740	1N4728	DZ							10*	10	2.5W
1N5020A	S	1N4740A	1N4728	DZ							10*	5.0	2.5W
1N5021	S	1N4741	1N4728	DZ							11*	10	2.5W
1N5021A	S	1N4741A	1N4728	DZ							11*	5.0	2.5W
1N5022	S	1N4742	1N4728	DZ							12*	10	2.5W
1N5022A	S	1N4742A	1N4728	DZ							12*	5.0	2.5W
1N5023	S	1N4743	1N4728	DZ							13*	10	2.5W
1N5023A	S	1N4743A	1N4728	DZ							13*	5.0	2.5W
1N5024	S	1M14ZS10		DZ							14*	10	2.5W
1N5024A	S	1M14ZS5		DZ							14*	5.0	2.5W
1N5025	S	1N4744	1N4728	DZ							15*	10	2.5W
1N5025A	S	1N4744A	1N4728	DZ							15*	5.0	2.5W
1N5026	S	1N4745	1N4728	DZ							16*	10	2.5W
1N5026A	S	1N4745A	1N4728	DZ							16*	5.0	2.5W
1N5027	S	1M17ZS10		DZ							17*	10	2.5W
1N5027A	S	1M17ZS5		DZ							17*	5.0	2.5W
1N5028	S	1N4746	1N4728	DZ							18*	10	2.5W
1N5028A	S	1N4746A	1N4728	DZ							18*	5.0	2.5W
1N5029	S	1M19ZS10		DZ							19*	10	2.5W
1N5029A	S	1M19ZS5		DZ							19*	5.0	2.5W
1N5030	S	1N4747	1N4728	DZ							20*	10	2.5W
1N5030A	S	1N4747A	1N4728	DZ							20*	5.0	2.5W
1N5031	S	1N4748	1N4728	DZ							22*	10	2.5W
1N5031A	S	1N4748A	1N4728	DZ							22*	5.0	2.5W
1N5032	S	1N4749	1N4728	DZ							24*	10	2.5W
1N5032A	S	1N4749A	1N4728	DZ							24*	5.0	2.5W
1N5033	S	1M25ZS10		DZ							25*	10	2.5W
1N5033A	S	1M25ZS5		DZ							25*	5.0	2.5W
1N5034	S	1N4750	1N4728	DZ							27*	10	2.5W
1N5034A	S	1N4750A	1N4728	DZ							27*	5.0	2.5W
1N5035	S	1N4751	1N4728	DZ							30*	10	2.5W
1N5035A	S	1N4751A	1N4728	DZ							30*	5.0	2.5W
1N5036	S	1N4752	1N4728	DZ							33*	10	2.5W
1N5036A	S	1N4752A	1N4728	DZ							33*	5.0	2.5W
1N5037	S	1N4753	1N4728	DZ							36*	10	2.5W
1N5037A	S	1N4753A	1N4728	DZ							36*	5.0	2.5W
1N5038	S	1N4754	1N4728	DZ							39*	10	2.5W
1N5038A	S	1N4754A	1N4728	DZ							39*	5.0	2.5W
1N5039	S	1N4755	1N4728	DZ							43*	10	2.5W
1N5039A	S	1N4755A	1N4728	DZ							43*	5.0	2.5W
1N5040	S	1M45ZS10		DZ							45*	10	2.5W
1N5040A	S	1M45ZS5		DZ							45*	5.0	2.5W
1N5041	S	1N4756	1N4728	DZ							47*	10	2.5W
1N5041A	S	1N4756A	1N4728	DZ							47*	5.0	2.5W
1N5042	S	1M50ZS10		DZ							50*	10	2.5W
1N5042A	S	1M50ZS5		DZ							50*	5.0	2.5W
1N5043	S	1N4757	1N4728	DZ							51*	10	2.5W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F (Amps)	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N5043A	S	1N4757A	1N4728	DZ							51*	5.0	2.5W
1N5044	S	1M52ZS10	1N4728	DZ							52*	10	2.5W
1N5044A	S	1M52ZS5	1N4728	DZ							52*	5.0	2.5W
1N5045	S	1N4758	1N4728	DZ							56*	10	2.5W
1N5045A	S	1N4758A	1N4728	DZ							56*	5.0	2.5W
1N5046	S	1N4759	1N4728	DZ							62*	10	2.5W
1N5046A	S	1N4759A	1N4728	DZ							62*	5.0	2.5W
1N5047	S	1N4760	1N4728	DZ							68*	10	2.5W
1N5047A	S	1N4760A	1N4728	DZ							68*	5.0	2.5W
1N5048	S	1N4761	1N4728	DZ							75*	10	2.5W
1N5048A	S	1N4761A	1N4728	DZ							75*	5.0	2.5W
1N5049	S	1N4762	1N4728	DZ							82*	10	2.5W
1N5049A	S	1N4762A	1N4728	DZ							82*	5.0	2.5W
1N5050	S	1N4763	1N4728	DZ							91*	10	2.5W
1N5050A	S	1N4763A	1N4728	DZ							91*	5.0	2.5W
1N5051	S	1N4764	1N4728	DZ							100*	10	2.5W
1N5051A	S	1N4764A	1N4728	DZ							100*	5.0	2.5W
1N5052	S	1N4006	1N4001	R*	700	1.3	1.5	0.5	50				
1N5053	S	1N4006	1N4001	R*	800	1.3	1.5	0.5	50				
1N5054	S	1N4007	1N4001	R*	1000	1.3	1.5	0.5	50				
1N5055	S			R*	100	1.4	1.0	0.25	30				
1N5056	S			R*	200	1.4	1.0	0.25	30				
1N5057	S			R*	300	1.4	0.8	0.25	30				
1N5058	S			R*	400	1.4	0.8	0.25	30				
1N5059	S	1N4003	1N4001	R*	200	1.0	1.5	0.3	100				
1N5060	S	1N4004	1N4001	R*	400	1.0	1.5	0.3	100				
1N5061	S	1N4005	1N4001	R*	600	1.0	1.5	0.2	100				
1N5062	S	1N4006	1N4001	R*	800	1.0	1.25	0.2	100				
1N5063	S	1N4736A	1N4728	DZ							6.8*	5.0	1.0W
1N5064	S	1N4737A	1N4728	DZ							7.5*	5.0	1.0W
1N5065	S	1N4738A	1N4728	DZ							8.2*	5.0	1.0W
1N5066	S	1N4739A	1N4728	DZ							9.1*	5.0	1.0W
1N5067	S	1N4740A	1N4728	DZ							10*	5.0	1.0W
1N5068	S	1N4741A	1N4728	DZ							11*	5.0	1.0W
1N5069	S	1N4743A	1N4728	DZ							13*	5.0	1.0W
1N5070	S	1M14ZS5		DZ							14*	5.0	1.0W
1N5071	S	1N4744A	1N4728	DZ							15*	5.0	1.0W
1N5072	S	1N4745A	1N4728	DZ							16*	5.0	1.0W
1N5073	S	1N4746A	1N4728	DZ							18*	5.0	1.0W
1N5074	S	1N4748A	1N4728	DZ							22*	5.0	1.0W
1N5075	S	1N4749A	1N4728	DZ							24*	5.0	1.0W
1N5076	S	1N4750A	1N4728	DZ							27*	5.0	1.0W
1N5077	S	1N4751A	1N4728	DZ							30*	5.0	1.0W
1N5078	S	1N4752A	1N4728	DZ							33*	5.0	1.0W
1N5079	S	1N4753A	1N4728	DZ							36*	5.0	1.0W
1N5080	S	1N4754A	1N4728	DZ							39*	5.0	1.0W
1N5081	S	1M40ZS5		DZ							40*	5.0	1.0W
1N5082	S	1N4755A	1N4728	DZ							43*	5.0	1.0W
1N5083	S	1M45ZS5		DZ							45*	5.0	1.0W
1N5084	S	1N4756A	1N4728	DZ							47*	5.0	1.0W
1N5085	S	1M50ZS5		DZ							50*	5.0	1.0W
1N5086	S	1N4757A	1N4728	DZ							51*	5.0	1.0W
1N5087	S	1N4758A	1N4728	DZ							56*	5.0	1.0W
1N5088	S	1M60ZS5		DZ							60*	5.0	1.0W
1N5089	S	1N4759A	1N4728	DZ							62*	5.0	1.0W
1N5090	S	1N4760A		DZ							68*	5.0	1.0W
1N5091	S	1M70ZS5		DZ							70*	5.0	1.0W
1N5092	S	1N4761A	1N4728	DZ							75*	5.0	1.0W
1N5093	S	1M80ZS5		DZ							80*	5.0	1.0W
1N5094	S	1N4762A	1N4728	DZ							82*	5.0	1.0W
1N5095	S	1N4763A	1N4728	DZ							91*	5.0	1.0W
1N5096	S	1M110ZS5	1N4728	DZ							110*	5.0	1.0W
1N5097	S	1M120ZS5	1N4728	DZ							120*	5.0	1.0W
1N5098	S	1M130ZS5	1N4728	DZ							130*	5.0	1.0W
1N5099	S	1M140ZS5	1N4728	DZ							140*	5.0	1.0W
1N5100	S	1M160ZS5	1N4728	DZ							160*	5.0	1.0W
1N5101	S	1M170ZS5	1N4728	DZ							170*	5.0	1.0W
1N5102	S	1M180ZS5	1N4728	DZ							180*	5.0	1.0W
1N5103	S	1M190ZS5	1N4728	DZ							190*	5.0	1.0W
1N5104	S	1M200ZS5	1N4728	DZ							200*	5.0	1.0W
1N5105	S	1M110ZSB5	1N4728	DZ							220*	5.0	1.0W
1N5106	S	1M120ZSB5	1N4728	DZ							240*	5.0	1.0W
1N5107	S	1M130ZSB5	1N4728	DZ							260*	5.0	1.0W
1N5108	S	1M135ZSB5	1N4728	DZ							270*	5.0	1.0W
1N5109	S	1M140ZSB5	1N4728	DZ							280*	5.0	1.0W
1N5110	S	1M150ZSB5	1N4728	DZ							300*	5.0	1.0W
1N5111	S	1M160ZSB5	1N4728	DZ							320*	5.0	1.0W
1N5112	S	1M165ZSB5	1N4728	DZ							330*	5.0	1.0W
1N5113	S	1M170ZSB5	1N4728	DZ							340*	5.0	1.0W
1N5114	S	1M180ZSB5	1N4728	DZ							360*	5.0	1.0W
1N5115	S	1M190ZSB5	1N4728	DZ							380*	5.0	1.0W
1N5116	S	1M195ZSB5	1N4728	DZ							390*	5.0	1.0W

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ I_F (volts)		I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N5117	S	1M200ZSB5		DZ							400*	5.0	1.0W
1N5118	S	1N5341B	1N5333	DZ							14*	5.0	3.0W
1N5119	S	5M40ZS5		DZ							40*	5.0	3.0W
1N5120	S	5M45ZS5		DZ							45*	5.0	3.0W
1N5121	S	5M50ZS5		DZ							50*	5.0	3.0W
1N5122	S	1N5371B	1N5333	DZ							60*	5.0	3.0W
1N5123	S	5M70ZS5		DZ							70*	5.0	3.0W
1N5124	S	5M80ZS5		DZ							80*	5.0	3.0W
1N5125	S	5M90ZS5		DZ							90*	5.0	3.0W
1N5126	S	1N5382B	1N5333	DZ							140*	5.0	3.0W
1N5127	S	1N5385B	1N5333	DZ							170*	5.0	3.0W
1N5128	S	1N5387B	1N5333	DZ							190*	5.0	3.0W
1N5129	S	5M130ZSB5		DZ							260*	5.0	3.0W
1N5130	S	5M140ZSB5		DZ							280*	5.0	3.0W
1N5131	S	5M160ZSB5		DZ							320*	5.0	3.0W
1N5132	S	5M170ZSB5		DZ							340*	5.0	3.0W
1N5133	S	5M190ZSB5		DZ							380*	5.0	3.0W
1N5134	S	5M200ZSB5		DZ							400*	5.0	3.0W
1N5136 thru 1N5157		Varactor Diodes, see Table on Page 92											
1N5136A thru 1N5148A		Varactor Diodes, see Table on Page 92											
1N5150A		Varactor Diodes, see Table on Page 92											
1N5152A													
1N5153A													
1N5155A		Varactor Diodes, see Table on Page 92											
1N5156 thru 1N5157													
1N5158 thru 1N5160		4-Layer Diodes, see Table on Page 102											
1N5163	S	Harmonic Generator											
1N5164		Harmonic Generator											
1N5165,A thru 1N5167,A		Hot Carrier Diodes											
1N5168		Hot Carrier Diode											
1N5169		Hot Carrier Diode											
1N5170	S			R*	15	1.2	2.0	0.025	200				
1N5171	S			R*	50	1.2	2.0	0.025	200				
1N5172	S			R*	100	1.2	2.0	0.025	200				
1N5173	S			R*	300	1.2	2.0	0.025	200				
1N5174	S			R*	400	1.2	2.0	0.025	200				
1N5175	S			R*	500	1.2	2.0	0.025	200				
1N5176	S			R*	600	1.2	2.0	0.025	200				
1N5177	S			R*	800	1.2	2.0	0.025	200				
1N5178	S			R*	1000	1.2	2.0	0.025	200				
1N5179	S			DS		2.8	1.0	50	200				
1N5180	S			R*	100	1.25	4.0	100	100				
1N5181	S			R*	4000		0.6	0.02					
1N5182	S			R*	5000		0.6	0.02					
1N5183	S			R*	7500		0.6	0.02					
1N5184	S			R*	10000		0.6	0.02					
1N5185	S			R*	50	1.1	3.0	0.100	80				
1N5186	S			R*	100	1.1	3.0	0.100	80				
1N5187	S			R*	200	1.1	3.0	0.100	80				
1N5188	S			R*	400	1.1	3.0	0.100	80				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F (Amps)	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N5189	S			R*	500	1.1	3.0	0.100	80				
1N5190	S			R*	600	1.1	3.0	0.100	80				
1N5197	S			R*	50		2.0	0.1					
1N5198	S			R*	100		2.0	0.1					
1N5199	S			R*	200		2.0	0.1					
1N5200	S			R*	400		2.0	0.1					
1N5201	S			R*	600		2.0	0.1					
1N5206	S			R*	400	1.1	2.0	0.003	25				
1N5207	S			R*	400	1.25	4.0	0.005	100				
1N5211	S			R*	200	1.2	1.0	0.2	50				
1N5212	S			R*	400	1.2	1.0	0.2	50				
1N5213	S			R*	600	1.2	1.0	0.2	50				
1N5214	S			R*	800	1.2	0.75	0.2	50				
1N5215	S			R*	200	1.2	1.0	0.2	50				
1N5216	S			R*	400	1.2	1.0	0.2	50				
1N5217	S			R*	600	1.2	1.0	0.2	50				
1N5218	S			R*	800	1.2	0.75	0.2	50				
1N5219	S			DS	30	1.0	50	50	0.002				
1N5220	S			DS	30	1.2	50	50					
1N5221	S		1N5221	DZ							2.4*	10	500M
1N5221A	S		1N5221	DZ							2.4*	10	500M
1N5221B	S		1N5221	DZ							2.4*	5.0	500M
1N5222	S		1N5221	DZ							2.5*	10	500M
1N5222A	S		1N5221	DZ							2.5*	10	500M
1N5222B	S		1N5221	DZ							2.5*	5.0	500M
1N5223	S		1N5221	DZ							2.7*	10	500M
1N5223A	S		1N5221	DZ							2.7*	10	500M
1N5223B	S		1N5221	DZ							2.7*	5.0	500M
1N5224	S		1N5221	DZ							2.8*	10	500M
1N5224A	S		1N5221	DZ							2.8*	10	500M
1N5224B	S		1N5221	DZ							2.8*	5.0	500M
1N5225	S		1N5221	DZ							3.0*	10	500M
1N5225A	S		1N5221	DZ							3.0*	10	500M
1N5225B	S		1N5221	DZ							3.0*	5.0	500M
1N5226	S		1N5221	DZ							3.3*	10	500M
1N5226A	S		1N5221	DZ							3.3*	10	500M
1N5226B	S		1N5221	DZ							3.3*	5.0	500M
1N5227	S		1N5221	DZ							3.6*	10	500M
1N5227A	S		1N5221	DZ							3.6*	10	500M
1N5227B	S		1N5221	DZ							3.6*	5.0	500M
1N5228	S		1N5221	DZ							3.9*	10	500M
1N5228A	S		1N5221	DZ							3.9*	10	500M
1N5228B	S		1N5221	DZ							3.9*	5.0	500M
1N5229	S		1N5221	DZ							4.3*	10	500M
1N5229A	S		1N5221	DZ							4.3*	10	500M
1N5229B	S		1N5221	DZ							4.3*	5.0	500M
1N5230	S		1N5221	DZ							4.7*	10	500M
1N5230A	S		1N5221	DZ							4.7*	10	500M
1N5230B	S		1N5221	DZ							4.7*	5.0	500M
1N5231	S		1N5221	DZ							5.1*	10	500M
1N5231A	S		1N5221	DZ							5.1*	10	500M
1N5231B	S		1N5221	DZ							5.1*	5.0	500M
1N5232	S		1N5221	DZ							5.6*	10	500M
1N5232A	S		1N5221	DZ							5.6*	10	500M
1N5232B	S		1N5221	DZ							5.6*	5.0	500M
1N5233	S		1N5221	DZ							6.0*	10	500M
1N5233A	S		1N5221	DZ							6.0*	10	500M
1N5233B	S		1N5221	DZ							6.0*	5.0	500M
1N5234	S		1N5221	DZ							6.2*	10	500M
1N5234A	S		1N5221	DZ							6.2*	10	500M

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N5234B	S		1N5221	DZ							6.2*	5.0	500M
1N5235	S		1N5221	DZ							6.8*	10	500M
1N5235A	S		1N5221	DZ							6.8*	10	500M
1N5235B	S		1N5221	DZ							6.8*	5.0	500M
1N5236	S		1N5221	DZ							7.5*	10	500M
1N5236A	S		1N5221	DZ							7.5*	10	500M
1N5236B	S		1N5221	DZ							7.5*	5.0	500M
1N5237	S		1N5221	DZ							8.2*	10	500M
1N5237A	S		1N5221	DZ							8.2*	10	500M
1N5237B	S		1N5221	DZ							8.2*	5.0	500M
1N5238	S		1N5221	DZ							8.7*	10	500M
1N5238A	S		1N5221	DZ							8.7*	10	500M
1N5238B	S		1N5221	DZ							8.7*	5.0	500M
1N5239	S		1N5221	DZ							9.1*	10	500M
1N5239A	S		1N5221	DZ							9.1*	10	500M
1N5239B	S		1N5221	DZ							9.1*	5.0	500M
1N5240	S		1N5221	DZ							10*	10	500M
1N5240A	S		1N5221	DZ							10*	10	500M
1N5240B	S		1N5221	DZ							10*	5.0	500M
1N5241	S		1N5221	DZ							11*	10	500M
1N5241A	S		1N5221	DZ							11*	10	500M
1N5241B	S		1N5221	DZ							11*	5.0	500M
1N5242	S		1N5221	DZ							12*	10	500M
1N5242A	S		1N5221	DZ							12*	10	500M
1N5242B	S		1N5221	DZ							12*	5.0	500M
1N5243	S		1N5221	DZ							13*	10	500M
1N5243A	S		1N5221	DZ							13*	10	500M
1N5243B	S		1N5221	DZ							13*	5.0	500M
1N5244	S		1N5221	DZ							14*	10	500M
1N5244A	S		1N5221	DZ							14*	10	500M
1N5244B	S		1N5221	DZ							14*	5.0	500M
1N5245	S		1N5221	DZ							15*	10	500M
1N5245A	S		1N5221	DZ							15*	10	500M
1N5245B	S		1N5221	DZ							15*	5.0	500M
1N5246	S		1N5221	DZ							16*	10	500M
1N5246A	S		1N5221	DZ							16*	10	500M
1N5246B	S		1N5221	DZ							16*	5.0	500M
1N5247	S		1N5221	DZ							17*	10	500M
1N5247A	S		1N5221	DZ							17*	10	500M
1N5247B	S		1N5221	DZ							17*	5.0	500M
1N5248	S		1N5221	DZ							18*	10	500M
1N5248A	S		1N5221	DZ							18*	10	500M
1N5248B	S		1N5221	DZ							18*	5.0	500M
1N5249	S		1N5221	DZ							19*	10	500M
1N5249A	S		1N5221	DZ							19*	10	500M
1N5249B	S		1N5221	DZ							19*	5.0	500M
1N5250	S		1N5221	DZ							20*	10	500M
1N5250A	S		1N5221	DZ							20*	10	500M
1N5250B	S		1N5221	DZ							20*	5.0	500M
1N5251	S		1N5221	DZ							22*	10	500M
1N5251A	S		1N5221	DZ							22*	10	500M
1N5251B	S		1N5221	DZ							22*	5.0	500M
1N5252	S		1N5221	DZ							24*	10	500M
1N5252A	S		1N5221	DZ							24*	10	500M
1N5252B	S		1N5221	DZ							24*	5.0	500M
1N5253	S		1N5221	DZ							25*	10	500M
1N5253A	S		1N5221	DZ							25*	10	500M
1N5253B	S		1N5221	DZ							25*	5.0	500M
1N5254	S		1N5221	DZ							27*	10	500M
1N5254A	S		1N5221	DZ							27*	10	500M
1N5254B	S		1N5221	DZ							27*	5.0	500M
1N5255	S		1N5221	DZ							28*	10	500M
1N5255A	S		1N5221	DZ							28*	10	500M
1N5255B	S		1N5221	DZ							28*	5.0	500M
1N5256	S		1N5221	DZ							30*	10	500M
1N5256A	S		1N5221	DZ							30*	10	500M
1N5256B	S		1N5221	DZ							30*	5.0	500M
1N5257	S		1N5221	DZ							33*	10	500M
1N5257A	S		1N5221	DZ							33*	10	500M
1N5257B	S		1N5221	DZ							33*	5.0	500M
1N5258	S		1N5221	DZ							36*	10	500M
1N5258A	S		1N5221	DZ							36*	10	500M
1N5258B	S		1N5221	DZ							36*	5.0	500M
1N5259	S		1N5221	DZ							39*	10	500M
1N5259A	S		1N5221	DZ							39*	10	500M
1N5259B	S		1N5221	DZ							39*	5.0	500M
1N5260	S		1N5221	DZ							43*	10	500M
1N5260A	S		1N5221	DZ							43*	10	500M
1N5260B	S		1N5221	DZ							43*	5.0	500M
1N5261	S		1N5221	DZ							47*	10	500M
1N5261A	S		1N5221	DZ							47*	10	500M
1N5261B	S		1N5221	DZ							47*	5.0	500M

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N5262	S		1N5221	DZ							51*	10	500M
1N5262A	S		1N5221	DZ							51*	10	500M
1N5262B	S		1N5221	DZ							51*	5.0	500M
1N5263	S		1N5221	DZ							56*	10	500M
1N5263A	S		1N5221	DZ							56*	10	500M
1N5263B	S		1N5221	DZ							56*	5.0	500M
1N5264	S		1N5221	DZ							60*	10	500M
1N5264A	S		1N5221	DZ							60*	10	500M
1N5264B	S		1N5221	DZ							60*	5.0	500M
1N5265	S		1N5221	DZ							62*	10	500M
1N5265A	S		1N5221	DZ							62*	10	500M
1N5265B	S		1N5221	DZ							62*	5.0	500M
1N5266	S		1N5221	DZ							68*	10	500M
1N5266A	S		1N5221	DZ							68*	10	500M
1N5266B	S		1N5221	DZ							68*	5.0	500M
1N5267	S		1N5221	DZ							75*	10	500M
1N5267A	S		1N5221	DZ							75*	10	500M
1N5267B	S		1N5221	DZ							75*	5.0	500M
1N5268	S		1N5221	DZ							82*	10	500M
1N5268A	S		1N5221	DZ							82*	10	500M
1N5268B	S		1N5221	DZ							82*	5.0	500M
1N5269	S		1N5221	DZ							87*	10	500M
1N5269A	S		1N5221	DZ							87*	10	500M
1N5269B	S		1N5221	DZ							87*	5.0	500M
1N5270	S		1N5221	DZ							91*	10	500M
1N5270A	S		1N5221	DZ							91*	10	500M
1N5270B	S		1N5221	DZ							91*	5.0	500M
1N5271	S		1N5221	DZ							100*	10	500M
1N5271A	S		1N5221	DZ							100*	10	500M
1N5271B	S		1N5221	DZ							100*	5.0	500M
1N5272	S		1N5221	DZ							110*	10	500M
1N5272A	S		1N5221	DZ							110*	10	500M
1N5272B	S		1N5221	DZ							110*	5.0	500M
1N5273	S		1N5221	DZ							120*	10	500M
1N5273A	S		1N5221	DZ							120*	10	500M
1N5273B	S		1N5221	DZ							120*	5.0	500M
1N5274	S		1N5221	DZ							130*	10	500M
1N5274A	S		1N5221	DZ							130*	10	500M
1N5274B	S		1N5221	DZ							130*	5.0	500M
1N5275	S		1N5221	DZ							140*	10	500M
1N5275A	S		1N5221	DZ							140*	10	500M
1N5275B	S		1N5221	DZ							140*	5.0	500M
1N5276	S		1N5221	DZ							150*	10	500M
1N5276A	S		1N5221	DZ							150*	10	500M
1N5276B	S		1N5221	DZ							150*	5.0	500M
1N5277	S		1N5221	DZ							160*	10	500M
1N5277A	S		1N5221	DZ							160*	10	500M
1N5277B	S		1N5221	DZ							160*	5.0	500M
1N5278	S		1N5221	DZ							170*	10	500M
1N5278A	S		1N5221	DZ							170*	10	500M
1N5278B	S		1N5221	DZ							170*	5.0	500M
1N5279	S		1N5221	DZ							180*	10	500M
1N5279A	S		1N5221	DZ							180*	10	500M
1N5279B	S		1N5221	DZ							180*	5.0	500M
1N5280	S		1N5221	DZ							190*	10	500M
1N5280A	S		1N5221	DZ							190*	10	500M
1N5280B	S		1N5221	DZ							190*	5.0	500M
1N5281	S		1N5221	DZ							200*	10	500M
1N5281A	S		1N5221	DZ							200*	10	500M
1N5281B	S		1N5221	DZ							200*	5.0	500M
1N5282	S			DS	55	1.3	500M	0.1*	0.004				
1N5283 thru 1N5314		Current Regulator Diodes, See Data Sheet											
1N5315	S			DS	75	0.49	0.1M	0.05*	0.004				
1N5316	S			DS	75	0.49	0.1M	0.05*	0.004				
1N5317	S			DS	55	1.17	500M	0.1*	0.004				
1N5318	S			DS	50	0.87	200M	0.1*	0.004				
1N5319	S			DS	25	1.0	100M	100*	0.004				
1N5320	S			R*	100		1.0		20				
1N5324	S			R*	15000	24	0.010	0.025	0.75				
1N5326	S			R*	100		12		200				

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * / V_Z (max)	Tol V_Z %	P_D (W)
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F @ (volts)	I_F (mA)	I_R	t_{rr} (µs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N5329	S			R*	100		0.135	0.150	10				
1N5330	S			R*	100		0.540	0.150	15				
1N5331	S			R*	1200		12		240				
1N5332	S			R*	1200		35		500				
1N5333	S		1N5333	DZ							3.3	20	5.0
1N5333A	S		1N5333	DZ							3.3	10	5.0
1N5333B	S		1N5333	DZ							3.3	5	5.0
1N5334	S		1N5333	DZ							3.6	20	5.0
1N5334A	S		1N5333	DZ							3.6	10	5.0
1N5334B	S		1N5333	DZ							3.6	5	5.0
1N5335	S		1N5333	DZ							3.9	20	5.0
1N5335A	S		1N5333	DZ							3.9	10	5.0
1N5335B	S		1N5333	DZ							3.9	5	5.0
1N5336	S		1N5333	DZ							4.3	20	5.0
1N5336A	S		1N5333	DZ							4.3	10	5.0
1N5336B	S		1N5333	DZ							4.3	5	5.0
1N5337	S		1N5333	DZ							4.7	20	5.0
1N5337A	S		1N5333	DZ							4.7	10	5.0
1N5337B	S		1N5333	DZ							4.7	5	5.0
1N5338	S		1N5333	DZ							5.1	20	5.0
1N5338A	S		1N5333	DZ							5.1	10	5.0
1N5338B	S		1N5333	DZ							5.1	5	5.0
1N5339	S		1N5333	DZ							5.6	20	5.0
1N5339A	S		1N5333	DZ							5.6	10	5.0
1N5339B	S		1N5333	DZ							5.6	5	5.0
1N5340	S		1N5333	DZ							6.0	20	5.0
1N5340A	S		1N5333	DZ							6.0	10	5.0
1N5340B	S		1N5333	DZ							6.0	5	5.0
1N5341	S		1N5333	DZ							6.2	20	5.0
1N5341A	S		1N5333	DZ							6.2	10	5.0
1N5341B	S		1N5333	DZ							6.2	5	5.0
1N5342	S		1N5333	DZ							6.8	20	5.0
1N5342A	S		1N5333	DZ							6.8	10	5.0
1N5342B	S		1N5333	DZ							6.8	5	5.0
1N5343	S		1N5333	DZ							7.5	20	5.0
1N5343A	S		1N5333	DZ							7.5	10	5.0
1N5343B	S		1N5333	DZ							7.5	5	5.0
1N5344	S		1N5333	DZ							8.2	20	5.0
1N5344A	S		1N5333	DZ							8.2	10	5.0
1N5344B	S		1N5333	DZ							8.2	5	5.0
1N5345	S		1N5333	DZ							8.7	20	5.0
1N5345A	S		1N5333	DZ							8.7	10	5.0
1N5345B	S		1N5333	DZ							8.7	5	5.0
1N5346	S		1N5333	DZ							9.1	20	5.0
1N5346A	S		1N5333	DZ							9.1	10	5.0
1N5346B	S		1N5333	DZ							9.1	5	5.0
1N5347	S		1N5333	DZ							10	20	5.0
1N5347A	S		1N5333	DZ							10	10	5.0
1N5347B	S		1N5333	DZ							10	5	5.0
1N5348	S		1N5333	DZ							11	20	5.0
1N5348A	S		1N5333	DZ							11	10	5.0
1N5348B	S		1N5333	DZ							11	5	5.0
1N5349	S		1N5333	DZ							12	20	5.0
1N5349A	S		1N5333	DZ							12	10	5.0
1N5349B	S		1N5333	DZ							12	5	5.0
1N5350	S		1N5333	DZ							13	20	5.0
1N5350A	S		1N5333	DZ							13	10	5.0
1N5350B	S		1N5333	DZ							13	5	5.0
1N5351	S		1N5333	DZ							14	20	5.0
1N5351A	S		1N5333	DZ							14	10	5.0
1N5351B	S		1N5333	DZ							14	5	5.0
1N5352	S		1N5333	DZ							15	20	5.0
1N5352A	S		1N5333	DZ							15	10	5.0
1N5352B	S		1N5333	DZ							15	5	5.0
1N5353	S		1N5333	DZ							16	20	5.0
1N5353A	S		1N5333	DZ							16	10	5.0
1N5353B	S		1N5333	DZ							16	5	5.0
1N5354	S		1N5333	DZ							17	20	5.0
1N5354A	S		1N5333	DZ							17	10	5.0
1N5354B	S		1N5333	DZ							17	5	5.0
1N5355	S		1N5333	DZ							18	20	5.0
1N5355A	S		1N5333	DZ							18	10	5.0

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom) * V_Z (max)	Tol V_Z %	P_D (W)
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F (mA)	I_R	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N5355B	S		1N5333	DZ							18	5	5.0
1N5356	S		1N5333	DZ							19	20	5.0
1N5356A	S		1N5333	DZ							19	10	5.0
1N5356B	S		1N5333	DZ							19	5	5.0
1N5357	S		1N5333	DZ							20	20	5.0
1N5357A	S		1N5333	DZ							20	10	5.0
1N5357B	S		1N5333	DZ							20	5	5.0
1N5358	S		1N5333	DZ							22	20	5.0
1N5358A	S		1N5333	DZ							22	10	5.0
1N5358B	S		1N5333	DZ							22	5	5.0
1N5359	S		1N5333	DZ							24	20	5.0
1N5359A	S		1N5333	DZ							24	10	5.0
1N5359B	S		1N5333	DZ							24	5	5.0
1N5360	S		1N5333	DZ							25	20	5.0
1N5360A	S		1N5333	DZ							25	10	5.0
1N5360B	S		1N5333	DZ							25	5	5.0
1N5361	S		1N5333	DZ							27	20	5.0
1N5361A	S		1N5333	DZ							27	10	5.0
1N5361B	S		1N5333	DZ							27	5	5.0
1N5362	S		1N5333	DZ							28	20	5.0
1N5362A	S		1N5333	DZ							28	10	5.0
1N5362B	S		1N5333	DZ							28	5	5.0
1N5363	S		1N5333	DZ							30	20	5.0
1N5363A	S		1N5333	DZ							30	10	5.0
1N5363B	S		1N5333	DZ							30	5	5.0
1N5364	S		1N5333	DZ							33	20	5.0
1N5364A	S		1N5333	DZ							33	10	5.0
1N5364B	S		1N5333	DZ							33	5	5.0
1N5365	S		1N5333	DZ							36	20	5.0
1N5365A	S		1N5333	DZ							36	10	5.0
1N5365B	S		1N5333	DZ							36	5	5.0
1N5366	S		1N5333	DZ							39	20	5.0
1N5366A	S		1N5333	DZ							39	10	5.0
1N5366B	S		1N5333	DZ							39	5	5.0
1N5367	S		1N5333	DZ							43	20	5.0
1N5367A	S		1N5333	DZ							43	10	5.0
1N5367B	S		1N5333	DZ							43	5	5.0
1N5368	S		1N5333	DZ							47	20	5.0
1N5368A	S		1N5333	DZ							47	10	5.0
1N5368B	S		1N5333	DZ							47	5	5.0
1N5369	S		1N5333	DZ							51	20	5.0
1N5369A	S		1N5333	DZ							51	10	5.0
1N5369B	S		1N5333	DZ							51	5	5.0
1N5370	S		1N5333	DZ							56	20	5.0
1N5370A	S		1N5333	DZ							56	10	5.0
1N5370B	S		1N5333	DZ							56	5	5.0
1N5371	S		1N5333	DZ							60	20	5.0
1N5371A	S		1N5333	DZ							60	10	5.0
1N5371B	S		1N5333	DZ							60	5	5.0
1N5372	S		1N5333	DZ							62	20	5.0
1N5372A	S		1N5333	DZ							62	10	5.0
1N5372B	S		1N5333	DZ							62	5	5.0
1N5373	S		1N5333	DZ							68	20	5.0
1N5373A	S		1N5333	DZ							68	10	5.0
1N5373B	S		1N5333	DZ							68	5	5.0
1N5374	S		1N5333	DZ							75	20	5.0
1N5374A	S		1N5333	DZ							75	10	5.0
1N5374B	S		1N5333	DZ							75	5	5.0
1N5375	S		1N5333	DZ							82	20	5.0
1N5375A	S		1N5333	DZ							82	10	5.0
1N5375B	S		1N5333	DZ							82	5	5.0
1N5376	S		1N5333	DZ							87	20	5.0
1N5376A	S		1N5333	DZ							87	10	5.0
1N5376B	S		1N5333	DZ							87	5	5.0
1N5377	S		1N5333	DZ							91	20	5.0
1N5377A	S		1N5333	DZ							91	10	5.0
1N5377B	S		1N5333	DZ							91	5	5.0
1N5378	S		1N5333	DZ							100	20	5.0
1N5378A	S		1N5333	DZ							100	10	5.0
1N5378B	S		1N5333	DZ							100	5	5.0
1N5379	S		1N5333	DZ							110	20	5.0
1N5379A	S		1N5333	DZ							110	10	5.0
1N5379B	S		1N5333	DZ							110	5	5.0
1N5380	S		1N5333	DZ							120	20	5.0
1N5380A	S		1N5333	DZ							120	10	5.0
1N5380B	S		1N5333	DZ							120	5	5.0
1N5381	S		1N5333	DZ							130	20	5.0
1N5381A	S		1N5333	DZ							130	10	5.0
1N5381B	S		1N5333	DZ							130	5	5.0
1N5382	S		1N5333	DZ							140	20	5.0
1N5382A	S		1N5333	DZ							140	10	5.0
1N5382B	S		1N5333	DZ							140	5	5.0

TYPE	MATERIAL	REPLACEMENT	REF.	IDENTIFICATION	RECTIFIERS					ZENER DIODES			
					V_R (volts)	V_F (volts)	I_O (Amps)	I_R (mA)	I_{surge} (Amps)	V_Z (min)	V_Z (nom).* V_Z (max)	Tol V_Z %	P_D (W)
					SIGNAL DIODES					REFERENCE DIODES			
					PRV (volts)	V_F (volts) @	I_F (mA)	I_R N = nA *μA	t_{rr} (μs)	TC %/°C	V_Z	T (min) °C	T (max) °C
1N5383	S		1N5333	DZ							150	20	5.0
1N5383A	S		1N5333	DZ							150	10	5.0
1N5383B	S		1N5333	DZ							150	5	5.0
1N5384	S		1N5333	DZ							160	20	5.0
1N5384A	S		1N5333	DZ							160	10	5.0
1N5384B	S		1N5333	DZ							160	5	5.0
1N5385	S		1N5333	DZ							170	20	5.0
1N5385A	S		1N5333	DZ							170	10	5.0
1N5385B	S		1N5333	DZ							170	5	5.0
1N5386	S		1N5333	DZ							180	20	5.0
1N5386A	S		1N5333	DZ							180	10	5.0
1N5386B	S		1N5333	DZ							180	5	5.0
1N5387	S		1N5333	DZ							190	20	5.0
1N5387A	S		1N5333	DZ							190	10	5.0
1N5387B	S		1N5333	DZ							190	5	5.0
1N5388	S		1N5333	DZ							200	20	5.0
1N5388A	S		1N5333	DZ							200	10	5.0
1N5388B	S		1N5333	DZ							200	5	5.0
1N5389	S			R*	40,000	80	0.100	0.10	10				
1N5390		Hot Carrier Diode											
1N5391	S			R*	50		1.5		50				
1N5392	S			R*	100		1.5		50				
1N5393	S			R*	200		1.5		50				
1N5394	S			R*	300		1.5		50				
1N5395	S			R*	400		1.5		50				
1N5396	S			R*	500		1.5		50				
1N5397	S			R*	600		1.5		50				
1N5398	S			R*	800		1.5		50				
1N5399	S			R*	1000		1.5		50				
1N5400	S			R*	50		3.0		200				
1N5401	S			R*	100		3.0		200				
1N5402	S			R*	200		3.0		200				
1N5403	S			R*	300		3.0		200				
1N5404	S			R*	400		3.0		200				
1N5405	S			R*	500		3.0		200				
1N5406	S			R*	600		3.0		200				
1N5407	S			R*	800		3.0		200				
1N5408	S			R*	1000		3.0		200				
1N5409	S			R*	175		40		1000				
1N5410	S			R*	175		12		200				
1N5411	S	Diac (Trigger Diode)											
1N5412	S			DS	30	0.500	0.1M	100N	0.002				
1N5413	S			DS	55	0.500	0.1M	100N	0.002				
1N5414	S			DS	75	0.500	0.1M	100N	0.002				
1N5415	S			R*	50				200				
1N5416	S			R*	100				200				
1N5417	S			R*	200				200				
1N5418	S			R*	400				200				
1N5419	S			R*	500				200				
1N5420	S			R*	600				200				
1N5421 thru 1N5425		Varactor Diodes, see Table on Page 92											
1N5427	S			DS		1.0	10M	0.10*	0.004				
1N5428	S			DS		1.0	100M	0.10*	0.050				
1N5429	S			DS		1.0	200M	0.005*					
1N5430	S			DS		1.0	200M	0.10*	0.004				
1N5431	S			DS		1.3	500M	0.10*	0.004				
1N5432	S			DS		1.3	50M	0.050*	0.75N				

VARACTOR DIODES

INDEX AND SHORT-FORM SPECIFICATIONS

The following table provides a numerical index and short-form specifications for varactor diodes with EIA-registered type number.

KEY

		CAPACITANCE								GUARANTEED MULTIPLIER PERFORMANCE					
					Voltage Range				Max				Min		Min
TYPE	REF.	C_J C_T*	C Tol	C (max)/C (min)	V_1	V_2	BV_R	Q @ f	R_S	P_D @ 25°C	P_{in}	f_{in}	P_{out}	f_{out}	η
		pF	%		Volts	Volts	Volts	GHz	Ohms	Watts	Watts	GHz	Watts	GHz	%
Numerical Listing of Registered Type Numbers	Reference device number indicates specific Data Sheet on which device is characterized	Nominal Capacitance usually C_J (junction capacitance) With *, specified value is C_T (total capacitance) $C_T = C_J + C_C$	Tolerance of capacitance listed in preceding column	Effective tuning Ratio (Capacitance at Voltage V_1 divided by capacitance at Voltage V_2)	Voltage range over which the tuning range is measured		Reverse Breakdown Voltage	Figure of Merit at this specified frequency	Maximum Series Resistance	Power Dissipation at 25°C	Input Power	Input Frequency	Minimum Output Power at output frequency	Output frequency	Minimum efficiency ($P_{out}/P_{in} \times 100$)

TYPE	REF.	CAPACITANCE					BV_R Volts	Q	@ f GHz	Max R_S Ohms	P_D @ 25°C Watts	MULTIPLIER PERFORMANCE				
		C_J C_T* pF	C Tol %	C (max) / C (min)	Voltage Range V_1 Volts	V_2 Volts						P_{in} Watts	f_{in} GHz	Min P_{out} Watts	f_{out} GHz	Min η %
1N950		35		2.51	4.0	130	130	7.0	0.05							
1N951		50		2.4	4.0	80	80	7.0	0.05	4.5						
1N952		70		2.43	4.0	60	60	7.0	0.05	2.1						
1N953		100		2.4	4.0	25	25	7.0	0.05	1.5						
1N954		35		2.51	4.0	25	25	7.0	0.05							
1N955		50		2.4	4.0	25	25	7.0	0.05	5.0						
1N956		70		2.43	4.0	25	25	7.0	0.05	2.1						
1N2627		2.75		1.75	0	5.0	5.0	10	1.0							
1N2628		2.5		1.5	0	5.0	5.0	14	1.0							
1N3182		33					20	65	0.05	3.0	0.163					
1N3488		56					15	7.0	0.05							
1N3551		50	6.0	1.38	4.0	8.0	11	30	0.05							
1N3552		21.5	6.0				22	25	0.05							
1N3554		12					100									
1N3555		20					100	60	0.05							
1N3556		47					100	50	0.10							
1N3557		24					210	75	0.05							
1N3627		21.3		2.45	4.0	20	20	25	0.05							
1N3628		50		2.5	4.0	20	20	30	0.05							
1N3770		2.0					5.5									
1N3945		20		1.5	4.0	20	20	7.0	0.05		0.50					
1N3946		71					9.0	7.0	0.05		0.50					
1N3947		70					9.0	9.0	0.05							
1N4091		4.2		2.5			6.0				0.30					
1N4386		50					250	75	0.05	1.5	25	50	0.05	32.5	0.15	65
1N4387	1N4387	35					150	150	0.05	1.5	20	30	0.15	15	0.45	50
1N4388	1N4388	20					100	200	0.05	2.0	10	20	0.5	11	1.0	55
1N4598		22		4.04	4.0	90	90	50	0.05		0.25					
1N4599		47		5.0	2.0	100	110	100	0.05	100	0.50					
1N4609		22		2.64	4.0	35	35	60	0.05		0.25					
1N4786		6.8	20	2.56	0	4.0	25	15	0.05		0.50					
1N4786A		6.8	10	2.56	0	4.0	25	15	0.05		0.50					
1N4786B		6.8	5.0	2.56	0	4.0	25	15	0.05		0.50					
1N4786C		6.8	2.0	2.56	0	4.0	25	15	0.05		0.50					
1N4786D		6.8	1.0	2.56	0	4.0	25	15	0.05		0.50					
1N4787		8.2	20	2.56	0	4.0	25	15	0.05		0.50					
1N4787A		8.2	10	2.56	0	4.0	25	15	0.05		0.50					
1N4787B		8.2	5.0	2.56	0	4.0	25	15	0.05		0.50					
1N4787C		8.2	2.0	2.56	0	4.0	25	15	0.05		0.50					
1N4787D		8.2	1.0	2.56	0	4.0	25	15	0.05		0.50					
1N4788		10	20	2.50	0	4.0	25	15	0.05		0.50					
1N4788A		10	10	2.50	0	4.0	25	15	0.05		0.50					
1N4788B		10	5.0	2.50	0	4.0	25	15	0.05		0.50					
1N4788C		10	2.0	2.50	0	4.0	25	15	0.05		0.50					
1N4788D		10	1.0	2.50	0	4.0	25	15	0.05		0.50					
1N4789		12	20	2.49	0	4.0	25	15	0.05		0.50					
1N4789A		12	10	2.49	0	4.0	25	15	0.05		0.50					
1N4789B		12	5.0	2.49	0	4.0	25	15	0.05		0.50					
1N4789C		12	2.0	2.49	0	4.0	25	15	0.05		0.50					
1N4789D		12	1.0	2.49	0	4.0	25	15	0.05		0.50					
1N4790		15	20	2.49	0	4.0	25	15	0.05		0.50					
1N4790A		15	10	2.49	0	4.0	25	15	0.05		0.50					
1N4790B		15	5.0	2.49	0	4.0	25	15	0.05		0.50					
1N4790C		15	2.0	2.49	0	4.0	25	15	0.05		0.50					
1N4790D		15	1.0	2.49	0	4.0	25	15	0.05		0.50					
1N4791		18	20	2.48	0	4.0	20	15	0.05		0.50					
1N4791A		18	10	2.48	0	4.0	20	15	0.05		0.50					
1N4791B		18	5.0	2.48	0	4.0	20	15	0.05		0.50					
1N4791C		18	2.0	2.48	0	4.0	20	15	0.05		0.50					
1N4791D		18	1.0	2.48	0	4.0	20	15	0.05		0.50					
1N4792		22	20	2.46	0	4.0	20	15	0.05		0.50					
1N4792A		22	10	2.46	0	4.0	20	15	0.05		0.50					
1N4792B		22	5.0	2.46	0	4.0	20	15	0.05		0.50					
1N4792C		22	2.0	2.46	0	4.0	20	15	0.05		0.50					
1N4792D		22	1.0	2.46	0	4.0	20	15	0.05		0.50					
1N4793		27	20	2.46	0	4.0	20	15	0.05		0.50					
1N4793A		27	10	2.46	0	4.0	20	15	0.05		0.50					
1N4793B		27	5.0	2.46	0	4.0	20	15	0.05		0.50					
1N4793C		27	2.0	2.46	0	4.0	20	15	0.05		0.50					
1N4793D		27	1.0	2.46	0	4.0	20	15	0.05		0.50					

VARACTOR DIODES INDEX (continued)

TYPE	REF.	CAPACITANCE			Voltage Range		BV_R	Q	@ f	Max R_S	P_D @ 25°C	MULTIPLIER PERFORMANCE				
		C_J C_T* pF	C Tol %	C (max) / C (min)	V_1 Volts	V_2 Volts	Volts		GHz	Ohms	Watts	P_in Watts	f_in GHz	Min P_out Watts	f_out GHz	Min η %
1N4794		33	20	2.46	0	4.0	20	15	0.05		0.50					
1N4794A		33	10	2.46	0	4.0	20	15	0.05		0.50					
1N4794B		33	5.0	2.46	0	4.0	20	15	0.05		0.50					
1N4794C		33	2.0	2.46	0	4.0	20	15	0.05		0.50					
1N4794D		33	1.0	2.46	0	4.0	20	15	0.05		0.50					
1N4795		39	20	2.44	0	4.0	20	15	0.05		0.50					
1N4795A		39	10	2.44	0	4.0	20	15	0.05		0.50					
1N4795B		39	5.0	2.44	0	4.0	20	15	0.05		0.50					
1N4795C		39	2.0	2.44	0	4.0	20	15	0.05		0.50					
1N4795D		39	1.0	2.44	0	4.0	20	15	0.05		0.50					
1N4796		47	20	2.43	0	4.0	20	15	0.05		0.50					
1N4796A		47	10	2.43	0	4.0	20	15	0.05		0.50					
1N4796B		47	5.0	2.43	0	4.0	20	15	0.05		0.50					
1N4796C		47	2.0	2.43	0	4.0	20	15	0.05		0.50					
1N4796D		47	1.0	2.43	0	4.0	20	15	0.05		0.50					
1N4797		56	20	2.42	0	4.0	15	15	0.05		0.50					
1N4797A		56	10	2.42	0	4.0	15	15	0.05		0.50					
1N4797B		56	5.0	2.42	0	4.0	15	15	0.05		0.50					
1N4797C		56	2.0	2.42	0	4.0	15	15	0.05		0.50					
1N4797D		56	1.0	2.42	0	4.0	15	15	0.05		0.50					
1N4798		68	20	2.40	0	4.0	15	15	0.05		0.50					
1N4798A		68	10	2.40	0	4.0	15	15	0.05		0.50					
1N4798B		68	5.0	2.40	0	4.0	15	15	0.05		0.50					
1N4798C		68	2.0	2.40	0	4.0	15	15	0.05		0.50					
1N4798D		68	1.0	2.40	0	4.0	15	15	0.05		0.50					
1N4799		82	20	2.36	0	4.0	15	15	0.05		0.50					
1N4799A		82	10	2.36	0	4.0	15	15	0.05		0.50					
1N4799B		82	5.0	2.36	0	4.0	15	15	0.05		0.50					
1N4799C		82	2.0	2.36	0	4.0	15	15	0.05		0.50					
1N4799D		82	1.0	2.36	0	4.0	15	15	0.05		0.50					
1N4800		100	20	2.33	0	4.0	15	15	0.05		0.50					
1N4800A		100	10	2.33	0	4.0	15	15	0.05		0.50					
1N4800B		100	5.0	2.33	0	4.0	15	15	0.05		0.50					
1N4800C		100	2.0	2.33	0	4.0	15	15	0.05		0.50					
1N4800D		100	1.0	2.33	0	4.0	15	15	0.05		0.50					
1N4801		6.8	20	2.56	0	4.0	100	15	0.05		0.50					
1N4801A		6.8	10	2.56	0	4.0	100	15	0.05		0.50					
1N4801B		6.8	5.0	2.56	0	4.0	100	15	0.05		0.50					
1N4801C		6.8	2.0	2.56	0	4.0	100	15	0.05		0.50					
1N4801D		6.8	1.0	2.56	0	4.0	100	15	0.05		0.50					
1N4802		8.2	20	2.58	0	4.0	100	15	0.05		0.50					
1N4802A		8.2	10	2.58	0	4.0	100	15	0.05		0.50					
1N4802B		8.2	5.0	2.58	0	4.0	100	15	0.05		0.50					
1N4802C		8.2	2.0	2.58	0	4.0	100	15	0.05		0.50					
1N4802D		8.2	1.0	2.58	0	4.0	100	15	0.05		0.50					
1N4803		10	20	2.50	0	4.0	100	15	0.05		0.50					
1N4803A		10	10	2.50	0	4.0	100	15	0.05		0.50					
1N4803B		10	5.0	2.50	0	4.0	100	15	0.05		0.50					
1N4803C		10	2.0	2.50	0	4.0	100	15	0.05		0.50					
1N4803D		10	1.0	2.50	0	4.0	100	15	0.05		0.50					
1N4804		12	20	2.49	0	4.0	100	15	0.05		0.50					
1N4804A		12	10	2.49	0	4.0	100	15	0.05		0.50					
1N4804B		12	5.0	2.49	0	4.0	100	15	0.05		0.50					
1N4804C		12	2.0	2.49	0	4.0	100	15	0.05		0.50					
1N4804D		12	1.0	2.49	0	4.0	100	15	0.05		0.50					
1N4805		15	20	2.49	0	4.0	100	15	0.05		0.50					
1N4805A		15	10	2.49	0	4.0	100	15	0.05		0.50					
1N4805B		15	5.0	2.49	0	4.0	100	15	0.05		0.50					
1N4805C		15	2.0	2.49	0	4.0	100	15	0.05		0.50					
1N4805D		15	1.0	2.49	0	4.0	100	15	0.05		0.50					
1N4806		18	20	2.48	0	4.0	90	15	0.05	0.50						
1N4806A		18	10	2.48	0	4.0	90	15	0.05	0.50						
1N4806B		18	5.0	2.48	0	4.0	90	15	0.05	0.50						
1N4806C		18	2.0	2.48	0	4.0	90	15	0.05	0.50						
1N4806D		18	1.0	2.48	0	4.0	90	15	0.05	0.50						
1N4807		22	20	2.46	0	4.0	90	15	0.05		0.50					
1N4807A		22	10	2.46	0	4.0	90	15	0.05		0.50					
1N4807B		22	5.0	2.46	0	4.0	90	15	0.05		0.50					
1N4807C		22	2.0	2.46	0	4.0	90	15	0.05		0.50					
1N4807D		22	1.0	2.46	0	4.0	90	15	0.05		0.50					

TYPE	REF.	CAPACITANCE					BV_R	Q	@ f	Max R_S Typ*	P_D @ 25°C	MULTIPLIER PERFORMANCE				
		C_J C_T* pF	C Tol %	C (max) / C (min)	Voltage Range V_1 Volts	Voltage Range V_2 Volts	Volts		GHz	Ohms	Watts	P_in Watts	f_in GHz	Min P_out Watts	f_out GHz	Min η %
1N4808		27	20	2.46	0	4.0	65	15	0.05		0.50					
1N4808A		27	10	2.46	0	4.0	65	15	0.05		0.50					
1N4808B		27	5.0	2.46	0	4.0	65	15	0.05		0.50					
1N4808C		27	2.0	2.46	0	4.0	65	15	0.05		0.50					
1N4808D		27	1.0	2.46	0	4.0	65	15	0.05		0.50					
1N4809		33	20	2.46	0	4.0	60	15	0.05		0.50					
1N4809A		33	10	2.46	0	4.0	60	15	0.05		0.50					
1N4809B		33	5.0	2.46	0	4.0	60	15	0.05		0.50					
1N4809C		33	2.0	2.46	0	4.0	60	15	0.05		0.50					
1N4809D		33	1.0	2.46	0	4.0	60	15	0.05		0.50					
1N4810		39	20	2.44	0	4.0	55	15	0.05		0.50					
1N4810A		39	10	2.44	0	4.0	55	15	0.05		0.50					
1N4810B		39	5.0	2.44	0	4.0	55	15	0.05		0.50					
1N4810C		39	2.0	2.44	0	4.0	55	15	0.05		0.50					
1N4810D		39	1.0	2.44	0	4.0	55	15	0.05		0.50					
1N4811		47	20	2.43	0	4.0	50	15	0.05		0.50					
1N4811A		47	10	2.43	0	4.0	50	15	0.05		0.50					
1N4811B		47	5.0	2.43	0	4.0	50	15	0.05		0.50					
1N4811C		47	2.0	2.43	0	4.0	50	15	0.05		0.50					
1N4811D		47	1.0	2.43	0	4.0	50	15	0.05		0.50					
1N4812		56	20	2.42	0	4.0	40	15	0.05		0.50					
1N4812A		56	10	2.42	0	4.0	40	15	0.05		0.50					
1N4812B		56	5.0	2.42	0	4.0	40	15	0.05		0.50					
1N4812C		56	2.0	2.42	0	4.0	40	15	0.05		0.50					
1N4812D		56	1.0	2.42	0	4.0	40	15	0.05		0.50					
1N4813		68	20	2.40	0	4.0	30	15	0.05		0.50					
1N4813A		68	10	2.40	0	4.0	30	15	0.05		0.50					
1N4813B		68	5.0	2.40	0	4.0	30	15	0.05		0.50					
1N4813C		68	2.0	2.40	0	4.0	30	15	0.05		0.50					
1N4813D		68	1.0	2.40	0	4.0	30	15	0.05		0.50					
1N4814		82	20	2.36	0	4.0	20	15	0.05		0.50					
1N4814A		82	10	2.36	0	4.0	20	15	0.05		0.50					
1N4814B		82	5.0	2.36	0	4.0	20	15	0.05		0.50					
1N4814C		82	2.0	2.36	0	4.0	20	15	0.05		0.50					
1N4814D		82	1.0	2.36	0	4.0	20	15	0.05		0.50					
1N4815		100	20	2.33	0	4.0	20	15	0.05		0.50					
1N4815A		100	10	2.33	0	4.0	20	15	0.05		0.50					
1N4815B		100	5.0	2.33	0	4.0	20	15	0.05		0.50					
1N4815C		100	2.0	2.33	0	4.0	20	15	0.05		0.50					
1N4815D		100	1.0	2.33	0	4.0	20	15	0.05		0.50					
1N4885		35		2.57	6.0	150	150			0.70	20					
1N4886		35		2.57	6.0	120	120			0.80	20					
1N4941		0.4		2.0	0	6.0	6.0	2000	10	2.0	0.1					
1N5136		1.0*	20	2.2	4.0	60	60	350	0.05		0.4					
1N5136A		1.0*	10	2.2	4.0	60	60	350	0.05		0.4					
1N5137		2.2*	20	2.2	4.0	60	60	350	0.05		0.4					
1N5137A		2.2*	10	2.2	4.0	60	60	350	0.05		0.4					
1N5138		3.3*	20	2.4	4.0	60	60	350	0.05		0.4					
1N5138A		3.3*	10	2.4	4.0	60	60	350	0.05		0.4					
1N5139	1N5139	6.8*	10	2.9	4.0	60	60	350	0.05		0.4					
1N5139A	1N5139	6.8*	5.0	2.9	4.0	60	60	350	0.05		0.4					
1N5140	1N5139	10*	10	3.0	4.0	60	60	300	0.05		0.4					
1N5140A	1N5139	10*	5.0	3.0	4.0	60	60	300	0.05		0.4					
1N5141	1N5139	12*	10	3.0	4.0	60	60	300	0.05		0.4					
1N5141A	1N5139	12*	5.0	3.0	4.0	60	60	300	0.05		0.4					
1N5142	1N5139	15*	10	3.0	4.0	60	60	250	0.05		0.4					
1N5142A	1N5139	15*	5.0	3.0	4.0	60	60	250	0.05		0.4					
1N5143	1N5139	18*	10	3.0	4.0	60	60	250	0.05		0.4					
1N5143A	1N5139	18*	5.0	3.0	4.0	60	60	250	0.05		0.4					
1N5144	1N5139	22*	10	3.4	4.0	60	60	200	0.05		0.4					
1N5144A	1N5139	22*	5.0	3.4	4.0	60	60	200	0.05		0.4					
1N5145	1N5139	27*	10	3.4	4.0	60	60	200	0.05		0.4					
1N5145A	1N5139	27*	5.0	3.4	4.0	60	60	200	0.05		0.4					
1N5146	1N5139	33*	10	3.4	4.0	60	60	200	0.05		0.4					
1N5146A	1N5139	33*	5.0	3.4	4.0	60	60	200	0.05		0.4					
1N5147	1N5139	39*	10	3.4	4.0	60	60	200	0.05		0.4					
1N5147A	1N5139	39*	5.0	3.4	4.0	60	60	200	0.05		0.4					
1N5148	1N5139	47*	10	3.4	4.0	60	60	200	0.05		0.4					
1N5148A	1N5139	47*	5.0	3.4	4.0	60	60	200	0.05		0.4					
1N5149	1N5149	11.5*					80	800	0.05		10	20	0.5	11	1.0	55
1N5150	1N5149	11.5*					80	800	0.05		14	37	0.5	24	1.0	65
1N5150A	1N5150A	12	10				80	800	0.05	0.25*	29.2	37	0.5	25.1	1.0	68
1N5151	1N5151	5.8*					75	1100	0.05	0.5	5.5	12	1.0	6.0	2.0	50
1N5152	1N5151	5.8*					75	1100	0.05	0.5	5.5	12	1.0	6.0	2.0	50
1N5152A	1N5150A	6.0	10				75	1100	0.05	0.5*	11.7	12	1.0	7.5	2.0	60
1N5153	1N5151	5.8*					75	1100	0.05	0.5	5.5	12	1.0	6.0	2.0	50

VARACTOR DIODES INDEX (continued)

TYPE	REF.	CAPACITANCE					BV_R	Q	@ f	Max R_S Typ*	P_D @ 25°C 75°C*	MULTIPLIER PERFORMANCE				
		C_J C_T* pF	C Tol %	$\frac{C\ (max)}{C\ (min)}$	Voltage Range V_1 Volts	Voltage Range V_2 Volts	Volts		GHz	Ohms	Watts	P_{in} Watts	f_{in} GHz	Min P_{out} Watts	f_{out} GHz	Min η %
1N5153A	1N5150A	6.4	10				75	1100	0.05	0.5*	11.7	12	1.0	7.5	2.0	40
1N5154	1N5154	2.1*					35	1700	0.05	0.9	3.5	5.0	2.0	2.0	6.0	60
1N5155	1N5154	2.1*					35	1700	0.05	0.9	3.5	5.0	2.0	2.0	6.0	40
1N5155A	1N5150A	1.9	10				35	1700	0.05	0.9*	8.75	5.0	2.0	2.0	6.0	40
1N5156	1N5156	0.8	25				20	3600	0.05	1.1*	3.25*	2.6	5.0	1.0	10	38.5
1N5157	1N5156	0.8	25				20	3600	0.05	1.1*	3.25*	2.6	5.0	1.0	10	38.5
1N5421		210	20	4.1	4.0	100	210	200	0.025		0.25					
1N5422		340	20	4.1	4.0	100	210	200	0.025		0.25					
1N5423		680	20	4.1	4.0	100	210	150	0.025		0.25					
1N5424		680	20	4.2	4.0	100	115	300	0.010		0.25					
1N5425		1370	20	4.2	4.0	100	115	200	0.010		0.25					

TUNNEL DIODES

Index and Short-Form Specifications

This table contains a numerical listing and short-form specifications for tunnel diodes with EIA-registered 1N numbers.

KEY

TYPE	MATERIAL	I_P (mA)	I_P/I_V	V_P (mV)	C C_J* (pF)	f (GHz)
Numerical Listing of Registered Type Numbers	S = Silicon G = Germanium GA = Gallium Arsenide	Peak Current	Ratio of Peak Current to Valley Current	Forward Voltage measured at the Peak Point	Total Capacitance *Junction Capacitance	Resistive Cutoff Frequency

TUNNEL DIODES INDEX

TYPE	MATERIAL	I_P (mA)	I_P/I_V	V_P (mV)	C C_J* (pF)	f (GHz)
1N2927	S	0.10	2.5	75	80	
1N2927A	S	0.10	3.2	70	80	
1N2928	S	0.47	2.5	80	100	
1N2928A	S	0.47	3.2	74	100	
1N2929	S	1.0	2.5	80	150	
1N2929A	S	1.0	3.2	75	150	
1N2930	S	4.7	2.5	85	250	
1N2930A	S	4.7	3.2	79	250	
1N2931	S	10	2.5	85	400	
1N2931A	S	10	3.2	80	400	
1N2932	S	22	2.5	90	1200	
1N2932A	S	22	3.2	82	1200	
1N2933	S	47	2.5	90	1800	
1N2933A	S	47	3.2	83	1800	
1N2934	S	100	2.5	90	2500	
1N2934A	S	100	3.2	85	2500	
1N2939	G	1.0	10	65	15	2.2
1N2939A	G	1.0	7.0	60	10	
1N2940	G	1.0	7.7	65	10	2.2
1N2940A	G	1.0	4.4	65	7.0	
1N2941	G	4.7	7.9	65	50	2.6
1N2941A	G	4.7	4.4	65	30	
1N2969	G	2.2	7.6	65	25	2.5
1N2969A	G	2.2	4.5	65	15	
1N3113	GA	1.0	10		10	
1N3114	GA	2.2	10		10	
1N3115	GA	2.2	10		10	
1N3116	GA	4.7	10		15	
1N3117	GA	4.7	9.0		15	
1N3118	GA	10	10	160	20*	
1N3119	GA	10			20	
1N3120	GA	22	10			
1N3128	G	5.0	8.0	65	15	
1N3129	G	20	8.0	90	20	
1N3130	G	50	8.0	120	25	
1N3138	GA	50	13	260	30	
1N3149	G	10	7.7	65	90	2.6
1N3149A	G	10	4.4	65	50	
1N3150	G	22	7.6	65	125	2.2
1N3217	G	0.47	4.7		8.0	
1N3218	G	1.0	5.0		10	
1N3218A	G	1.0	5.0		5.0	
1N3219	G	2.2	5.0		20	
1N3219A	G	2.2	5.0		10	
1N3220	G	4.7	4.7		30	
1N3221	G	10	5.0	65	100	2.6
1N3221A	G	10	6.0		35	
1N3222	G	22	5.1		150	
1N3560	G	1.0	5.0	55	20	1.3
1N3561	G	1.0	8.0	55	20	1.3
1N3562	G	5.0	6.0	55	85	1.3
1N3712	G	1.0	5.0	65	10	2.3
1N3713	G	1.0	7.0	65	5.0	3.2
1N3714	G	2.2	4.2	65	25*	2.2
1N3715	G	2.2	7.0	65	10	3.0
1N3716	G	4.7	4.0	65	50	1.8
1N3717	G	4.7	7.6	65	25	3.4
1N3718	G	10	4.1	65	90	1.6
1N3719	G	10	7.0	65	50	
1N3720	G	22	4.2	65	150	1.6

TUNNEL DIODES INDEX (continued)

TYPE	MATERIAL	I_P (mA)	I_P/I_V	V_P (mV)	C C_J* (pF)	f (GHz)
1N3721	G	22	7.0	65	100	2.6
1N3847	G	5.0	6.0		25	
1N3848	G	10	6.0		25	
1N3849	G	20	6.0		30	
1N3850	G	50	6.0		40	
1N3851	G	100	6.0		40	
1N3852	G	5.0	8.0	70	15	
1N3853	G	10	8.0	75	15	
1N3854	G	20	8.0	85	20	
1N3855	G	50	8.0	105	25	
1N3856	G	100	8.0	115	25	
1N3857	G	5.0	8.0	70	8.0	
1N3858	G	10	8.0	75	8.0	
1N3859	G	20	8.0	85	10	
1N3860	G	50	8.0	105	12	
1N3948	S	4.7	3.5	80		
1N4393	S	0.10	2.5	75	80	
1N4393A	S	0.10	3.2	70	80	
1N4393B	S	0.10	3.5	65	80	
1N4394	S	0.22	2.5	80	90	
1N4394A	S	0.22	3.2	72	90	
1N4394B	S	0.22	3.6	67	90	
1N4395	S	0.47	2.5	80	100	
1N4395A	S	0.47	3.2	74	100	
1N4395B	S	0.47	3.5	69	100	
1N4396	S	1.0	2.5	80	150	
1N4396A	S	1.0	3.2	75	150	
1N4396B	S	1.0	3.5	70	150	
1N4397	S	2.2	2.5	80	200	
1N4397A	S	2.2	3.2	77	200	
1N4397B	S	2.2	3.5	73	200	
1N4398	S	4.7	2.5	85	250	
1N4398A	S	4.7	3.2	79	250	
1N4398B	S	4.7	3.5	74	250	
1N4399	S	10	2.5	85	400	
1N4399A	S	10	3.2	80	400	
1N4399B	S	10	3.5	75	400	

4-LAYER DIODES

INDEX AND SHORT-FORM SPECIFICATIONS

This table contains a numerical listing and short-form specifications with EIA-registered 1N numbers.

KEY

TYPE	REPLACE-MENT	REF.	$V_{(BR)F}$ (volts)		I_H (mA)		V_F @	I_F	I_F (mA)	P_D
			(min)	(max)	(min)	(max)	(volts)	(mA)	(max)	(mW)

Numerical listing of Registered Type Numbers

Type number of recommended replacement or nearest electrical equivalent fully characterized in this book

Reference device number indicates specific Data Sheet on which device is characterized

Forward Breakover (Switching) Voltage required to switch the device from the "blocking" state to the "on" state (in volts dc)

Holding Current — the value of current required to hold the diode in the conducting state

Forward Voltage — the forward voltage across the device at a specified forward current, I_F

Forward Current — the continuous or dc value of forward current during the "on" state

Steady state power dissipation

4-LAYER DIODES INDEX

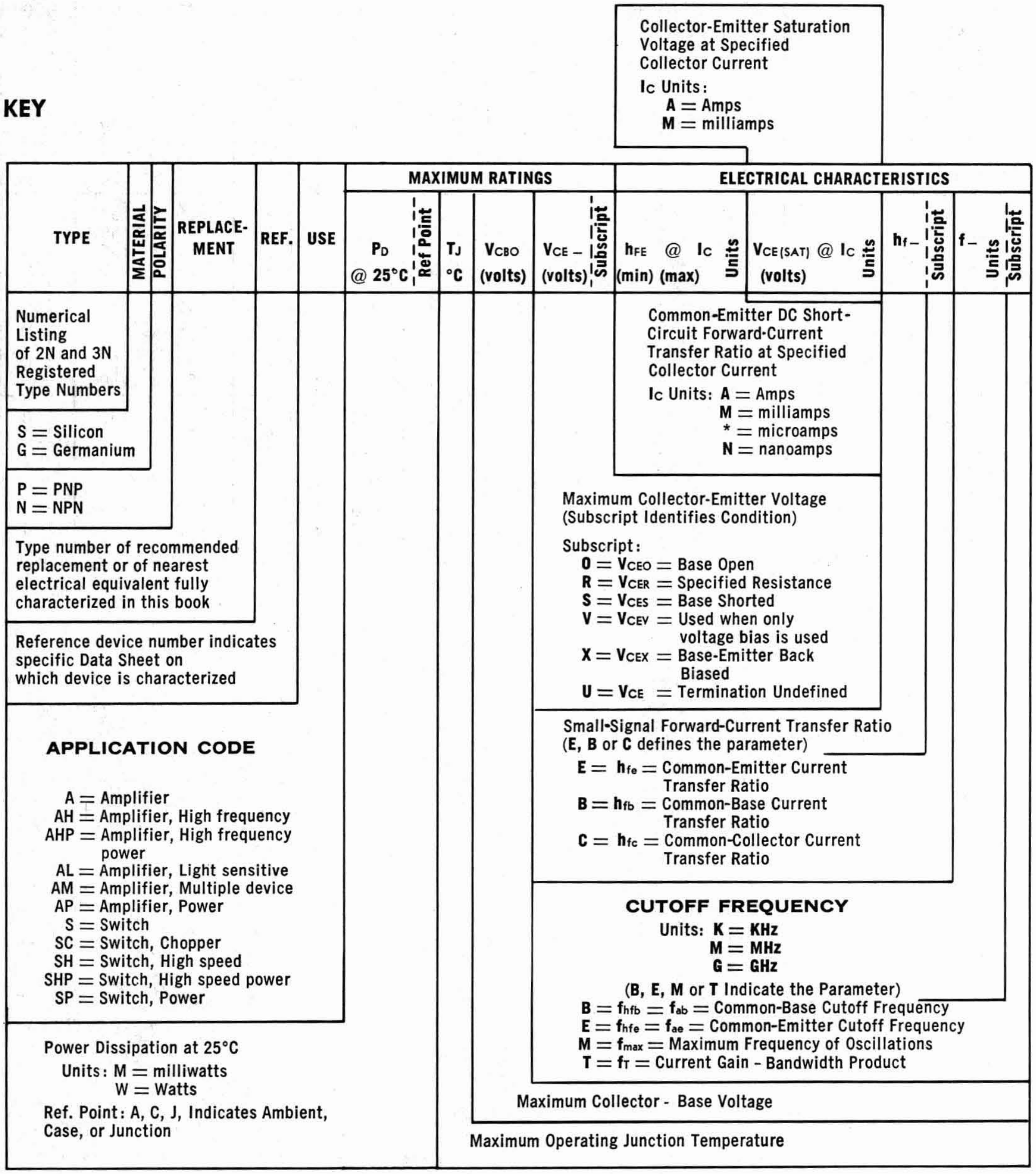
TYPE	REPLACE-MENT	REF.	$V_{(BR)F}$ (volts)		I_H (mA)		V_F	@ I_F	I_F (mA)	P_D
			(min)	(max)	(min)	(max)	(volts)	(mA)	(max)	(mW)
1N3299			36	44	1.0	15				150
1N3300			14.4	21.6	1.0	15	1.5	30	200	400
1N3300A			16.2	19.8	1.0	15	1.5	30	200	400
1N3301			17.6	26.4	1.0	15	1.5	30	200	400
1N3301A			19.8	24.2	1.0	15	1.5	30	200	400
1N3302			21.6	32.4	5.0	20	1.5	30	200	400
1N3302A			24.3	29.7	5.0	20	1.5	30	200	400
1N3303			26.4	39.6	5.0	20	1.5	30	200	400
1N3303A			29.7	36.3	5.0	20	1.5	30	200	400
1N3304			31.2	46.8	5.0	20	1.5	30	200	400
1N3304A			35.1	42.9	5.0	20	1.5	30	200	400
1N3489			16	24	1.0	6.0				150
1N3489A			16	24	1.0	6.0				150
1N3490			16	24	14	45				150
1N3771						4.0	1.2			
1N3772						50	1.2			
1N3831			16	24	0.5	15	1.2	15	150	150
1N3832			21	29	0.5	15	1.2	15	150	150
1N3833			26	34	0.5	15	1.2	15	150	150
1N3834			31	39	0.5	15	1.2	15	150	150
1N3835			36	44	0.5	15	1.2	15	150	150
1N3836			41	49	0.5	15	1.2	15	150	150
1N3837			46	54	0.5	15	1.2	15	150	150
1N3838			90	110	0.5	15	1.2	15	150	150
1N3839			16	24	14	50	1.2	50	150	150
1N3840			21	29	14	50	1.2	50	150	150
1N3841			26	34	14	50	1.2	50	150	150
1N3842			31	39	14	50	1.2	50	150	150
1N3843			36	44	14	50	1.2	50	150	150
1N3844			41	49	14	50	1.2	50	150	150
1N3845			46	54	14	50	1.2	50	150	150
1N3846			90	110	14	50	1.2	50	150	150
1N3935				30		30				
1N3936				20		8.0				
1N3937				100		3.5				
1N5158	M4L3052	1N5158	8.0	10	1.0	20	1.5	150	150	150
1N5159	M4L3053	1N5158	9.0	11	1.0	20	1.5	150	150	150
1N5160	M4L3054	1N5158	10	12	1.0	20	1.5	150	150	150

NUMERICAL INDEX

Numerical Listing of EIA-Registered 2N and 3N Type Numbers and Short-Form specifications for Bi-Polar Transistors.

This table serves two functions. It provides a complete listing of EIA-registered 2N and 3N type numbers, for device identification, and gives short-form specifications for bi-polar transistors. Type numbers for devices other than bi-polar transistors (i.e. thyristors, field-effect transistors, etc.), may be listed in blocks (2N — thru 2N —) with reference to subsequent tables where such devices are sequentially tabulated and short-form specifications are given.

KEY



						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS									
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CBO} (volts)	V_{CE} – (volts)	Subscript	h_{FE} (min) (max)	@ I_C	Units	$V_{CE(SAT)}$ (volts)	@ I_C	Units	h_f –	Subscript	f –	Units	Subscript

Collector-Emitter Saturation Voltage at Specified Collector Current

I_C Units:
A = Amps
M = milliamps

Numerical Listing of 2N and 3N Registered Type Numbers

S = Silicon
G = Germanium

P = PNP
N = NPN

Type number of recommended replacement or of nearest electrical equivalent fully characterized in this book

Reference device number indicates specific Data Sheet on which device is characterized

APPLICATION CODE

A = Amplifier
AH = Amplifier, High frequency
AHP = Amplifier, High frequency power
AL = Amplifier, Light sensitive
AM = Amplifier, Multiple device
AP = Amplifier, Power
S = Switch
SC = Switch, Chopper
SH = Switch, High speed
SHP = Switch, High speed power
SP = Switch, Power

Power Dissipation at 25°C

Units: M = milliwatts
W = Watts

Ref. Point: A, C, J, Indicates Ambient, Case, or Junction

Common-Emitter DC Short-Circuit Forward-Current Transfer Ratio at Specified Collector Current

I_C Units: A = Amps
M = milliamps
* = microamps
N = nanoamps

Maximum Collector-Emitter Voltage (Subscript Identifies Condition)

Subscript:
O = V_{CEO} = Base Open
R = V_{CER} = Specified Resistance
S = V_{CES} = Base Shorted
V = V_{CEV} = Used when only voltage bias is used
X = V_{CEX} = Base-Emitter Back Biased
U = V_{CE} = Termination Undefined

Small-Signal Forward-Current Transfer Ratio (E, B or C defines the parameter)

E = h_{fe} = Common-Emitter Current Transfer Ratio
B = h_{fb} = Common-Base Current Transfer Ratio
C = h_{fc} = Common-Collector Current Transfer Ratio

CUTOFF FREQUENCY

Units: K = KHz
M = MHz
G = GHz

(B, E, M or T Indicate the Parameter)

B = f_{hfb} = f_{ab} = Common-Base Cutoff Frequency
E = f_{hfe} = f_{ae} = Common-Emitter Cutoff Frequency
M = f_{max} = Maximum Frequency of Oscillations
T = f_T = Current Gain - Bandwidth Product

Maximum Collector - Base Voltage

Maximum Operating Junction Temperature

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N21		P			S	0.12W	A	85	100											
2N22	G	P			S	145M	A	55	100	100	O						2.0	B		
2N23	G	P			S	105M	A	55	40	50	O						2.0	B		
2N24	G	P			A	145M	A	50	30	30	O						2.2	B		
2N25	G	P			AH	200M	A	60	50	50	O						2.5	B	3.0M	B
2N26	G	P			S	90M	A	55	30	40	O									
2N27		N			A	50M	A	85	35								0.95	B	1.0M	B
2N28		N			A	50M	A	85	30								0.94	B	0.5M	B
2N29		N			A	50M	A	85	35								0.96	B	1.0M	B
2N30	G	P			A	100M	A	40	35										3.0M	B
2N31	G	P			A	100M	A	40	35										3.0M	B
2N32	G	P			S	50M	A		40											
2N32A	G	P			S	50M	A		40											
2N33	G	P			AH	30M	A		8.5											
2N34	G	P	2N1191	2N1191	A	50M	A		25											
2N34A	G	P			A	50M	A		25											
2N35	G	P			A	50M	A		25											
2N35A	G	N																		
2N36	G	P	2N1191	2N1191	A	50M	A	50	20											
2N37	G	P	2N1191	2N1191	A	50M	A	20									30	E		
2N38	G	P	2N1191	2N1191	A	50M	A										15	E		
2N38A	G	P			A	50M	A	20	20											
2N41	G	P			A	50M	A		25											
2N43	G	P			A	240M	A	85	45	30	O	34		20M			30	E	500K	B
2N43A	G	P	2N525	2N524	A	240M	A	85	45	30	O	34	65	20M			30	E	500K	B
2N44	G	P	2N524	2N524	A	240M	A	85	45	30	O	18	43	20M					500K	B
2N45	G	P	2N524	2N524	A	240M	A	85	45	30	O	18		20M					500K	B
2N46	G	P			A	50M	A		25											
2N47	G	P	2N1191	2N1191	A	50M			35											
2N48	G	P			A	50M			35											
2N49	G	P	2N1191	2N1191	A	50M			35											
2N50	G				S	50M	A	50	15											
2N51	G				S	0.1W	A	50	50											
2N52	G				S	0.12W	A	50	50											
2N53	G				S	0.1W	A	50	50											
2N54	G	P	2N1191	2N1191	A	0.2W	A	60	45											
2N55	G	P	2N1191	2N1191	A	0.2W	A	60	45											
2N56	G	P	2N1191	2N1191	A	0.2W	A	60	45											
2N57	G	P			AP	20W	C		60											
2N59	G	P	2N1193	2N1191	A	180M	A	85	25	25	O									
2N59A	G	P			A	180M	A	85	40	40	O									
2N59B	G	P			A	180M	A	85	50	50	O									
2N59C	G	P			A	180M	A	85	60	60	O									
2N60	G	P	2N1193	2N1191	A	180M	A	85	25	25	O									
2N60A	G	P			A	180M	A	85	40	40	O									
2N60B	G	P			A	180M	A	85	50	50	O									
2N60C	G	P			A	180M	A	85	60	60	O									
2N61	G	P	2N1192	2N1191	A	180M	A	85	25	25	O									
2N61A	G	P			A	180M	A	85	40	40	O									
2N61B	G	P			A	180M	A	85	50	50	O									
2N61C	G	P			A	180M	A	85	60	60	O									
2N62	G	P	2N1191	2N1191	A	50M			35											
2N63	G	P	2N1191	2N1191	A	102M	A	85	44	44	S									
2N64	G	P	2N1191	2N1191	A	102M	A	85	30	30	S									
2N65	G	P	2N1193	2N1191	A		A	85	24	24	S									
2N66		P			AP	27.5W	C	80	60	40										
2N67		P			S	0.1W	A	85	50											
2N68	G	P			AP	2.0W	A	70	25											
2N71		P			AP	1.0W	A	60	75	50	U									
2N72	G	P			S	50M	A		40											
2N73		P			SC	0.2W	A			50	U									
2N74		P			S	0.2W	A			50	U									
2N75		P			S	0.2W	A			20	U									
2N76	G	P	2N319	2N319	A	5.0M	J	60	20										500K	B
2N77	G	P	2N1191	2N1191	A	35M	A		25											
2N78	G	N			AH	65M	A	85	15	15	O	45	135	1.0M			0.97	B	5.0M	B
2N78A	G	N			AH	65M	A	85	20	15	O	45	135	1.0M			0.97	B	5.0M	B
2N79	G	P	2N1191	2N1191	A	35M	A		35											
2N80	G	P			A	50M	A		25											
2N81	G	P	2N1191	2N1191	A	50M	A	100		20	O						20	E		
2N82	G	P	2N1191	2N1191	A	35M	A	71	20			20	60	1.0M						
2N94	G	N			AH	150M	A	85	20	20	R	20	80	1.0M			7.5		2.0M	B
2N94A	G	N			AH	150M	A	85	20	20	R	20	80	1.0M			5.0		5.0M	B
2N95		N			AP	2.5W	A	70	25											
2N96	G	P			A	50M	A		30										500K	B
2N97	G	N			A	50M	A	75	30								5.0	E	0.5M	B
2N97A	G	N			A	50M	A	85	40								5.0	E	0.5M	B
2N98	G	N			A	50M	A	75	40								19	E	0.8M	B
2N98A	G	N			A	50M	A	85	40								24	E	0.8M	B
2N99	G	N			A	50M	A	75	40								19	E	2.0M	B
2N100		N			A	25M	A	50	25								99	E	2.5M	B
2N101	G	P			AP	1.0W	A	70	25											
2N102	G	N			AP	1.0W	A	70	25											
2N103	G	N			A	50M	A	75	35								1.5	E		
2N104	G	P	2N650	2N650	A	150M	A	70	30											
2N105	G	P			A	35M	A	50	35											
2N106	G	P	2N1191	2N1191	A	102M	A	85	6.0											
2N107	G	P	2N464	2N464	A	50M	A	60	12	6.0	O						0.95	B		

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N108	G	P			A	50M	A													
2N109	G	P	2N1192	2N1191	A	165M	A	71	35	25	O	65	115	50M	0.15	50M	50	E		
2N110	G	P			S	0.2W	A	85	50						2.5	18M				
2N111	G	P			AH	150M	A	85	30	15	O	15		1.0M						
2N111A	G	P			AH	150M	A	85	30	15	O	15		1.0M						
2N112	G	P			AH	150M	A	85	30	15	O	15		1.0M						
2N112A	G	P			AH	150M	A	85	30	15	O	15		1.0M						
2N113	G	P			AH	96M	A	85	10											
2N114	G	P			AH	96M	A	85	10											
2N115	G	P			SP	50W	C	75	32	32	R		110	30M						
2N117	S	N			SH	150M	C	150	30								0.9	B	1.0M	B
2N118	S	N			SH	150M	C	150	30								0.95	B	2.0M	B
2N118A	S	N			SH	150M	C	150	45											
2N119	S	N			SH	150M	C	150	30								0.974	B	2.0M	B
2N120	S	N			AH	150M	C	175	45			76	333				0.987	B		
2N122	S	N			AP	8.75W	C	150	120			3.0		100M						
2N123	G	P			SH	50M	J	85	20	15	O						0.98	B	5.0M	B
2N124	G	N			S	50M	A	75	10			12	24	5.0M	0.3	5.0M			0.3M	B
2N125	G	N			S	50M	A	75	10			24	48	5.0M	0.3	5.0M			5.0M	B
2N126	G	N			S	50M	A	75	10			48	100	5.0M	0.3	5.0M			5.0M	B
2N127	G	N			S	50M	A	75	10			100	200	5.0M	0.3	5.0M			5.0M	B
2N128	G	P			AH	30M	A	85	10	4.5	U						19	E	45M	M
2N129	G	P			AH	30M	A	85	10	4.5	U						11.5	E	30M	M
2N130	G	P	2N1191	2N1191	A	85M	A	85	44											
2N130A	G	P	2N650	2N650	A	100M	A	85	45	40	O						14	E		
2N131	G	P	2N1192	2N1191	A	85M	A	85	30											
2N131A	G	P	2N651	2N650	A	100M	A	85	45	30	O						27	E		
2N132	G	P	2N1192	2N1191	A	85M	A	85	24											
2N132A	G	P	2N651	2N650	A	100M	A	85	35	20	O									
2N133	G	P	2N1192	2N1191	A	85M	A	85	30											
2N133A	G	P	2N651	2N650	A	100M	A	85	35	20	O									
2N135	G	P			AH	100M	A	85	20	12	R						20	E	4.5M	B
2N136	G	P			AH	100M	A	85	20	12	R						40	E	6.5M	B
2N137	G	P			AH	100M	A	85	10	6.0	R						60	E	10M	B
2N138	G	P			A	50M	A	50	24											
2N138A	G	P			A	150M	A	85	45	30	O	10		50M						
2N138B	G	P			A	100M	A	85	45											
2N139	G	P			A	80M	A	70	16											
2N140	G	P			A	80M	A	70	16											
2N141	G	P			AP	1.5W	A	25	60	30										
2N142	G	N			AP	1.5W	A	25	60	30										
2N143	G	P			AP	1.0W	A	25	60	30										
2N144	G	N			AP	1.0W	A	25	60	30										
2N145	G	N			AH	65M	A	75		20	U									
2N146	G	N			AH	65M	A	75		20	U									
2N147	G	N			AH	65M	A	75		20	U									
2N148	G	N			AH	65M	A	75		16	U									
2N148A	G	N			AH	65M	A	75		32	U									
2N149	G	N			AH	65M	A	75		16	U									
2N149A	G	N			AH	65M	A	75		32	U									
2N150	G	N			AH	65M	A	75		16	U									
2N150A	G	N			AH	65M	A	75		32	U									
2N155	G	P	2N176	2N176	AP	1.5W	A	85	30			24		0.5A	0.65	0.5A				
2N156	G	P	2N176	2N176	AP	1.5W	A	85	30			24		0.5A	0.6	1.0A			145K	B
2N157	G	P	2N1531	2N1529	AP	1.5W	A	85	60			20		0.5A					100K	B
2N157A	G	P	2N1532	2N1529	AP	1.5W	A	85	90			20		0.5A					100K	B
2N158	G	P	2N2139	2N2137	AP	1.5W	A	85	60			21		0.5A	0.75	1.0A			145K	B
2N158A	G	P	2N2141	2N2137	AP	1.5W	A	95	80	60	O	21		0.5A	0.75	1.0A			4.0K	E
2N160	S	N			A	0.15W	A		40			9.0	19							
2N160A	S	N			A	0.15W	A		40			9.0	19							
2N161	S	N			A	0.15W	A		40			19	39							
2N161A	S	N			A	0.15W	A		40			19	39							
2N162	S	N			A	0.15W	A		40			19	199							
2N162A	S	N			A	0.15W	A		40			19	199							
2N163	S	N			A	0.15W	A		40			39	199							
2N163A	S	N			A	0.15W	A		40			39	199							
2N166	G	N			AH	25M	A	50		6.0	O									
2N167	G	N			AH	75M	A	85	30	30	O						0.952	B	5.0M	B
2N167A	G	N			SH	75M	A	85	30	30	O	17	90	8.0M			0.952	B	5.0M	B
2N168	G	N			AH	55M	A	75	15	15	O						20	E		
2N168A	G	N			AH	65M	A	85	15	15	O						20	E		
2N169	G	N			AH	65M	A	85	15	15	O						30	E		
2N169A	G	N			A	65M	A	85	25	25	O						30	E		
2N170	G	N			AH	25M	A	50		6.0	O									
2N172	G	N			AH	65M	A	75		16	U									
2N173	G	P		2N277	AP	10W	C	95	60	50	S	35	70	5.0A	1.0	12A				
2N174	G	P		2N173	SP	100W	C	95	80	70	S	25	50	5.0A	0.9	12A				
2N174A	G	P			SP	100W	C	95	80	70	S	40	80	1.2A	0.7	12A			100K	B
2N175	G	P	2N1192	2N1191	AH	50M	A	71	10											
2N176	G	P		2N176	AH	90W	C	80	40	30	R	25		0.5A	0.4	3.0A			4.0K	E
2N178	G	P		2N178	A	40W	C	90	30	30	R	15	45	0.5A	0.6	3.0A			5.0K	E
2N179	G	P	2N176	2N176	A															
2N180	G	P	2N1192	2N1191	A	0.15W	A	75	30											
2N181	G	P	2N1192	2N1191	A	0.25W	A	75	30											
2N182	G	N			S	0.1W	A	75	25											
2N183	G	N			S	0.1W	A	75	25											
2N184	G	N			S	0.1W	A	75	25											

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	$V_{CE—}$ (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	$h_{f—}$	Subscript	f— Units	Subscript
2N185	G	P	2N650	2N650	A	150M	A	50	20								35	E		
2N186	G	P	2N1191	2N1191	A	100M	A	85	25	25	R								800K	B
2N186A	G	P	2N1191	2N1191	A	200M	A	85	25	25	R								800K	B
2N187	G	P	2N1191	2N1191	A	100M	A	85	25	25	R								1.0M	B
2N187A	G	P	2N1191	2N1191	A	200M	A	85	25	25	R								1.0M	B
2N188	G	P	2N1191	2N1191	A	100M	A	85	25	25	R								1.2M	B
2N188A	G	P	2N1191	2N1191	A	200M	A	85	25	25	R								1.2M	B
2N189	G	P	2N1191	2N1191	A	75M	A	85	25	25	R								800K	B
2N190	G	P	2N1191	2N1191	A	75M	A	85	25	25	R								1.0M	B
2N191	G	P	2N1192	2N1191	A	75M	A	85	25	25	R								1.2M	B
2N192	G	P	2N1193	2N1191	A	75M	A	85	25	25	R								1.5M	B
2N193	G	N			AH	150M	A	85	18	18	R						4.0		2.0M	B
2N194	G	N			AH	50M	A	75	15	15	R						4.8		2.0M	B
2N194A	G	N			AH	50M	A	75	20	20	R						5.0		2.0M	B
2N206	G	P			A	75M	A		30											
2N207	G	P	2N1191	2N1191	A	50M	A	65	12	12	V						35	E		
2N207A	G	P	2N1193	2N1191	A	50M	A	65	12	12	V						35	E		
2N207B	G	P	2N1190	2N1189	A	50M	A	65	12	12	V						35	E		
2N211	G	N			AH	50M	A	75	10	10	R						3.8		2.0M	E
2N212	G	N			AH	150M	A	85	18	18		10		1.0M			10	E	4.0M	B
2N213	G	N			A	50M	A	75	40	25	R				0.6	100M	70	E		
2N213A	G	N			A	150M	A	85	40	25	R				1.0	100M	100	E	10K	E
2N214	G	N			A	125M	A	75	40			50	100	35M					600K	B
2N215	G	P	2N1189	2N1189	A	150M	A	70	30											
2N216	G	N			AH	50M	A	75	15								3.9	E	2.0M	B
2N217	G	P	2N1192	2N1191	A	150M	A	71	35	25	O	65	115	50M	0.15	50M				
2N218	G	P			A	80M	A	70	16											
2N219	G	P			A	80M	A	70	16											
2N220	G	P	2N1189	2N1189	A	50M	A	71	10											
2N223	G	P	2N1193	2N1191	A	100M	A	65		18	V						39	E		
2N224	G	P	2N1192	2N1191	A	250M	A	75	25			60	120	100M	0.25	100M				
2N225	G	P	2N1193	2N1191	A	250M	A	75	25			60	120	100M	0.25	100M				
2N226	G	P	2N1192	2N1191	A	250M	A	75	30			35	105	100M	0.25	100M				
2N227	G	P			A	250M	A	75	30			35	105	100M	0.25	100M				
2N228	G	P			A	50M	A	75	25			50	100	35M					600K	B
2N229	G	N			A	50M	A	75	10										550K	B
2N230	G	P			AP	15W	C	85	60	30	U	60	106	0.5A	0.8	2.0A			12K	E
2N231	G	P			AH	9.0M	A	55	4.5	4.5	V						19	E	30M	M
2N232	G	P			AH	9.0M	A	55	4.5	4.5	V						9.0	E	20M	M
2N233	G	N			AH	50M	A	75	10								3.0	E		
2N233A	G	N			AH	50M	A	75	10								3.5	E		
2N234	G	P	2N554	2N178	AP			90		25	R									
2N234A	G	P	2N555	2N178	AP	25W	C	90		25	R									
2N235	G	P	2N350A	2N350A	AP			90		40	U				0.8	1.0A				
2N235A	G	P	MP695A		AP	25W	C	90		40	U				0.8	1.0A				
2N235B	G	P	MP695B		AP	25W	C	85	50	35	R				0.8	1.0A			5.0K	E
2N236	G	P	2N350A	2N350A	AP			95		35	R				1.0	3.0A				
2N236A	G	P	2N351A	2N350A	AP	25W	C	95		35	R				1.0	3.0A				
2N236B	G	P	2N376A	2N350A	AP	25W		95	50	35	R				1.0	3.0A			5.0K	E
2N237	G	P			A	150M	A	55	45								0.98	B	500K	B
2N238	G	P	2N1192	2N1191	A	50M	A	60	20											
2N240	G	P			S	25M	A	85	6.0	6.0	S				0.1	8.0M	16	E	25M	T
2N241	G	P	2N321	2N319	A	100M	A	85	25	25	R								1.3M	B
2N241A	G	P	2N321	2N319	A	200M	A	85	25	25	R								1.3M	B
2N242	G	P		2N242	A	20W	C	85	45	45	R								5.0K	B
2N243	S	N			A	750M	C	150	60								0.9	B		
2N244	S	N			A	750M	C	150	60								0.961	B		
2N247	G	P			AH	80M	A		40											
2N248	G	P			A			75	25											
2N249	G	P			A	350M	A	60	25								30	E		
2N250	G	P	2N3611	2N3611	AP	12W	C	80	30			30		500M					8.0K	E
2N250A	G	P	2N3611	2N3611	AP	90W	C	100	40	35	V	25	100	3.0A	0.7	3.0A			200K	T
2N251	G	P	2N1530	2N1529	AP	12W	C	80	60			30		500M					8.0K	E
2N251A	G	P	2N3616	2N3615	AP	90W	C	100	60	55	V	25	100	3.0A	0.7	3.0A			200K	T
2N252	G	P			AH	30M	C	55		16	O									
2N253	G	N			AH	65M	C	75		12	O									
2N254	G	N			AH	65M	C	75		20	O									
2N255	G	P	MP708		AP	1.5W	A	85	15											
2N255A	G	P			AP	20W	C	85	15	15	R									
2N256	G	P	2N555	2N554	AP	1.5W	A	85	30											
2N256A	G	P			AP	20W	C	85	30	25	R									
2N257	G	P	MP707		AP	25W	C	85	40										7.0K	
2N258	S	P			A	250M	A	160	30	30	O						15	E		
2N259	S	P			A	250M	A	160	30	30	O						32	E		
2N260	S	P			A	0.2W	A	150	10											
2N260A	S	P			A	0.2W	A	150	30											
2N261	S	P			A	0.2W	A	150	75											
2N262	S	P			A	0.2W	A	150	10											
2N262A	S	P			A	0.2W	A	150	30											
2N263	S	N			A	150M	A	150	45	30	O	45	150	10M	1.5	10M	39	E	20M	B
2N264	S	N			A	125M	A	150	45	30	O	20	55	10M	1.5	10M	0.95	B	10M	B
2N265	G	P	2N1175	2N1413	A	75M	A	85		25	R								1.5M	B
2N266	G	P			A	75M	A	85		18	R								800K	B
2N267	G	P			AH	80M	A		40											
2N268	G	P	2N1530	2N1529	AP	25W	C	85	80										6.0K	
2N268A	G	P	MP759		SP	10W	C	90	80	60	V	20		2.0A	1.0	2.0A				
2N269	G	P			S	120M	A	85	25	24	O									
2N270	G	P	2N1193	2N1191	A	150M	A	50	25											

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N271	G	P			AH	150M	A	85	30	10	O									
2N271A	G	P			AH	150M	A	85	30	10	O									
2N272	G	P			A	150M	A	85	30	24	O						60	E		
2N273	G	P			A	150M	A	85	45	25	S	30		50M						
2N274	G	P			AH	120M	A	100	40	40	O	20	175	1.5M			20	E		
2N277	G	P		2N277	AP	70W	C	95	40	40	S	35	70	5.0A						
2N278	G	P		2N277	AP	70W	C	95	50	45	S	35	70	5.0A	1.0	12A				
2N279	G	P	2N650	2N650	A	125M	A	75		20							20	E		
2N280	G	P	2N650	2N650	A	125M	A	75		20							30	E		
2N281	G	P	2N651	2N650	A	167M	C	75	16	16	R	45	120						0.35M	B
2N282	G	P			A															
2N283	G	P	2N650	2N650	S	125M	A	75	20	20							30	E		
2N284	G	P			S	125M	A	75	32	32		15							0.35M	B
2N284A	G	P			S	125M	A	75	60	60		15							0.35M	B
2N285	G	P	2N285A		AP	25W	C	95		35	R				0.5	1.0A				
2N285A	G	P			AP	25W	C	95		35	R				0.5	1.0A				
2N290	G	P			AP	55W	C	95	70											
2N291	G	P	2N1191	2N1191	A	180M	A	50	25								30	E		
2N292	G	N			AH	65M	A	85	15	15	O	6.0	44							
2N293	G	N			AH	65M	A	85	15	15	O	6.0	55							
2N296	G	P	2N1531	2N1529	A	20W	C	85	60			19		1.0A	1.0	1.0A			4.0K	B
2N297	G	P	2N297A	2N297A	AP	35W	C	95	60	50	S	40	100	0.5A	1.0	2.0A			5.0K	E
2N297A	G	P		2N297A	AP	35W	C	95	60	50	S	40	100	0.5A	1.0	2.0A			5.0K	E
2N299	G	P			AH	20M	A	85	5.0	4.5	V								90M	M
2N300	G	P			AH	20M	A	85	5.0	4.5	V						11	E	85M	M
2N301	G	P			AP	11W	A	85	40											
2N301A	G	P			AP	11W	A	85	60											
2N302	G	P			AH	150M	A	85	30	10	O						45	E	7.0M	B
2N303	G	P			AH	150M	A	85	30	10	O						75	E	14M	B
2N306	G	N			A	50M	A	75	20	15	R				0.5	0.1A	25	E	0.6M	B
2N307	G	P		2N242	AP	25W	C	75	35	35	R	20		0.2A	1.0	0.2A			3.0K	E
2N307A	G	P		2N242	AP	25W	C	75	35	35	R	20		0.2A	0.8	1.0A			3.5K	E
2N308	G	P			AH	30M	A	55		20	O									
2N309	G	P			AH	30M	A	55		20	O									
2N310	G	P			AH	30M	A	55		30	O									
2N311	G	P			SP	75M	A	85	15	15	O	25	75	10M	0.075	10M				
2N312	G	N			SP	75M	A	85	15	15	O	25	75	10M	0.075	10M				
2N315	G	P			S	100M	A	85	20	15	O	15	30	100M	0.15	100M				
2N315A	G	P			S	150M	A	100	30	20	O	20	50	100M	0.15	100M				
2N315B	G	P			S	150M	A	100	30	20	O	20	50	100M	0.15	100M				
2N316	G	P			S	100M	A	85	20	10	O	20	50	200M	0.18	200M				
2N316A	G	P			S	150M	A	100	30	15	O	20	50	200M	0.18	200M				
2N317	G	P			S	100M	A	85	20	6.0	O	20	60	400M	0.2	400M				
2N317A	G	P			S	150M	A	100	25	10	O	20	60	400M	0.2	400M				
2N318	G	P			AL	50M	A		12											
2N319	G	P		2N319	A	225M	A	85		20	R									
2N320	G	P		2N319	A	225M	A	85		20	R									
2N321	G	P		2N319	A	225M	A	85		20	R									
2N322	G	P		2N322	A	140M	A	60	18	18	R	34	65	20M					1.0M	B
2N323	G	P		2N322	A	140M	A	60	18	18	R	53	125	20M					1.5M	B
2N324	G	P		2N322	A	140M	A	60	18	18	R	72	198	20M					2.0M	B
2N325	G	P	2N3611	2N3611	A	12W	C	85	35	35	S	30	60	500M	0.6	500M			150K	B
2N326	G	N			A	7.0W	C	85	35	35	S	30	60	500M	0.6	500M			150K	B
2N327	S	P			A	350M	A	160	50								9.0	E		
2N327A	S	P			AM	385M	A	160	50	40	O	9.0	22	3.0M	0.3	5.0M				
2N327B	S	P			AM	385M	A	200	50	40	O	9.0	22	3.0M	0.3	5.0M				
2N328	S	P			A	350M	A	160	35								18	E		
2N328A	S	P			AM	385M	A	160	50	35	O	18	44	3.0M	0.5	10M				
2N328B	S	P			AM	385M	A	200	50	35	O	18	44	3.0M	0.5	10M				
2N329	S	P			A	350M	A	160	30								36	E		
2N329A	S	P			AM	385M	A	160	50	30	O	36	88	3.0M	0.6	15M				
2N329B	S	P			AM	385M	A	200	50	30	O	36	88	3.0M	0.6	15M				
2N330	S	P			A	350M	A	160	45								9.0	E		
2N330A	S	P			AM	385M	A	160	50	30	O									
2N331	G	P		2N331	A	200M	A	71	30											
2N332	S	N			AH	150M	A	175	45			9.0	20				0.9	B		
2N332A	S	N			A	500M	A	175	45	45	O				1.0	5.0M	0.9	B	2.5M	B
2N333	S	N			AH	150M	A	175	45			18	40				0.948	B		
2N333A	S	N			A	500M	A	175	45	45	O				1.0	5.0M	0.948	B	2.5M	B
2N334	S	N			AH	150M	A	175	45			18	86				0.948	B		
2N334A	S	N			A	500M	A	175	45	45	O				1.0	5.0M	0.948	B	8.0M	B
2N334B	S	N			A	500M	A	175	60	60	O	15	85	1.0M	1.0	5.0M	18	E	8.0M	B
2N335	S	N			AH	150M	A	175	45			36	86				0.973	B		
2N335A	S	N			A	500M	A	175	45	45	O				1.0	5.0M	0.973	B	2.5M	B
2N335B	S	N			A	500M	A	175	60	60	O	28	90	1.0M	1.0	5.0M	37	E	2.5M	B
2N336	S	N			AH	150M	A	175	45			76	333				0.987	B		
2N336A	S	N			A	500M	A	175	45	45	O				1.0	5.0M	0.987	B	2.5M	B
2N337	S	N			S	125M	C	150	45			20	55	10M					10M	B
2N337A	S	N			A	500M	A	175	45			20	55	10M			19	E	15M	B
2N338	S	N			S	125M	C	150	45			45	150	10M					20M	B
2N338A	S	N			A	500M	A	175	45			45	150	10M			39	E	25M	B
2N339	S	N			A	1.0W	C	150	55	55	O						0.9	B		
2N339A	S	N			AH	3.0W	A	200	60	60	O	20	80				25	E	10M	T
2N340	S	N			A	1.0W	C	150	85	85	O						0.9	B		
2N340A	S	N			AH	3.0W	A	200	85	85	O	20	80				25	E	10M	T
2N341	S	N			A	1.0W	C	150	125	85	O						0.9	B		
2N341A	S	N			AH	3.0W	A	200	125	125	O	20	80				25	E	10M	T

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N342	S	N			A	1.0W	C	150	60	60	O						0.9	B		
2N342A	S	N			A	1.0W	C	150	85	85	O						0.9	B		
2N342B	S	N			A	750M	A	175	85	85	O						9.0	E		
2N343	S	N			A	1.0W	C	150	60	60	O						0.966	B		
2N343A	S	N			A	1.0W	C	150	60	60	O						0.966	B		
2N343B	S	N			A	750M	A	175	65	65	O						28	E		
2N344	G	P			AH	20M	A	55	5.0	5.0	V						11	E	30M	M
2N345	G	P			AH	20M	A	55	5.0	5.0	V						25	E	30M	M
2N346	G	P			AH	20M	A	55	5.0	5.0	V						10	E	60M	M
2N350	G	P			AP	10W	A	100	50	40	O	20	60	700M						
2N350A	G	P		2N350A	AP	90W	J	100	50	40	S	20	60	0.7A	1.75	3.0A			5.0K	E
2N351	G	P			AP	10W	A	100	50	40	O	25	90	700M						
2N351A	G	P		2N350A	AP	90W	J	100	50	40	S	25	90	0.7A	1.75	4.0A			5.0K	E
2N352	G	P	2N1536	2N1529	AP	25W	C	100		40	R	30	140	1.0A					10K	E
2N353	G	P	2N1536	2N1529	AP	30W	C	100		40	R	40	150	1.0A					7.0K	E
2N354	S	P			AH	150M	A	140	25	25	U						9.0	E	8.0M	M
2N355	S	P			S	150M	A	140	10	10	U				0.15	5.0M	9.0	E	8.0M	M
2N356	G	N			S	100M	A	85	20	18	O	20	50	100M	0.2	100M				
2N356A	G	N			S	150M	A	100	30	20	O	20	50	100M	0.2	100M				
2N357	G	N			S	100M	A	85	20	15	O	20	50	200M	0.2	200M				
2N357A	G	N			S	150M	A	100	30	20	O	25	75	200M	0.2	200M				
2N358	G	N			S	100M	A	85	20	12	O	20	50	300M	0.2	300M				
2N358A	G	N			S	150M	A	100	30	15	O	25	75	300M	0.2	300M				
2N359	G	P	2N652	2N650	A	170M	A	85	25	18	R	100	300	50M						
2N360	G	P	2N1192	2N1191	A	170M	A	85	32	30	R	50	150	50M						
2N361	G	P	2N1191	2N1191	A	170M	A	85	32	30	R	25	75	50M						
2N362	G	P	2N1192	2N1191	A	170M	A	85	25	18	O						50	E		
2N363	G	P	2N1192	2N1191	A	170M	A	85	32	28	O						25	E		
2N364	G	N			S	150M	A	100	30								9.0	E	1.0M	B
2N365	G	N			S	150M	A	100	30								19	E	1.0M	B
2N366	G	N			S	150M	A	100	30								49	E	1.0M	B
2N367	G	P	2N1191	2N1191	S	100M	A	75	30								9.0	E	300K	B
2N368	G	P	2N1191	2N1191	S	100M	A	75	30								19	E	400K	B
2N369	G	P	2N1191	2N1191	S	100M	A	75	30								49	E	500K	B
2N370	G	P	2N3324	2N3323	AH	80M	A	71	24											
2N371	G	P	2N3324	2N3323	AH	80M	A	71	24											
2N372	G	P	2N3324	2N3323	AH	80M	A	71	24											
2N373	G	P			AH	80M	A	71	25											
2N374	G	P	2N3325	2N3323	AH	80M	A	71	25											
2N375	G	P		2N350A	AP	58W	C	95	80	60	S	35	90	1.0A	1.0	2.0A			7.0K	E
2N376	G	P			AP	10W	A	100	50	40	O	35	120	700M						
2N376A	G	P		2N350A	AP	90W	J	100	50	40	S	35	120	0.7A	1.75	5.0A			5.0K	E
2N377	G	N			S	150M	A	100	25	20	V	20	60	30M	0.5	200M			5.0M	B
2N377A	G	N			S	150M	A	100	40	40	V	20	60	30M						
2N378	G	P		2N376A	SP	50W	C	100	20			40	80	2.0A	1.0	2.0A			5.0K	E
2N379	G	P		2N376A	SP	50W	C	100	40			20	70	2.0A	1.0	2.0A			5.0K	E
2N380	G	P		2N376A	SP	50W	C	100	30			30	70	2.0A	1.0	2.0A			5.0K	E
2N381	G	P		2N381	A	0.2W	A	100	50	25	R	35	65	20M			35	E		
2N382	G	P		2N381	A	0.2W	A	100	50	25	R	60	95	20M			70	E		
2N383	G	P		2N381	A	0.2W	A	100	50	25	R	75	120	20M			90	E		
2N384	G	P	2N3325	2N3323	AH	120M	A	100	40	40	O	20	175	1.5M						
2N385	G	N			S	150M	A	100	25	25	R	30	110	30M					4.0M	B
2N385A	G	N			S	150M	A	100	40	40	V	30	110	30M					4.0M	B
2N386	G	P	MP689		AP	500M	C	100	60	60	V	20		2.5A					7.0K	E
2N387	G	P	MP687		AP	500M	C	100	80	80	V	20		2.5A					6.0K	E
2N388	G	N			S	150M	A	100	25	20	R	60	180	30M					5.0M	B
2N388A	G	N			S	150M	A	100	40	40	V	60	200	0.30M					5.0M	B
2N389	S	N	2N3445	2N3445	AP	85W	C	200		60	R	12	60	1.0A						
2N389A	S	N			AP	85W	C	200		60	R	12	60	1.0A	0.75	1.0A			1.0M	T
2N392	G	P	2N1550	2N1539	AP	48W	C	95	60	40	R	60	150	3.0A	0.5	3.0A				
2N393	G	P	2N967	2N960	S	25M	A	100	6.0	6.0	S	20		50M	0.07	8.0M	40	E	25M	T
2N394	G	P			SH	150M	A	85	10	10	O	20	150	10M					4.0M	B
2N394A	G	P			SH	150M	A	85	10	30	O	30	120	10M					4.0M	B
2N395	G	P			SH	200M	A	100	30	15	R	20	150	10M	0.2	50M			3.0M	B
2N396	G	P			SH	200M	A	100	30	20	R	30	150	10M	0.2	50M			5.0M	B
2N396A	G	P			SH	200M	A	100	30	20	O	30	150	10M	0.2	50M			5.0M	B
2N397	G	P			SH	200M	A	100	30	15	R	40	150	10M	0.2	50M			10M	B
2N398	G	P		2N398	SP	50M	A	55	105	105	S	20		5.0M						
2N398A	G	P		2N398	A	150M	A	100	105	105	S	20		5.0M	0.35	5.0M	20	E		
2N398B	G	P	2N2043	2N2042	SP	250M	A	100	105	105	S	20		5.0M	0.25	5.0M	40	E	1.0M	B
2N399	G	P	2N351A	2N350A	AP	25W	C	90		35	R				1.0	1.2A				
2N400	G	P	2N350A	2N350A	AP	35W	C	95	25	20	O	40	300	0.5A	0.8	1.0A	25	E	3.0K	E
2N401	G	P	2N3611	2N3611	AP	25W	C	90		35	R				1.0	1.2A				
2N402	G	P	2N1191	2N1191	A	180M	A	85	25	20	O									
2N403	G	P	2N1191	2N1191	A	180M	A	85	25	20	O									
2N404	G	P			S	150M	A	85	25											
2N404A	G	P			S	150M	A	100	40	35	O	30		12M	0.15	12M			4.0M	B
2N405	G	P	2N322	2N322	A	150M	A	71	20											
2N406	G	P	2N322	2N322	A	150M	A	71	20											
2N407	G	P	2N324	2N322	A	150M	A	71	20											
2N408	G	P	2N324	2N322	A	150M	A	71	20											
2N409	G	P			AH	80M	A	71	13											
2N410	G	P			AH	80M	A	71	13											
2N411	G	P			AH	80M	A	71	13											
2N412	G	P			AH	80M	A	71	13											
2N413	G	P			AH	150M	A	85	30	18	O									
2N413A	G	P			AH	150M	A	85	30	15	O									
2N414	G	P			AH	150M	A	85	30	15	O									

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N414A	G	P			AH	150M	A	85	30	15	0									
2N414B	G	P			AH	0.2W	A	100	30	24	V						40	E	4.0M	B
2N414C	G	P			AH	0.2W	A	100	30	24	V						40	E	4.0M	B
2N415	G	P			AH	150M	A	85	30	10	0									
2N415A	G	P			AH	150M	A	85	30	10	0									
2N416	G	P			AH	150M	A	85	30	12	0									
2N417	G	P			AH	150M	A	85	30	10	0									
2N418	G	P	2N1537	2N1529	SP	25W	C	100	100	75	R	40		4.0A	2.0	4.0A				
2N419	G	P			AP	35W	C	95	25	20	0	50	350	0.5A	0.8	1.5A	25	E	3.0K	E
2N420	G	P	2N1535	2N1529	SP	25W	C	100	65	40	R	40		4.0A	2.0	4.0A				
2N420A	G	P	2N1537	2N1529	SP	25W	C	100	90	65	R	40		4.0A	2.0	4.0A				
2N422	G	P	2N651	2N650	A	150M	A	85	35	20	0									
2N422A	G	P			A	175M	A	100	35	20	0						30	E	1.5M	B
2N424	S	N	2N3446	2N3445	AP	85W	C	200		80	R	12	60	1.0A						
2N424A	S	N			AP	85W	C	200		80	R	12	60	1.0A	0.75	1.0A			1.0M	T
2N425	G	P			S	175M	A	85	30	20	0	20	40		0.32	100M			2.5M	B
2N426	G	P			S	175M	A	85	30	10	0	30	60		0.32	100M			3.0M	B
2N427	G	P			S	175M	A	85	30	15	0	40	80		0.32	150M			5.0M	B
2N428	G	P			S	175M	A	85	30	12	0	60			0.32	200M			10M	B
2N428A	G	P			S	0.15W	A	100	30	18	0	80			0.32	0.2A			10M	B
2N438	G	N			S	0.1W	A	85	30	25	0	20		50M					2.5M	B
2N438A	G	N			S	0.15W	A	85	30	25	0	20		50M					2.5M	B
2N439	G	N			S	0.1W	A	85	30	20	0	30		50M					5.0M	B
2N439A	G	N			S	0.15W	A	85	30	20	0	30		50M					5.0M	B
2N440	G	N			S	0.1W	A	85	30	15	0	40		50M					10M	B
2N440A	G	N			S	0.15W	A	85	30	15	0	40		50M		50M			10M	B
2N441	G	P		2N441	AP	50W	C	95	40	40	S	20	40	5.0A						
2N442	G	P		2N441	AP	50W	C	95	50	45	S	20	40	5.0A						
2N443	G	P		2N441	AP	50W	C	95	60	50	S	20	40	5.0A	1.0	12A				
2N444	G	N			A	100M	A	85	15	15	0								0.5M	B
2N444A	G	N			A	150M	A	100	40	25	0	20	40	20M			15	E	0.5M	B
2N445	G	N			A	100M	A	85	15	12	0								0.5M	B
2N445A	G	N			A	150M	A	100	30	18	0	40	160	20M			35	E	2.0M	B
2N446	G	N			S	100M	A	85	15	10	0								5.0M	B
2N446A	G	N			S	150M	A	100	30	15	0	60	250	20M			60	E	5.0M	B
2N447	G	N			S	100M	A	85	15	6.0	0								5.0M	B
2N447A	G	N			S	150M	A	100	30	12	0	80	300	20M			85	E	9.0M	B
2N447B	G	N			S	150M	A	100	25	12	0	80	300	20M			150	E	9.0M	B
2N448	G	N			AH	65M	A	85	15	15	0	8.0	51	1.0M						
2N449	G	N			AH	65M	A	85	15	15	0	34		1.0M						
2N450	G	P			SH	150M	A	85	20	12	0	30		10M	0.2	10M			5.0M	B
2N456	G	P	2N456A	2N456A	AP	50W	C	95	40	40	X				1.0	5.0A				
2N456A	G	P		2N456A	AP	150W	C		40	40	0	30	90	5.0A	0.5	5.0A			4.0K	E
2N456B	G	P	MP1971		AP	150W	C	100	40	30	0	30	90	5.0A	0.5	5.0A			200K	T
2N457	G	P	MP251		AP	50W		95	60	60	X				1.0	5.0A				
2N457A	G	P		2N456A	AP	150W	C		60	60	0	30	90	5.0A	0.5	5.0A			4.0K	E
2N457B	G	P	MP1972		AP	150W	C	100	60	40	0	30	90	5.0A	0.5	5.0A			200K	T
2N458	G	P			AP	50W		95	80	80	X				1.0	5.0A				
2N458A	G	P		2N456A	AP	150W	C		80	80	0	30	90	5.0A	0.5	5.0A			4.0K	E
2N458B	G	P	MP1973		AP	150W	C	100	80	45	0	30	90	5.0A	0.5	5.0A			200K	T
2N459	G	P		2N376A	SP	50W	C	100	60			20	70	2.0A	1.0	2.0A			5.0K	E
2N459A	G	P		2N376A	SP	106W	C	110	105	60	0	40	70	2.0A	0.3	2.0A			5.0K	E
2N460	G	P		2N460	A	0.2W	A	100	45			16	32							
2N461	G	P		2N460	A	0.2W	A	100	45			32	100							
2N462	G	P			S	150M	A	75	40			20		200M					500K	B
2N463	G	P	2N1551	2N1539	AP	37.5W	C	100	60	60		20	60	2.0A					4.0K	E
2N464	G	P		2N464	A	150M	A	85	45	40	0									
2N465	G	P		2N464	A	150M	A	85	45	30	0									
2N466	G	P		2N464	A	150M	A	85	35	20	0									
2N467	G	P		2N464	A	150M	A	85	35	15	0									
2N469	G	P			AL	50M	A	75	6.0			10		1.0M						
2N469A	G	P			AL	50M	A	85	20	15	R						30	E		
2N470	S	N			AH	0.2W	A	200	15	15	0				1.5	5.0M	10	E	8.0M	T
2N471	S	N			A	0.2W	A	200	30	30	0				1.5	5.0M	10	E	8.0M	T
2N471A	S	N			A	0.2W	A	200	30	30	0				1.0	5.0M	10	E	8.0M	T
2N472	S	N			AH	0.2W	A	200	45	45	0				1.5	5.0M	10	E	8.0M	T
2N472A	S	N			A	0.2W	A	200	45	45	0				1.0	5.0M	10	E	8.0M	T
2N473	S	N			A	0.2W	A	200	15	15	0				1.5	5.0M	20	E	8.0M	T
2N474	S	N			A	0.2W	A	200	30	30	0				1.5	5.0M	20	E	8.0M	T
2N474A	S	N			A	0.2W	A	200	30	30	0	10			1.0	5.0M	20	E	8.0M	T
2N475	S	N			A	0.2W	A	200	45	45	0				1.5	5.0M	20	E	8.0M	T
2N475A	S	N			A	0.2W	A	200	45	45	0	10			1.0	5.0M	20	E	8.0M	T
2N476	S	N			A	0.2W	A	200	15	15	0				1.5	5.0M	30	E	12M	T
2N477	S	N			A	0.2W	A	200	30	30	0				1.5	5.0M	30	E	12M	T
2N478	S	N			AH	0.2W	A	200	15	15	0				1.5	5.0M	40	E	20M	T
2N479	S	N			AH	0.2W	A	200	30	30	0				1.5	5.0M	40	E	20M	T
2N479A	S	N			A	0.2W	A	200	30	30	0	10			1.0	5.0M	40	E	20M	T
2N480	S	N			AH	0.2W	A	200	45	45	0				1.5	5.0M	40	E	20M	T
2N480A	S	N			A	0.2W	A	200	45	45	0	10			1.0	5.0M	40	E	20M	T
2N481	G	P			AH	150M	A	85	12	12	0									
2N482	G	P			AH	150M	A	85	12	12	0									
2N483	G	P			AH	150M	A	85	12	12	0									
2N484	G	P			AH	150M	A	85	12	12	0									
2N485	G	P			AH	150M	A	85	12	12	0									
2N486	G	P			AH	150M	A	85	12	12	0									
2N487	G	P			A	100M	A	85	18	18	R	20		1.0M			10	E	10M	T

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N489 thru 2N494	Unijunction Transistors, see Table on Page 184																			
2N495	S	P			AH	150M	A	140	25	25	U						15	E	8.0M	M
2N496	S	P			S	150M	A	140	10	10	U	15		15M	0.15	5.0M	9.0	E	7.2M	T
2N497	S	N	2N4238	2N4237	A	4.0W	C	200	60	60	0	12	36	200M						
2N497A	S	N			A	5.0W	C	200	60	60	0	12	36	200M						
2N498	S	N	2N4239	2N4237	A	4.0W	C	200	100	100	0	12	36	200M						
2N498A	S	N			A	5.0W	C	200	100	100	0	12	36	200M						
2N499	G	P		2N499	AH	30M	A	85	30	18	0								120M	T
2N499A	G	P		2N499	AH	60M	A	100	30	18	0						20	E	120M	T
2N500	G	P	2N3323	2N3323	AH	50M	A	85	20	15										
2N501	G	P			SH	60M	A	100	15	12	S	20		10M	0.2	10M			90M	T
2N501A	G	P			SH	60M	A	100	15	12	S	30		10M	0.2	10M			90M	T
2N502	G	P		2N499	AH	60M	A	85	20	20	S						9.0	E	220M	T
2N502A	G	P		2N499	AH	75M	A	100	30	30	S						15	E	220M	T
2N502B	G	P		2N499	AH	75M	A	100	30	30	S						20	E		
2N503	G	P	2N3284	2N3283	AH	25M	A	85	20	20	S						9.0	E	168M	T
2N504	G	P	2N3323	2N3323	AH	30M	A	85	35	25	S	20	200	10M			16	E	50M	M
2N506	G	P			A	50M	A	85	40			25	50	50M	0.6	50M			600K	B
2N507	G	N			A	50M	A	85	40			25	50	50M	0.6	50M			600K	B
2N508	G	P		2N322	A	200M	A	100	18	18	R	99	198	20M					2.5M	B
2N508A	G	P		2N508A	A	0.2W	A	100	30	30	S	100	200	20M			75	E	2.5M	B
2N509	G	P			AH	225M	A	100	30								0.96	B	400M	T
2N511	G	P	2N1554	2N1539	AP	150W	C		40			20	60	10A	0.5	10A			260K	T
2N511A	G	P	2N1555	2N1539	AP	150W	C		60			20	60	10A	0.5	10A			260K	T
2N511B	G	P	2N1556	2N1539	SP	150W	C		80			20	60	10A	0.5	10A			260K	T
2N512	G	P	2N1558	2N1539	AP	150W	C		40			20	60	15A	0.75	15A			260K	T
2N512A	G	P	2N1559	2N1539	AP	150W	C		60			20	60	15A	0.75	15A			260K	T
2N512B	G	P	2N1560	2N1539	SP	150W	C		80			20	60	15A	0.5	10A			260K	T
2N513	G	P	2N1163	2N1162	AP	150W	C		40			20	60	20A	1.25	20A			300K	T
2N513A	G	P	2N1165	2N1162	AP	150W	C		60			20	60	20A	1.25	20A			260K	T
2N513B	G	P	2N1167	2N1162	SP	150W	C		80			20	60	20A	0.5	10A			260K	T
2N514	G	P	2N1163	2N1162	SP	80W	C	95	40	40	X				1.25	25A				
2N514A	G	P	2N1165	2N1162	SP	80W	C	95	60	60	X				1.25	25A				
2N514B	G	P	2N1167	2N1162	SP	80W	C	95	80	80	X				1.25	25A				
2N515	G	N			AH	50M	A	75	20	18	R						4.0	E	2.0M	B
2N516	G	N			AH	50M	A	75	20	18	R						4.0	E	2.0M	B
2N517	G	N			AH	50M	A	75	20	18	R						4.0	E	2.0M	B
2N518	G	P			S	0.15W	A	85	45	12	0	60		10M	0.15	10M			10M	B
2N519	G	P			S	100M	A	85	15	15	0						15	E	0.5M	B
2N519A	G	P			S	150M	A	100	25	18	0	20	50	20M			15	E	0.5M	B
2N520	G	P			S	100M	A	85	15	12	0						20	E	3.0M	B
2N520A	G	P			S	150M	A	100	25	15	0	40	170	20M			40	E	2.0M	B
2N521	G	P			S	100M	A	85	15	10	0						35	E	8.0M	B
2N521A	G	P			S	150M	A	100	25	12	0	60	250	20M			70	E	8.0M	B
2N522	G	P			S	100M	A	85	15	8.0	0						60	E	15M	B
2N522A	G	P			S	150M	A	100	25	10	0	80	320	20M			100	E	15M	B
2N523	G	P			S	100M	A	85	15	6.0	0						80	E	21M	B
2N523A	G	P			S	150M	A	100	20	6.0	0	100	400	20M			125	E	21M	B
2N524	G	P		2N524	A	225M	A	100	45	30	R	25	42	20M	0.13	20M	16	E	800K	B
2N524A	G	P			A	225M	A	100	45	30	R	25	42	20M	0.13	20M	18	E	0.8M	B
2N525	G	P		2N524	A	225M	A	100	45	30	R	34	65	20M	0.13	20M	30	E	1.0M	B
2N525A	G	P			A	225M	A	100	45	30	R	34	65	20M	0.13	20M	30	E	1.0M	B
2N526	G	P		2N524	A	225M	A	100	45	30	R	53	90	20M	0.13	20M	44	E	1.3M	B
2N526A	G	P			A	225M	A	100	45	30	R	53	90	20M	0.13	20M	44	E	1.3M	B
2N527	G	P		2N524	A	225M	A	100	45	30	R	72	121	20M	0.13	20M	60	E	1.5M	B
2N527A	G	P			A	225M	A	100	45	30	R	72	121	20M	0.13	20M	60	E	1.5M	B
2N528	G	P				2.5W	C	100	40	40		20		0.5A						
2N529	G					100M	A	85	15	15	0									
2N530	G					100M	A	85	15	15	0									
2N531	G					100M	A	85	15	15	0									
2N532	G					100M	A	85	15	15	0									
2N533	G					100M	A	85	15	15	0									
2N534	G	P	2N1189	2N1189	A	25M	A	65	50	50	U						35	E		
2N535	G	P	2N1192	2N1191	A	50M	A	85	20	20	U						35	E		
2N535A	G	P	2N1192	2N1191	A	50M	A	85	20	20	U						35	E		
2N535B	G	P			A	50M	A	85	20	20	U						35	E		
2N536	G	P	2N1193	2N1191	S	50M	A	85	20	20	U	100		30M	0.13	10M			1.0M	B
2N537	G	P			AH			100	30						4.0	70M	0.9	B		
2N538	G	P	2N2140	2N2137	SP	34W	J	95	80	60		20	50	2.0A	0.6	2.0A				
2N538A	G	P	2N2140	2N2137	SP	34W	J	95	80	60		20	50	2.0A	0.6	2.0A				
2N539	G	P	2N2145	2N2137	SP	34W	J	95	80	55		30	75	2.0A	0.6	2.0A				
2N539A	G	P	2N2145	2N2137	SP	11W	J	95	80	55		30	75	2.0A	0.6	2.0A				
2N540	G	P	2N1551	2N1539	SP	34W	J	95	80	55		45	113	2.0A	0.6	2.0A				
2N540A	G	P	2N1551	2N1539	SP	34W	J	95	80	55		45	113	2.0A	0.6	2.0A				
2N541	S	N			AH	0.2W	A	200	15	15	U				1.5	5.0M	80	E	10M	T
2N541A	S	N			A	0.2W	A	200	15	15	0	20			1.0	5.0M	80	E	8.0M	T
2N542	S	N			AH	0.2W	A	200	30	30	U				1.5	5.0M	80	E	10M	T
2N542A	S	N			A	0.2W	A	200	30	30	0	20			1.0	5.0M	80	E	10M	T
2N543	S	N			AH	0.2W	A	200	50	50	U				1.5	5.0M	80	E	10M	T
2N543A	S	N			A	0.2W	A	200	45	45	0	20			1.0	5.0M	80	E	10M	T
2N544	G	P			AH	80M	A	71	34											
2N545	S	N			AH	5W	C	200	60	60	0	15	80	0.5A	5.0	0.5A				
2N546	S	N			AH	5W	C	200	30	30	0	15	80	0.5A	3.0	0.5A				
2N547	S	N	2N3766	2N3766	AH	5W	C	200	60	60	0	20	80	0.5A	5.0	0.5A			4.0M	T
2N548	S	N	2N4898	2N4898	AH	5W	C	200	30	30	0	20	80	0.5A	3.0	0.5A			4.0M	T
2N549	S	N			AH	5W	C	200	60	60	0	20	80	0.2A	4.0	0.2A			4.0M	T

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N550	S	N			AH	5W	C	200	30	30	0	20	80	0.2A	4.0	0.2A			4.0M	T
2N551	S	N			AH	5W	C	200	60	60	0	20	80	50M	2.0	50M			3.0M	T
2N552	S	N			AH	5W	C	200	30	30	0	20	80	50M	2.0	50M			3.0M	T
2N553	G	P			SP	35W	C	95	80			40	80	500M	0.9	3.0A				
2N554	G	P		2N178	AP	40W	J	90												
2N555	G	P		2N178	AP	10W	J	90	40										5.0K	B
2N556	G	N			S	100M	A	85	25	20	X	35	70	1.0M	0.5	200M				
2N557	G	N			S	100M	A	85	20	20	X	20		1.0M	0.5	200M				
2N558	G	N			S	100M	A	75	15	15	X	60		1.0M	0.75	200M				
2N559	G	P		2N554	S	0.15W	A	100	15	15					0.3	10M				
2N560	S	N			S	500M	A	150		60	S	20		100M	0.5	10M				
2N561	G	P	MP447		A	50W	A	100	80	50	0	20	50	4.0A						
2N563	G	P	2N650	2N650	S	150M	A	85	30	25	0	10	30							
2N564	G	P	2N650	2N650	S	120M	A	85	30	25	0	10	30							
2N565	G	P	2N651	2N650	S	150M	A	85	30	25	0	30	50							
2N566	G	P	2N651	2N650	S	120M	A	85	30	25	0	30	50							
2N567	G	P	2N651	2N650	S	150M	A	85	30	25	0	50	70							
2N568	G	P	2N651	2N650	S	120M	A	85	30	25	0	50	70							
2N569	G	P	2N1193	2N1191	S	150M	A	85	30	20	0	70	100							
2N570	G	P	2N1192	2N1191	S	120M	A	85	30	20	0	70	100							
2N571	G	P	2N1193	2N1191	S	150M	A	85	30	10	0	100								
2N572	G	P	2N1193	2N1191	S	120M	A	85	30	10	0	100								
2N573	G	P			A	0.2W	A	100	40	25	0	30	300	50M						
2N574	G	P	2N1550	2N1539	SP	180W	J	100	60	55	0	9.0	22	10A	0.2	10A				
2N574A	G	P	2N1551	2N1539	SP	180W	J	100	80	60	0	9.0	22	10A	0.2	10A				
2N575	G	P	2N1554	2N1539	SP	180W	J	100	60	50	0	19	42	10A	0.5	25A				
2N575A	G	P	2N1555	2N1539	SP	180W	J	100	80	55	0	19	42	10A	0.5	25A				
2N576	G	N			S	200M	A	100	20	20	R	20	60	400M	0.4	400M			2.0M	B
2N576A	G	N			S	200M	A	100	40	20	R	20	60	400M	0.4	400M			5.0M	B
2N577		P			AL	25M	A	55	25											
2N578	G	P			S	120M	A	71	20			10		400M	0.3	400M			3.0M	B
2N579	G	P			S	120M	A	71	20			20		400M	0.3	400M			5.0M	B
2N580	G	P			S	120M	A	71	20			30		400M	0.3	400M			10M	B
2N581	G	P			S	80M	A	71	18			20		20M		20M			4.0M	B
2N582	G	P			S	120M	A	71	25			40		20M	0.3	100M			14M	B
2N583	G	P			S	80M	A	71	18			20		20M		20M			4.0M	B
2N584	G	P			S	120M	A	71	25			40		20M	0.3	100M			14M	B
2N585	G	P			S	120M	A	71	25			20		20M	0.2	20M			3.0M	B
2N586	G	P	2N1191	2N1191	S	250M	A	85	45			35		250M	0.5	250M				
2N587	G	N			S	150M	A	100	40	20	R	20		200M	0.5	200M				
2N588	G	P	2N3324	2N3323	AH	30M	A	85	15	15	S								200M	M
2N588A	G	P			AH	60M	A	85	15	15	S	30		10M	0.2	10M			200M	M
2N589	G	P	2N1532	2N1529	AP	90W	C	100	100	75	S	20	40	3.0A	1.5	3.0A			5.0K	E
2N591	G	P	2N1192	2N1191	A	50M	A	71	32	32	0									
2N592	G	P			S	125M	A	85	20	20	0	20								
2N593	G	P			S	125M	A	85	40	30	0	30								
2N594	G	N			S	100M	A	85	20	20	0	20							1.5M	E
2N595	G	N			S	100M	A	85	15	15	0	35							3.0M	E
2N596	G	N			S	100M	A	85	10	10	0	50							5.0M	E
2N597	G	P	2N3427	2N3427	S	250M	A	100	45	40	S	40		100M	0.2	10M			3.0M	B
2N598	G	P	2N3427	2N3427	S	250M	A	100	35	35	S	70	225	100M	0.2	10M			5.6M	T
2N599	G	P	2N3428	2N3427	S	250M	A	100	30	20	S	100		100M	0.2	10M			10M	T
2N600	G	P	2N3427	2N3427	SP	750M	C	100	35	35	S	70	225	100M	0.2	10M			5.6M	T
2N601	G	P	2N3428	2N3427	SP	750M	C	100	30	20	S	100		100M	0.2	10M			10M	T
2N602	G	P			SH	120M	A	85	20	20	0	20	80		0.25	10M			10M	T
2N603	G	P			SH	120M	A	85	30	20	0	30	100		0.25	15M			30M	T
2N604	G	P			SH	120M	A	85	30	20	0	40	140		0.25	20M			50M	T
2N605	G	P			AH	0.12W	A	85	15	15	0									
2N606	G	P			AH	0.12W	A	85	15	15	0									
2N607	G	P			AH	0.12W	A	85	15	15	0									
2N608	G	P			AH	0.12W	A	85	15	15	0									
2N609	G	P	2N1193	2N1191	A	180M	A	85	25	15	0									
2N610	G	P	2N1193	2N1191	A	180M	A	85	25	15	0									
2N611	G	P	2N1192	2N1191	A	180M	A	85	25	15	0									
2N612	G	P	2N1191	2N1191	A	180M	A	85	25	15	0									
2N613	G	P	2N1191	2N1191	A	180M	A	85	25	15	0									
2N614	G	P			AH	180M	A	85	20	15	0									
2N615	G	P			AH	180M	A	85	20	15	0									
2N616	G	P			AH	180M	A	85	15	12	0									
2N617	G	P			AH	180M	A	85	15	12	0									
2N618	G	P		2N350A	AP	90W	C	95	80	60	S	60	140	1.0A	0.8	2.0A			5.0K	E
2N619	S	N			A	175M	A	160	50	40	0	9.0	22	5.0M	0.5	8.0M			200K	B
2N620	S	N			A	175M	A	160	50	35	0	18	44	5.0M	0.4	8.0M			250K	B
2N621	S	N			A	175M	A	160	50	30	0	36	88	5.0M	0.3	8.0M			300K	B
2N622	S	N			AM	385M	A	160	50	30	0								300K	B
2N624	G	P			AH	100M	A	100	30	20	S						20	E	20M	E
2N625	G	N			S	1500M	C	100	40	30	S	20		500M	1.0	500M				
2N626																				
2N627	G	P			AP	90W	C	100	40	30	S	10	30	10A	1.0	10A			5.0K	E
2N628	G	P			AP	90W	C	100	60	45	S	10	30	10A	1.0	10A			5.0K	E
2N629	G	P			AP	90W	C	100	80	60	S	10	30	10A	1.0	10A			5.0K	E
2N630	G	P			AP	90W	C	100	100	75	S	10	30	10A	1.0	10A			5.0K	E
2N631	G	P	2N1194	2N1191	A	167M	A	85	25	20	R									
2N632	G	P	2N1193	2N1191	A	167M	A	85	36	20	R									
2N633	G	P	2N1192	2N1191	A	167M	A	85	35	30	R									
2N634	G	N			SH	150M	A	85	20	20	0	15		200M					5.0M	B
2N634A	G	N			S	2.5M	J	85	25	20	R	40	120	10M	0.2	10M			5.0M	B
2N635	G	N			SH	150M	A	85	20	20	0	25		200M					10M	B

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N635A	G	N			S	2.5M	J	85	25	20	R	80	240	10M	0.2	10M			10M	B
2N636	G	N			SH	150M	A	85	20	20	O	35		200M					15M	B
2N636A	G	N			S	2.5M	J	85	25	15	R	100	300	10M	0.15	10M			15M	B
2N637	G	P	MP277		SP	60W	C	100		35	R	30	60	3.0A	1.5	3.0A				
2N637A	G	P	MP278		SP	60W	C	100		65	R	30	60	3.0A	1.5	3.0A				
2N637B	G	P	MP279		SP	60W	C	100		75	R	30	60	3.0A	1.5	3.0A				
2N638	G	P	MP1338		SP	60W	C	100		35	R	20	40	3.0A	2.0	3.0A				
2N638A	G	P	MP1338A		SP	60W	C	100		65	R	20	40	3.0A	2.0	3.0A				
2N638B	G	P	MP1338B		SP	60W	C	100		75	R	20	40	3.0A	2.0	3.0A				
2N639	G	P	MP259		SP	37W	C	100		35	R	15		3.0A	2.5	3.0A				
2N639A	G	P	MP260		SP	37W	C	100		65	R	15		3.0A	2.5	3.0A				
2N639B	G	P	MP261		SP	37W	C	100		75	R	15		3.0A	2.5	3.0A				
2N640	G	P			A	80M	A	71	34											
2N641	G	P			A	80M	A	71	34											
2N642	G	P			A	80M	A	71	34											
2N643	G	P	2N2955	2N2955	S	120M	A	71	30			20		10M					20M	T
2N644	G	P	2N2955	2N2955	S	120M	A	71	30			20		10M					20M	T
2N645	G	P	2N2955	2B2955	S	120M	A	71	30			20		10M					20M	T
2N646	G	N			A	100M	A	85	25	25	O	50	150	30M						
2N647	G	N			A	100M	A	71	25	25	O									
2N649	G	N			A	100M	A	71	20	18	O									
2N650	G	P		2N650	A	0.2W	A	100	45	30	R	30		10M	0.25	50M	30	E	0.75M	E
2N650A	G	P		2N650	A	0.2W	A	100	45	30	R	33		10M	0.25	50M	30	E	0.75M	B
2N651	G	P		2N650	A	0.2W	A	100	45	30	R	45		10M	0.25	50M	50	E	1.0M	E
2N651A	G	P		2N650	A	0.2W	A	100	45	30	R	45		10M	0.25	50M	50	E	1.0M	B
2N652	G	P		2N650	A	0.2W	A	100	45	30	R	80		10M	0.25	50M	100	E		
2N652A	G	P		2N650	A	0.2W	A	100	45	30	R	80		10M	0.25	50M	100	E		
2N653	G	P		2N653	A	0.2W	A	100	30	25	R	20		10M			30	E		
2N654	G	P		2N653	A	0.2W	A	100	30	25	R	40		10M			50	E		
2N655	G	P		2N653	A	0.2W	A	100	30	25	R	70		10M			100	E		
2N656	S	N	2N4238	2N4237	A	4.0W	C	200	60	60	O	30	90	200M						
2N656A	S	N			A	5.0W	C	200	60	60	O	30	90	200M						
2N657	S	N	2N4239	2N4237	A	4.0W	C	200	100	100	O	30	90	200M						
2N657A	S	N			A	5.0W	C	200	100	100	O	30	90	200M						
2N658	G	P			S	167M	A	85	25	16	O	25	80		3.45	150M			2.5M	B
2N659	G	P			S	167M	A	85	25	14	O	40	110		3.5	250M			5.0M	B
2N660	G	P			S	167M	A	85	25	11	O	60	150		3.5	400M			10M	B
2N661	G	P			S	167M	A	85	25	9.0	O	80			3.5	550M			15M	B
2N662	G	P			S	167M	A	85	25	11	O	30			3.4	180M			4.0M	B
2N663	G	P	MP967		SP	35W	C	100	50	25	O	25	75	500M	1.0	3.0A			15K	E
2N665	G	P		2N665	SP	35W	C	95	80	40	O	40	80	500M	0.9	3.0A			20K	E
2N669	G	P		2N176	AP	62.5W	C	100	40	30	S		250	0.5A					3.0K	E
2N670	G	P	2N3428	2N3427	A	300M	A	85	40	40	V	40	250	1.0A	0.35	1.0A			500K	B
2N671	G	P	2N3428	2N3427	A	800M	C	85	40	40	V	40	250	1.0A	0.35	1.0A			500K	B
2N672	G	P	2N3428	2N3427	A	300M	A	85	25	25	S				0.2	400M				
2N673	G	P	2N3428	2N3427	A	800M	C	85	25	25	S				0.2	400M				
2N674	G	P	2N3428	2N3427	A	300M	A	85	75	75	V	40	250	1.0A	0.35	1.0A			400K	B
2N675	G	P	2N3428	2N3427	A	800M	C	85	75	75	V	40	250	1.0A	0.35	1.0A			400K	B
2N677	G	P	MP439		AP	90W	C	100	50	30	S	20	60	10A	1.0	10A				
2N677A	G	P	MP439A		AP	90W	C	100	60	40	S	20	60	10A	1.0	10A				
2N677B	G	P	MP439B		AP	90W	C	100	90	70	S	20	60	10A	1.0	10A				
2N677C	G	P	MP439C		AP	90W	C	100	100	80	S	20	60	10A	1.0	10A				
2N678	G	P	MP327		AP	90W	C	100	50	20	O	50	100	10A	1.0	10A				
2N678A	G	P	MP328		AP	90W	C	100	60	30	O	50	100	10A	1.0	10A				
2N678B	G	P	MP329		AP	90W	C	100	90	60	O	50	100	10A	1.0	10A				
2N678C	G	P	MP330		AP	90W	C	100	100	70	O	50	100	10A	1.0	10A				
2N679	G	N			S	150M	A	85	25	20	X	20		30M	0.3	100M			2.0M	B
2N680	G	P	2N1191	2N1191	A	150M	A	75	20	20	S	18	165	50M	0.75	50M	15	E		
2N681 thru	Thyristors, see Table on Page 164																			
2N692																				
2N694	G	P			AH	0.1W	A	100	30	15	O	10		2.0M			0.9	B	340M	T
2N695	G	P			SH	75M	A	100	15	15	S	25		10M	1.0	50M				
2N696	S	N		2N696	S	600M	A	175	60	40	R	20	60	150M	1.5	150M			40M	T
2N696A	S	N	2N2218	2N2218	S	800M	A	300	60	35	O	20	60	150M	1.5	150M	15	E	40M	T
2N697	S	N		2N696	S	600M	A	175	60	40	R	40	120	150M	1.5	150M			40M	T
2N697A	S	N	2N2218	2N2218	S	800M	A	300	60	35	O	40	120	150M	1.5	150M	25	E	50M	T
2N698	S	N	2N3498	2N3498	S	800M	A	200	120	80	R	20	60	150M	1.2	50M	15	E	40M	T
2N699	S	N		2N699	S	600M	A	175	120	80	R	40	120	150M	5.0	150M	35	E	50M	T
2N699A	S	N			S	800M	A	300	120	80	R	40	120	150M	5.0	150M	35	E	50M	T
2N699B	S	N	2N3498	2N3498	S	870M	A	200	120	100	R	40	120	150M	1.2	50M	35	E	60M	T
2N700	G	P		2N700	AH	75M	A	100	25	20	S	1.5		2.0M			4.0	E	270M	T
2N700A	G	P		2N700	AH	75M	A	100	25	25	O	1.5		6.0M			4.0	E	360M	T
2N702	S	N		2N702	SH	300M	A	175	25	25	O	20	60	10M	0.5	10M			70M	T
2N703	S	N		2N702	SH	300M	A	175	25	25	O	40	100	10M	0.5	10M			70M	T
2N705	G	P		2N705	SH	300M	C	100	15	15	S	25		10M	0.3	10M				
2N705A	G	P			SH	150M	A	100	15	15	S	25		10M	0.3	10M				
2N706	S	N		2N706	SH	300M	A	175	25	20	R	20		10M	0.6	10M			200M	T
2N706A	S	N		2N706	SH	300M	A	175	25	20	R	20	60	10M	0.6	10M			200M	T
2N706B	S	N		2N706	SH	300M	A	175	25	15	O	20	60	10M	0.4	10M			200M	T
2N706C	S	N	2N835	2N834	SH	360M	A	200	40	20	R	20	60	10M	0.4	10M			200M	T
2N707	S	N		2N707	AHP	300M	A	175	56	28	R	9.0		10M	0.6	10M				
2N707A	S	N		2N707	AH	500M	A	175	70	40	O	9.0	50	10M	0.6	10M			70M	T
2N708	S	N		2N708	SH	360M	A	200	40	20	R	30	120	10M	0.4	10M			300M	T
2N708A	S	N	2N834	2N834	SH	360M	A	200	50	30	R	40	120	10M	0.15	10M			300M	T
2N709	S	N			SH	300M	A	200	15	6.0	O	20	120	10M	0.3	3.0M			600M	T
2N709A	S	N			SH	300M	A	200	15	6.0	O	30	90	10M	0.3	3.0M			800M	T
2N710	G	P			SH	300M	C	100	15	15	S	25		10*	0.5	10M				

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N710A	G	P			SH	150M	A	100	15	15	S	25		10M	0.5	10M				
2N711	G	P		2N711	SH	150M	A	100	12	12	S	20	250	10M	0.5	10M			150M	T
2N711A	G	P		2N711	SH	150M	A	100	15	7.0	O	25	150	10M	0.55	50M			150M	T
2N711B	G	P		2N711	SH	150M	A	100	18	7.0	O	30	150	10M	0.25	10M			150M	T
2N715	S	N	2N2221	2N2218	AH	500M	A	175	50	35	O	10	50	15M	1.2	15M			70M	E
2N716	S	N	2N2221	2N2218	AH	500M	A	175	70	40	O	10	50	15M	1.2	15M			70M	E
2N717	S	N	2N2221	2B2218	AH	400M	A	175	60	40	R	20	60	150M	1.5	150M			40M	T
2N718	S	N		2N718	AH	400M	A	175	60	40	R	40	120	150M	1.5	150M			50M	T
2N718A	S	N		2N718A	AH	500M	A	200	75	50	R	40	120	150M	1.5	150M	30	E	60M	T
2N719	S	N	2N3498	2N3498	AH	400M	A	175	120	80	R	20	60	150M	5.0	150M	15	E	40M	T
2N719A	S	N	2N3498	2N3498	AH	500M	A	200	120	80	R	20	60	150M	1.2	50M	15	E	40M	T
2N720	S	N	2N3498	2N3498	AH	400M	A	175	120	80	R	40	120	150M	5.0	150M	35	E	50M	T
2N720A	S	N	2N3498	2N3498	S	500M	A	200	120	100	R	40	120	150M	5.0	150M	30	E	50M	T
2N721	S	P		2N721	AH	400M	A	200	50	50	R	20	45	150M	1.5	150M	15	E	50M	T
2N721A	S	P			AH	500M	A	200	50	50	R	20	45	150M	0.5	150M	15	E	50M	T
2N722	S	P		2N722	AH	400M	A	175	50	50	R	30	90	150M	1.5	150M	25	E	60M	T
2N722A	S	P	2N2837	2N2800	AH	500M	A	200	50	50	R	30	90	150M	0.5	150M	25	E	60M	T
2N725	G	P			SH	150M	A	100	15	12	S	20		10M						
2N726	S	P	2N3250	2N3250	A	300M	A	175	25	20	O	15	45	10M	0.6	10M	15	E	140M	T
2N727	S	P	2N3250	2N3250	A	300M	A	175	25	20	O	30	120	10M	0.6	10M	30	E	140M	T
2N728	S	N	2N2539	2N2537	SH	4.0M	A	175	15	15	O	20	200	10M	0.7	10M			100M	T
2N729	S	N	2N2539	2N2537	SH	4.0M	A	175	30	30	O	20	200	10M	0.7	10M			100M	T
2N730	S	N	2N2218	2N2218	A	500M	A	175	60	40	R	20	60	150M	1.5	150M			40M	T
2N731	S	N		2N731	A	500M	A	175	60	40	R	40	120	150M	1.5	150M			25M	T
2N734	S	N	2N2221	2N2218	A	500M	A	175	80	60	O	15	50	5.0M	1.0	10M	20	E		
2N734A	S	N			A	0.5W	A	200	80	60	O	15	50	5.0M	0.5	10M	20	E	30M	T
2N735	S	N	2N2221	2N2218	A	500M	A	175	80	60	O	30	100	5.0M	1.0	10M	40	E		
2N735A	S	N			A	0.5W	A	200	80	60	O	30	100	5.0M	0.5	10M	40	E	60M	T
2N736	S	N	2N2222	2N2218	A	500M	A	175	80	60	O	60	200	5.0M	1.0	10M	80	E		
2N736A	S	N	2N2222	2N2218	A	500M	A	175	80	60	O	60	200	5.0M	0.6	10M	80	E	100M	T
2N736B	S	N			A	0.5W	A	200	80	60	O	60	200	5.0M	0.5	10M	80	E	100M	T
2N738	S	N			A	500M	A	175	125	80	O	15	50	5.0M	1.0	10M	20	E		
2N738A	S	N			A	0.5W	A	200	125	80	O	15	50	5.0M	0.5	10M	20	E	30M	T
2N739	S	N		2N735	A	500M	A	175	125	80	O	30	100	5.0M	1.0	10M	40	E		
2N739A	S	N			A	0.5W	A	200	125	80	O	30	100	5.0M	0.5	10M	40	E	60M	T
2N740	S	N		2N735	A	0.5W	A	200	125	80	O	60	200	5.0M			80	E		
2N740A	S	N			A	0.5W	A	200	125	80	O	60	200	5.0M	0.5	10M	80	E	100M	T
2N741	G	P		2N741	AH	150M	A	100	15	15	S	10		5.0M			20	E		
2N741A	G	P		2N741	AH	150M	A	100	20	20	S	10		5.0M			20	E	300M	T
2N742	S	N	2N2218	2N2218	S	0.5W	A	200	60	60	O	25		10M	0.5	10M				
2N742A	S	N	2N2218	2N2218	S	0.5W	A	200	60	60	O	25		10M	0.5	10M				
2N743	S	N		2N743	SH	300M	A	200	20	12	O	20	60	10M	0.35	10M			200M	T
2N743A	S	N			SH	0.36W	A	200	40	15	O	20	60	10M					500M	T
2N744	S	N		2N744	SH	300M	A	175	20	12	O	40	120	10M	0.35	10M			300M	T
2N744A	S	N			SH	0.36W	A	200	40	15	O	40	120	10M					500M	T
2N745	S	N			A	0.15W	A	175	45	30	O	20	55	10M			19	E	10M	B
2N746	S	N			A	0.15W	A	175	45	30	O	45	150	10M			39	E	10M	B
2N747	S	N			S	200M	A	175	25	25	O	30	90	10M	0.6	5.0M				
2N748	S	N			S	200M	A	175	30	30	O	20	40	10M	0.5	5.0M				
2N749	S	N			AH	200M	A	175	45	25	O	15	55	10M			30	E	50M	B
2N751	S	N			AH	200M	A	175	20	20	O	30	150	10M			10	E	20M	B
2N752	S	N	2N2221	2N2218	AH	0.5W	A	200	85	45	O				1.2	15M	40	E	200M	T
2N753	S	N		2N706	SH	300M	A	175		20	R	40	120	10M	0.6	10M			200M	T
2N754	S	N	2N2218	2N2218	AH	0.3W	A	175	60	60	R	20	80	5.0M	0.8	10M			30M	T
2N755	S	N	2N2218	2N2218	AH	0.3W	A	175	100	80	R	20	80	5.0M	0.8	10M			30M	T
2N756	S	N			A	0.5W	A	200	45	45	O				1.0	10M	12	E	50M	B
2N756A	S	N			A	0.5W	A	200	60	60	O				1.0	10M	12	E	50M	B
2N757	S	N			A	0.5W	A	200	45	45	O				1.0	10M	18	E	50M	B
2N757A	S	N			A	0.5W	A	200	60	60	O				1.0	10M	18	E	50M	B
2N758	S	N			A	0.5W	A	200	45	45	O				1.0	10M	18	E	50M	B
2N758A	S	N			A	0.5W	A	200	60	60	O				1.0	10M	18	E	50M	B
2N758B	S	N			A	0.5W	A	200	60	60	O	12		1.0M	0.5	10M	18	E	50M	B
2N759	S	N			A	0.5W	A	200	45	45	O				1.0	10M	36	E	50M	B
2N759A	S	N			A	0.5W	A	200	60	60	O				1.0	10M	36	E	50M	B
2N759B	S	N			A	0.5W	A	200	60	60	O	25		1.0M	0.5	10M	36	E	50M	B
2N760	S	N			A	0.5W	A	200	45	45	O				1.0	10M	76	E	50M	B
2N760A	S	N			A	0.5W	A	200	60	60	O				1.0	10M	76	E	50M	B
2N760B	S	N			A	0.5W	A	200	60	60	O	50		1.0M	0.5	10M	76	E	50M	B
2N761	S	N			A	0.5W	A	200	50	30	O	20	55	10M	1.0	10M	19	E	50M	B
2N762	S	N			A	0.5W	A	200	50	30	O	45	150	10M	1.0	10M	39	E	50M	B
2N764 thru 2N767	Thyristors, see Table on Page 164																			
2N768	G	P	2N961	2N956	SH	35M	A	100	12	10	S	25		2.0M	0.13	2.0M			125M	T
2N769	G	P	2N961	2N956	SH	35M	A	100	12	7.0	O	25		20M	0.25	10M			100M	T
2N770	S	N			SH	150M	A	150	20	15	O	12	60	20M	0.25	10M			75M	T
2N771	S	N			SH	150M	A	150	20	15	O	30	150	20M	0.25	10M			100M	T
2N772	S	N			SH	150M	A	150	25	25	O	20		10M	0.25	10M			75M	T
2N773	S	N			AH	150M	A	150	20	15	O	4.0	16	1.5M			6.0	E		
2N774	S	N			AH	150M	A	150	20	15	O	7.0	30	1.5M			11	E		
2N775	S	N			AH	150M	A	150	20	15	O	20	80	1.5M			28	E		
2N776	S	N			AH	150M	A	150	20	15	O	4.0	16	1.5M			6.0	E		
2N777	S	N			AH	150M	A	150	20	15	O	7.0	30	1.5M			11	E		
2N778	S	N			AH	150M	A	150	20	15	O	20	80	1.5M			28	E		
2N779	G	P	2N964	2N956	SH	60M	A	100	15	15	S	50	200	10M	0.16	10M			320M	T
2N779A	G	P	2N964	2N956	SH	60M	A	100	15	15	S	50	200	10M	0.125	10M			320M	T
2N779B	G	P	2N964	2N956	SH	150M	A	100	15	15	S	50	200	10M	0.125	10M			320M	T
2N780	S	N	2N2220		A	1.0W	C	175	45	45		35	140	500*	1.0	10M			60M	T

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N781	G	P			SH	150M	A	100	15	15	S	25		10M	0.16	10M				
2N782	G	P			SH	150M	A	100	12	12	S	20		10M	0.20	10M				
2N783	S	N	2N834	2N834	SH	300M		175	40	20	R	20	60	10M	0.25	10M			200M	T
2N784	S	N	2N834	2N834	SH	300M	A	175	30	15	R	25		10M	0.19	10M			200M	T
2N784A	S	N	2N834	2N834	SH	350M	A	200	40	20	R	25	150	10M	0.65	100M			300M	T
2N785	G	P			A	50M	A	85	12	12	S						40	E		
2N789	S	N			A	150M	A	175	45	30	O				1.0	5.0M	9.0	E	1.0M	B
2N790	S	N			A	150M	A	175	45	30	O				1.0	5.0M	18	E	2.0M	B
2N791	S	N			A	150M	A	175	45	30	O				1.0	5.0M	18	E	8.0M	B
2N792	S	N			A	150M	A	175	45	30	O				1.0	5.0M	36	E	2.0M	B
2N793	S	N			A	150M	A	175	45	30	O				1.0	5.0M	76	E	2.0M	B
2N794	G	P			SH	120M	A	85	13			30		10M	0.3	10M			25M	T
2N795	G	P			SH	120M	A	85	13			30		10M	0.5	40M			35M	T
2N796	G	P			SH	120M	A	85	13			50		10M	0.5	40M			50M	T
2N797	G	N			SH	150M	A	100	20	7.0	O	40		10M	0.14	10M			600M	T
2N799	G	P			S	75M	A	85	25	12	O	30		12M	0.15	12M			4.0M	B
2N800	G	P			S	75M	A	85	25	12	O	30			0.15	12M			4.0M	B
2N801	G	P			S	75M	A	85	30	18	O	30	60							
2N802	G	P			S	75M	A	85	30	18	O	30	60							
2N803	G	P			S	75M	A	85	30	15	O	40	80							
2N804	G	P			S	75M	A	85	30	15	O	40	80							
2N805	G	P			S	75M	A	85	30	12	O	60								
2N806	G	P			S	75M	A	85	30	12	O	60								
2N807	G	P			S	70M	A	85	25	14	V	40		20M	0.2	20M			14M	B
2N808	G	P			S	70M	A	85	25	14	V	40		20M	0.2	20M			14M	B
2N809	G	P			AH	75M	A	85	30	15	O	25	110	25M			30	E	3.0M	B
2N810	G	P			AH	75M	A	85	30	15	O	25	110	25M			30	E	3.0M	B
2N811	G	P			AH	75M	A	85	30	12	O	45	180	45M			50	E	5.0M	B
2N812	G	P			AH	75M	A	85	30	12	O	45	180	45M			50	E	5.0M	B
2N813	G	P			AH	75M	A	85	30	10	O	55	220	55M			70	E	15M	B
2N814	G	P			AH	75M	A	85	30	10	O	55	220	55M			70	E	15M	B
2N815	G	N			S	75M	A	85	25	15	O	60	180	30M	0.75	200M				
2N816	G	N			S	75M	A	85	25	15	O	60	180	30M	0.75	200M				
2N817	G	N			S	75M	A	85	30	15	O	20		50M	0.25	50M				
2N818	G	N			S	75M	A	85	30	15	O	20		50M	0.25	50M				
2N819	G	N			S	75M	A	85	30	20	O	30		50M	0.25	50M				
2N820	G	N			S	75M	A	85	30	20	O	30		50M	0.25	50M				
2N821	G	N			S	75M	A	85	30	25	O	40		50M	0.25	50M				
2N822	G	N			S	75M	A	85	30	25	O	40		50M	0.25	50M				
2N823	G	N			S	75M	A	85	25	12	O	40		20M	0.15	12M			4.0M	B
2N824	G	P			AH	70M	A	85	30	18	O								2.0M	B
2N825	G	P			S	70M	A	85	30	20	O	40	40						2.5M	B
2N826	G	P			S	70M	A	85	30	20	O	20	40						2.5M	B
2N827	G	P		2N827	SH	150M	A	100	20	20	S	100		10M	0.25	10M			250M	T
2N828	G	P		2N828	SH	150M	A	100	15	15	S	25		10M	0.2	10M			300M	T
2N828A	G	P		2N828	SH	150M	A	100	15	15	S	25		10M	0.2	10M			300M	T
2N829	G	P		2N828	SH	150M	A	100	15	15	S	50		10M	0.2	10M			300M	T
2N834	S	N		2N834	SH	300M	A	175	40	30	S	25		10M	0.25	10M			350M	T
2N834A	S	N			SH	360M	A	200	40	30	S	25		10M	0.25	10M			500M	T
2N835	S	N		2N834	SH	0.3W	A	175	25	20	O	20		10M	0.3	10M			300M	T
2N837	G	P			SH	150M	A	100	12	12	S	30		10M	0.25	10M				
2N838	G	P		2N838	SH	150M	A	100	30	30	S	30		10M	0.18	10M			300M	T
2N839	S	N	2N2222	2N2218	AH	0.3W	A	175	45	45	O	15	50	10M	2.0	10M	20	E	30M	T
2N840	S	N	2N2221	2N2218	AH	0.3W	A	175	45	45	O	30	100	10M	2.0	10M	40	E	30M	T
2N841	S	N	2N2222	2N2218	AH	0.3W	A	175	45	45	O	60	400	10M	2.0	10M	80	E	40M	T
2N842	S	N	2N2221	2N2218	AH	0.3W	A	175	45	45	O	20	55	10M	1.2	10M	20	E	30M	T
2N843	S	N	2N2222	2N2218	AH	0.3W	A	175	45	45	O	45	150	10M	1.2	10M	40	E	40M	T
2N844	S	N			AH	0.3W	A	175	60	60	R	40	120	5.0M	0.8	10M			50M	T
2N845	S	N			AH	0.3W	A	175	100	80	R	40	120	5.0M	0.8	10M			50M	T
2N846	G	P	2N960	2N956	SH	60M	A	100	15	15	S	25	125	10M	0.18	10M			320M	T
2N846A	G	P	2N960	2N956	SH	60M	A	100	15	15	S	25	125	10M	0.14	10M			320M	T
2N846B	G	P	2N960	2N956	SH	150M	A	100	15	15	S	25	125	10M	0.14	10M			320M	T
2N847	S	N			S	0.2W	A	175	20	15	O				1.5	10M				
2N848	S	N			S	0.2W	A	175	40	25	O				1.5	10M				
2N849	S	N	2N835	2N834	SH	300M	A	175	25	15	O	20	60	10M	0.6	10M			600M	T
2N850	S	N	2N834	2N834	SH	300M	A	175	25	15	O	40	120	10M	0.6	10M			600M	T
2N851	S	N	2N835	2N834	SH	300M	A	175	20	12	O	20	60	10M					300M	T
2N852	S	N	2N834	2N834	SH	300M	A	175	20	12	O	40	120	10M					300M	T
2N858	S	P			S	150M	A	140	40	40	O	10	60	5.0M	0.15	5.0M	15	E	5.0M	T
2N859	S	P			S	150M	A	140	40	40	O	25	100	5.0M	0.15	5.0M	30	E	6.0M	T
2N860	S	P			S	150M	A	140	25	25	O	10	40	5.0M	0.15	5.0M	15	E	6.5M	T
2N861	S	P			S	150M	A	140	25	25	O	25	75	5.0M	0.15	5.0M	30	E	7.5M	T
2N862	S	P			S	150M	A	140	15	15	O	12	48	5.0M	0.15	5.0M	20	E	8.0M	T
2N863	S	P			S	150M	A	140	15	15	O	25	100	5.0M	0.15	5.0M	40	E	10M	T
2N864	S	P			S	150M	A	140	6.0	6.0	O	20	100	5.0M	0.1	5.0M	25	E	16M	T
2N864A	S	P			S	300M	A		6.0	6.0	O	20	250	5.0M	0.1	5.0M	25	E	16M	T
2N865	S	P			S	150M	A	140	10	6.0	O	45	125	5.0M	0.1	5.0M	100	E	24M	T
2N865A	S	P			S	300M	A		10	10	O	45	400	5.0M	0.1	5.0M	100	E	24M	T
2N866	S	N			S	500M	A	175	30	20	R	15	45	150M	1.5	150M			40M	T
2N867	S	N			S	500M	A	175	30	20	R	30	90	150M	1.5	150M			50M	T
2N869	S	P		2N869	AH	360M	A	200	25	18	O	20	120	10M	1.0	10M			100M	T
2N869A	S	P		2N869A	S	360M	A	200	25	18	O	40	120	30M	0.15	10M			400M	T
2N870	S	N			AH	500M	A	200	100	80	R	40	120	150M	1.2	50M	30	E	50M	T
2N871	S	N			AH	500M	A	200	100	80	R	100	300	150M	1.2	50M	50	E	60M	T
2N876 thru 2N901	Thyristors, see Table on Page 164																			
2N902	S	N			A	150M	A	175	45	30	O				1.0	5.0M	9.0	E	1.0M	

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N903	S	N			A	150M	A	175	45	30	O				1.0	5.0M	18	E	2.0M	
2N904	S	N			A	150M	A	175	45	30	O				1.0	5.0M	18	E	8.0M	
2N905	S	N			A	150M	A	175	45	30	O				1.0	5.0M	36	E	2.0M	
2N906	S	N			A	150M	A	175	45	30	O				1.0	5.0M	76	E	2.0M	
2N907	S	N			A	0.15W	A	175	45	30	O	20	55	10M			19	E	12M	T
2N908	S	N			A	0.15W	A	175	45	30	O	45	150	10M			39	E	25M	T
2N909	S	N	2N2222	2N2218	A	400M	A	175	60	30	R	110	350	50M	0.5	10M	40	E	50M	T
2N910	S	N		2N910	A	500M	A	200	100	80	R	75		10M	0.4	10M	76	E	60M	T
2N911	S	N		2N910	A	500M	A	200	100	80	R	35		10M	0.4	10M	36	E	50M	T
2N912	S	N			A	500M	A	200	100	80	R	15		10M	0.4	10M	18	E	40M	T
2N914	S	N		2N914	SH	360M	A	200	40	20	R	30	120	10M	0.7	200M			300M	T
2N914A	S	N			SH	360M	A	200	40	20	R	30	120	10M	0.4	200M			300M	T
2N915	S	N		2N915	AH	360M	A	200	70	50	O	50	200	10M	1.0	10M	50	E	250M	T
2N915A	S	N			AHP	1.2W	C	200	70	50	O	50	250	5.0M	0.2	10M	50	E	600M	T
2N916	S	N		2N916	AH	360M	A	200	45	25	O	50	200	10M	0.5	10M	50	E	300M	T
2N916A	S	N			AH	360M	A	200	45	25	O	50	200	10M	0.5	10M	50	E	300M	T
2N916B	S	N			AHP	1.2W	C	200	60	30	O	50	200	10M	0.2	10M	50	E	500M	T
2N917	S	N			AH	200M	A	200	30	15	O	20	200	3.0M	0.5	3.0M			500M	T
2N917A	S	N			AH	200M	A	200	30	15	O	20	200	3.0M	0.4	10M			600M	T
2N918	S	N		2N918	AH	200M	A	200	30	15	O	20		3.0M	0.4	10M			600M	T
2N919	S	N	2N834	2N834	SH	0.36W	A	200	25	15	O	20	60	10M	0.2	10M			200M	T
2N920	S	N	2N834	2N834	SH	0.36W	A	200	25	15	O	40	120	10M	0.2	10M			200M	T
2N921	S	N	2N834	2N834	SH	0.36W	A	200	50	20	O	20	60	10M	0.3	10M			200M	T
2N922	S	N	2N834	2N834	SH	0.36W	A	200	50	20	O	40	120	10M	0.3	10M			200M	T
2N923	S	P			A	0.25W	A	200	40	25	O				0.5	5.0M	12	E	0.8M	B
2N924	S	P			A	0.25W	A	200	40	25	O				0.5	5.0M	24	E	0.8M	B
2N925	S	P			A	0.25W	A	200	50	40	O				0.5	5.0M	10	E	0.8M	B
2N926	S	P			A	0.25W	A	200	50	40	O				0.5	5.0M	20	E	0.8M	B
2N927	S	P			A	0.25W	A	200	70	60	O				0.5	5.0M	8.0	E	0.8M	B
2N928	S	P			A	0.25W	A	200	70	60	O				0.5	5.0M	18	E	0.8M	B
2N929	S	N		2N929	A	600M	C	175	45	45	O	40	120	10*	1.0	10M	150	E	1.0M	E
2N929A	S	N		2N929	A	0.5W	A	200	60	45	O	40	120	10*	0.5	10M	60	E	45M	T
2N930	S	N		2N929	A	600M	C	175	45	45	O	100	300	10*	1.0	10M	150	E	1.0M	E
2N930A	S	N		2N929	A	0.5W	A	200	60	45	O	100	300	10*	0.5	10M	150	E	45M	T
2N930B	S	N			A	500M	A		60	45	O	100	300	10*	0.5	10M	150	E	45M	T
2N934	G	P	2N965	2N960	SH	150M	A	85	13	12		40		40M	0.3	40M			35M	T
2N935	S	P			A	0.25W	A	160	50	40	O	9.0	22		0.3	5.0M				
2N936	S	P			A	0.25W	A	160	50	35	O	18	44		0.5	5.0M				
2N937	S	P			A	0.25W	A	160	50	30	O	36	88		0.6	5.0M				
2N938	S	P			A	0.25W	A	175	40	35	O				0.3	5.0M	9.0	E	1.0M	B
2N939	S	P			A	0.25W	A	175	40	35	O				0.3	5.0M	18	E	2.0M	B
2N940	S	P			A	0.25W	A	175	40	35	O				0.3	5.0M	36	E	2.0M	B
2N941	S	P			SC	0.25W	A	175	25	8	U	10		1.0M			25	E	16M	T
2N942	S	P			SC	0.25W	A	175	25	8	U	10		1.0M			25	E	10M	T
2N943	S	P			SC	0.25W	A	175	40	18	O	10			0.003		25	E	1.0M	B
2N944	S	P			SC	0.25W	A	175	40	18	O	10			0.004		25	E	1.0M	B
2N945	S	P			SC	0.25W	A	175	50	50	O	10			0.005		25	E	1.0M	B
2N946	S	P			SC	0.25W	A	175	80	80	O	10			0.005		25	E	1.0M	B
2N947	S	N	2N834	2N834	S	360M	A	150	20	15	R	20		10M	0.4	5.0M			200M	T
2N948 thru 2N951	Thyristors, see Table on Page 164																			
2N955	G	N			SH	150M	A	100	12	8.0	O	30		30M	0.5	30M				
2N955A	G	N			SH	150M	A	100	12	8.0	O	30		30M	0.3	30M				
2N956	S	N	2N2222	2N2218	AH	500M	A	200	75	50	R	100	300	150M	1.5	150M	50	E	70M	T
2N957	S	N	2N2501	2N2501	AH	250M	A	150	40	20	O	45		10M	1.5	10M			200M	T
2N958	S	N			SH	0.25W	C	150	25	15	O	20		10M	0.2	10M			200M	T
2N959	S	N			SH	0.25W	C	150	25	15	O	40		10M	0.2	10M			200M	T
2N960	G	P		2N956	SH	150M	A	100	15	15	S	20		10M	0.2	10M			300M	T
2N961	G	P		2N956	SH	150M	A	100	12	12	S	20		10M	0.2	10M			300M	T
2N962	G	P		2N956	SH	150M	A	100	12	12	S	20		10M	0.2	10M			300M	T
2N963	G	P		2N960	SH	150M	A	100	12	12	S	20		10M	0.2	10M			250M	T
2N964	G	P		2N960	SH	150M	A	100	15	15	S	40		10M	0.18	10M			300M	T
2N964A	G	P		2N964	SH	150M	A	100	15	15	S	40		10M	0.18	10M			300M	T
2N965	G	P		2N960	SH	150M	A	100	12	12	S	40		10M	0.18	10M			300M	T
2N966	G	P		2N960	SH	150M	A	100	12	12	S	40		10M	0.18	10M			300M	T
2N967	G	P		2N960	SH	150M	A	100	12	12	S	40		10M	0.2	10M			250M	T
2N968	G	P		2N965	SH	150M	A	100	15	15	S	17		10M	0.25	10M			300M	T
2N969	G	P		2N965	SH	150M	A	100	12	12	S	17		10M	0.25	10M			300M	T
2N970	G	P		2N965	SH	150M	A	100	12	12	S	17		10M	0.25	10M			300M	T
2N971	G	P		2N965	SH	150M	A	100	7.0	7.0	S	17		10M	0.25	10M			300M	T
2N972	G	P		2N965	SH	150M	A	100	15	15	S	40		10M	0.25	10M			300M	T
2N973	G	P		2N965	SH	150M	A	100	12	12	S	40		10M	0.25	10M			300M	T
2N974	G	P		2N965	SH	150M	A	100	12	12	S	40		10M	0.25	10M			300M	T
2N975	G	P		2N965	SH	150M	A	100	7.0	7.0	S	40		10M	0.25	10M			300M	T
2N976	G	P	2N964	2N960	SH	100M	A	100	15	10	O	30		20M	0.17	20M			249M	T
2N977	G	P	2N964	2N960	SH	150M	A	100	15	10	O	50		40M	0.2	40M			400M	T
2N978	S	P	2N2837	2N2800	AH	330M	A	150	30	20	O	15	60	150M	1.5	150M			40M	T
2N979	G	P			SH	60M	A	100	20	15	O	30		10M	0.25	10M			100M	T
2N980	G	P			SH	60M	A	100	20	12	O	30		10M	0.25	10M			100M	T
2N981	S	N			A	0.5W	A	200	80	80	O				3.0	10M	36	E	50M	B
2N982	G	P			SH	60M	A	100	20	15	O	50		10M	0.125	10M				
2N983	G	P			SH	60M	A	100	15	15	O	40		10M	0.15	10M				
2N984	G	P			SH	60M	A	100	15	10	O	50		10M	0.18	10M				
2N985	G	P		2N985	SH	150M	A	100	15	7.0	O	40		10M	0.15	10M			300M	T
2N986	S	N			AL	500M	A	200	100	80	R									
2N987	G	P			AH	0.1W	A	100	40	40	O	40	250	1.0M			40	E		
2N988	S	N	2N2221	2N2218	AH	0.3W	A	175	20	10	O	20	120	10M	0.5	10M			300M	T
2N989	S	N	2N2221	2N2218	AH	0.3W	A	175	20	10	O	20	120	10M	0.5	10M			300M	T
2N990	G	P			AH	67M	A	75	20	20	R	40		1.0M			40	E	44M	T
2N991	G	P			AH	67M	A	75	20	20	R	40		1.0M			40	E	44M	T

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	$V_{CE—}$ (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	$h_{f—}$	Subscript	$f_—$ Units	Subscript
2N992	G	P			AH	67M	A	75	20	20	R	40		1.0M			40	E		
2N993	G	P			AH	67M	A	75	20	20	R	40		1.0M			40	E	44M	T
2N994	G	P			SH	200M	A	150	15	6.0	O	45	140	10M	0.18	10M				
2N995	S	P			AH	360M	A	200	20	15	O	35	140	20M	0.2	20M			100M	T
2N995A	S	P	2N3250	2N3250	AH	360M	A	200	20	15	O	35	140	20M	0.2	20M			100M	T
2N996	S	P	2N3248	2N3248	AH	360M	A	200	15	12	O	35		20M	0.3	60M			100M	T
2N997	S	N			A	500M	A	175	75	40	O	35		100*	1.6	100M				
2N998	S	N		2N998	AL	500M	A	200	100	60	O				1.2	50M	1000	E		
2N999	S	N		2N998	AL	500M	A	200	60	60	O				1.6	100M				
2N1000	G	N			S	150M	A	100	40	25	O	40		10M	0.25	100M			7.0M	E
2N1003	G	P			AH	120M	A	100	35	20	U						10	E		
2N1004	G	P			AH	120M	A	100	35	20	U						10	E		
2N1005	S	N			A	150M	A	175	15	15	O	10	25	10M	0.6	10M				
2N1006	S	N			A	150M	A	175	15	15	O	25	150	10M	0.6	10M				
2N1007	G	P			AP	35W	C	95	25	20	O	50	250	1.0A	1.0	2.0A	25	E	60K	T
2N1008	G	P		2N1008	A	0.3W	C	85	20	15	R				0.25	0.1A	40	E		
2N1008A	G	P		2N1008	A	0.3W	C	85	40	35	R				0.25	0.1A	40	E		
2N1008B	G	P		2N1008	A	0.3W	C	85	60	55	R				0.25	0.1A	40	E		
2N1009	G	P			A	0.4W	C	85	35	35	R				0.25	0.1A	40	E	7.5K	E
2N1010	G	N			A	20M	A	55	10	10	O									
2N1011	G	P		2N1011	AP	35W	C	95	80	80	S	30	75	3.0A	1.5	3.0A	20	E	5.0K	E
2N1012	G	N			S	150M	A	100	40	22	O	40		100M	0.2	100M			3.0M	E
2N1014	G	P	MP448		AP	50W	C	100	100	65	O	20	50	4.0A	0.8	4.0A			0.5M	B
2N1015	S	N	2N3713	2N3713	SP	150W	C	150	30	30	V	10		2.0A	1.5	2.0A				
2N1015A	S	N			SP	150W	C	150	60	60	V	10		2.0A	1.5	2.0A				
2N1015B	S	N			SP	150W	C	150	100	100	V	10		2.0A	1.5	2.0A				
2N1015C	S	N			SP	150W	C	150	150	150	V	10		2.0A	1.5	2.0A				
2N1015D	S	N			SP	150W	C	150	200	200	V	10		2.0A	1.5	2.0A				
2N1015E	S	N			SP	150W	C	150	250	250	V	10		2.0A	1.5	2.0A				
2N1015F	S	N			SP	150W	C	150	300	300	V	10		2.0A	1.5	2.0A				
2N1016	S	N	2N3713	2N3713	SP	150W	C	150	30	30	V	10		5.0A	2.5	5.0A				
2N1016A	S	N			SP	150W	C	150	60	60	V	10		5.0A	2.5	5.0A				
2N1016B	S	N			SP	150W	C	150	100	100	V	10		5.0A	2.5	5.0A				
2N1016C	S	N			SP	150W	C	150	150	150	V	10		5.0A	2.5	5.0A				
2N1016D	S	N			SP	150W	C	150	200	200	V	10		5.0A	2.5	5.0A				
2N1016E	S	N			SP	150W	C	150	250	250	V	10		5.0A	2.5	5.0A				
2N1016F	S	N			SP	150W	C	150	300	300	V	10		5.0A	2.5	5.0A				
2N1017	G	P			S	150M	A	85	30	10	O	70		20M	2.6	200M			15M	B
2N1018	G	P			S	200M	A	100	30	6.0	O	70		70M	2.6	200M			20M	B
2N1021	G	P		2N1021	AP	50W	C	95	100	100	X	23	70	1.0A	1.0	5.0A				
2N1021A	G	P	MP1974		AP	150W	C	100	100	50	O	30	90	5.0A	0.5	5.0A			200K	T
2N1022	G	P		2N1021	AP	50W	C	95	120	120	X	23	70	5.0A	1.0	5.0A				
2N1022A	G	P	MP1975		AP	150W	C	100	120	55	O	30	90	5.0A	0.5	5.0A			200K	T
2N1023	G	P	2N3323	2N3323	A	120M	A	100	40	40	O	20	175	1.5M						
2N1024	S	P			A	0.25W	A	175	18	15	U						9.0	E	1.0M	B
2N1025	S	P			A	0.25W	A	175	40	35	U						9.0	E	1.0M	B
2N1026	S	P			A	0.25W	A	175	40	35	U						18	E	2.0M	B
2N1027	S	P			A	0.25W	A	175	18	15	U						18	E	4.0M	B
2N1028	S	P			A	0.25W	A	175	12	10	U						9.0	E	7.2M	T
2N1029	G	P	2N1553	2N1539	AP	90W	C	100	50	20	O	20	60	10A	1.0	10A				
2N1029A	G	P	2N1554	2N1539	AP	90W	C	100	60	30	O	20	60	10A	1.0	10A				
2N1029B	G	P	2N1555	2N1539	AP	90W	C	100	90	60	O	20	60	10A	1.0	10A				
2N1029C	G	P	2N1556	2N1539	AP	90W	C	100	100	70	O	20	60	10A	1.0	10A				
2N1030	G	P	2N1557	2N1539	AP	90W	C	100	50	20	O	50	100	10A	1.0	10A				
2N1030A	G	P	2N1558	2N1539	AP	90W	C	100	60	30	O	50	100	10A	1.0	10A				
2N1030B	G	P	2N1559	2N1539	AP			100	90	60	O	50	100	10A	1.0	10A				
2N1030C	G	P	2N1560	2N1539	AP			100	100	70	O	50	100	10A	1.0	10A				
2N1031	G	P	2N1553	2N1539	AP	90W	C	100	50	30	S	20	60	10A	1.0	10A	10	E	2.0K	E
2N1031A	G	P	2N1554	2N1539	AP	90W	C	100	60	40	S	20	60	10A	1.0	10A	10	E	2.0K	E
2N1031B	G	P	2N1555	2N1539	AP	90W	C	100	90	70	S	20	60	10A	1.0	10A	10	E	2.0K	E
2N1031C	G	P	2N1556	2N1539	AP	90W	C	100	100	80	S	20	60	10A	1.0	10A	10	E	2.0K	E
2N1032	G	P	MP327		AP	90W	C	100	50	30	S	50	100	10A	1.0	10A	25	E	2.0K	E
2N1032A	G	P	MP328		AP	90W	C	100	60	40	S	50	100	10A	1.0	10A	25	E	2.0K	E
2N1032B	G	P	MP329		AP	90W	C	100	90	70	S	50	100	10A	1.0	10A	25	E	2.0K	E
2N1032C	G	P	MP330		AP	90W	C	100	100	80	S	50	100	10A	1.0	10A	25	E	2.0K	E
2N1034	S	P			A	250M	A	160	50	40	O				0.5	8.0M	9.0	E	150K	B
2N1035	S	P			A	250M	A	160	50	35	O				0.4	8.0M	18	E	200K	B
2N1036	S	P			A	250M	A	160	50	30	O				0.3	8.0M	34	E	300K	B
2N1037	S	P			A	250M	A	160	50	35	O				0.5	8.0M	9.0	E	150K	B
2N1038	G	P		2N1038	AP	20W	C	95	40	40	V	20	60	1.0A	0.25	1.0A	18	E	8.0K	E
2N1039	G	P		2N1038	AP	20W	C	95	60	60	V	20	60	1.0A	0.25	1.0A	18	E	8.0K	E
2N1040	G	P		2N1038	AP	20W	C	95	80	80	V	20	60	1.0A	0.25	1.0A	18	E	8.0K	E
2N1041	G	P		2N1038	AP	20W	C	95	100	100	V	20	60	1.0A	0.25	1.0A	18	E	8.0K	E
2N1042	G	P	2N2143	2N2137	AP	20W	C	100	40	40	V	20	60	3.0A	0.75	3.0A	2.0	E	250K	T
2N1043	G	P	2N2144	2N2137	AP	20W	C	100	60	60	V	20	60	3.0A	0.25	1.0A			250K	T
2N1044	G	P	2N2145	2N2137	AP	20W	C	100	80	80	V	20	60	3.0A	0.25	1.0A			250K	T
2N1045	G	P	2N2146	2N2137	AP	20W	C	100	100	100	V	20	60	3.0A	0.25	1.0A			250K	T
2N1046	G	P	MP1046		AHP	50W	C	100	100	50	O	40		5.0A	0.2	500M			15M	T
2N1046A	G	P	MP1046		AHP	50W	C	100	130	50	O	40		5.0A	0.4	5.0A			15M	T
2N1046B	G	P	MP1046		AHP	50W	C	100	130	50	O	20		10A	0.4	5.0A			15M	T
2N1047	S	N			AP	40W	C	200	80			12	36	500M	7.5	500M				
2N1047A	S	N			AP	40W	C	200	80	80	O	12	36	500M	7.5	500M			75K	E
2N1047B	S	N			AP	40W	C	200	80	80	O	12	36	500M	2.0	500M			125K	E
2N1047C	S	N			AP	40W	C	200	80	80	O	12	36	500M	1.0	500M			125K	E
2N1048	S	N			AP	40W	C	200	120			12	36	500M	7.5	500M				
2N1048A	S	N			AP	40W	C	200	120	120	O	12	36	500M	7.5	500M			75K	E
2N1048B	S	N			AP	40W	C	200	120	120	O	12	36	500M	2.0	500M			125K	E
2N1048C	S	N			AP	40W	C	200	120	120	O	12	36	500M	1.0	500M			125K	E

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N1049	S	N			AP	40W	C	200	80			30	90	500M	7.5	500M				
2N1049A	S	N			AP	40W	C	200	80	80	O	30	90	500M	7.5	500M			75K	E
2N1049B	S	N			AP	40W	C	200	80	80	O	30	90	500M	2.0	500M			125K	E
2N1049C	S	N			AP	40W	C	200	80	80	O	30	90	500M	1.0	500M			125K	E
2N1050	S	N			AP	40W	C	200	120			30	90	500M	7.5	500M				
2N1050A	S	N			AP	40W	C	200	120	120	O	30	90	500M	7.5	500M			75K	E
2N1050B	S	N			AP	40W	C	200	120	120	O	30	90	500M	2.0	500M			125K	E
2N1050C	S	N			AP	40W	C	200	120	80	O	30	90	500M	1.0	500M			125K	E
2N1051	S	N			AH	0.5W	A	150	40	40	O	25		50M	3.0	50M	30	E	80M	T
2N1052	S	N			AH	6.0M	A	200	200	200	V	20	80	0.2A	5.0	0.2A				
2N1054	S	N			AH	0.8W	A	200	125	115	O	20		0.2A			15	E	8.0M	T
2N1055	S	N			AH	5.5M	A	200	100	100	O	20	80	50M	2.0	50M			3.0M	T
2N1056	G	P	2N2043	2N2042	A	240M	A	100	70	50	R	18	43	20M	0.13	20M			500K	B
2N1057	G	P	2N1924	2N1924	A	240M	A	100	45	45	V	34	90	20M	0.13	20M			500K	B
2N1058	G	N				50M		75	20	20	R						10	B	4.0M	B
2N1059	G	N			A	180M		75	40	15	R			10M					10K	E
2N1060	S	N	2N2501	2N2501	SH	0.25W	A	150	40	40	O	17		5.0M	0.3	5.0M				
2N1065	G	P			A	0.12W	A	85	40	20	O	20	80		0.25	10M			10M	T
2N1066	G	P	2N3323	2N3323	AH	120M	A	100	40	40	O	20	175	1.5M						
2N1067	S	N	2N3766	2N3766	SP	5.0W	C	175	60	30	O	15	75	200M	2.0	200M			0.75M	B
2N1068	S	N	2N3766	2N3766	SP	10W	C	175	60	30	O	15	75	750M	2.0	200M			0.75M	B
2N1069	S	N	2N4913	2N4913	SP	50W	C	175	60	45	O	20	50	1.5A	1.33	0.5A			0.5M	B
2N1070	S	N	2N4913	2N4913	SP	50W	C	175	60	45	O	20	50	1.5A	0.5	1.5A			0.5M	B
2N1072	S	N	2N3766	2N3766	SP	2.0W	A	150	75	30	O	20		0.75A	2.0	0.75A				
2N1073	G	P		2N1073	AP			110	40	40	R	20	60	5.0A	1.0	5.0A				
2N1073A	G	P		2N1073	AP			110	80	80	R	20	60	5.0A	1.0	5.0A				
2N1073B	G	P		2N1073	AP			110	120	120	R	20	60	5.0A	1.0	5.0A				
2N1074	S	N			A	250M	A	160	50	40	O						9.0	E	200K	B
2N1075	S	N			A	250M	A	160	50	35	O						18	E	250K	B
2N1076	S	N			A	250M	A	160	50	30	O						36	E	300K	B
2N1077	S	N			A	250M	A	160	50	35	O				1.0	8.0M	9.0	E	200K	B
2N1078	G	P			AP	20W	C	85	60	60	S	40		0.5A	1.0	1.0A				
2N1079	S	N			AHP	60W	C	200	60	60	S	20	80	1.0A	3.0	1.0A	20	E	10M	T
2N1080	S	N			AHP	60W	C	200	60	60	S	20	80	2.0A	5.0	2.0A	20	E	10M	T
2N1081	S	N			S	6.0M	A	200	40	40	O	20	100	0.5A	4.0	0.5A				
2N1082	S	N			AH	0.2W	A	200	25	25	S	10	50	10M			10	E	17M	T
2N1086	G	N			AH	65M	A	85	9.0	9.0	O	17	195	1.0M						
2N1086A	G	N			AH	65M	A	85	9.0	9.0	O	17	195	1.0M						
2N1087	G	N			AH	65M	A	85	9.0	9.0	O	17	195	1.0M						
2N1090	G	N			S	120M	A	85	25			30		20M	0.2	20M			5.0M	B
2N1091	G	N			S	120M	A	85	25			40		20M	0.3	200M			10M	B
2N1092	S	N			SP	2.0W	A	175	60	30	O	15	75	200M	2.0	200M			0.75M	B
2N1093	G	P			A	150M	A	95	30	15	O	50	150	20M	0.2	20M	40	E	5.0M	B
2N1094	G	P			AH	0.15W	A	100	30	15	O	15		4.0M			0.96	B	560M	T
2N1097	G	P	2N1414	2N1413	A	200M	A	100	18	18	R	34	90	20M					1.0M	B
2N1098	G	P	2N1414	2N1413	A	200M	A	100	18	18	R	25	90	20M					1.0M	B
2N1099	G	P		2N277	AP	50W	C	95	80	70	S	35	70	5.0A	0.7	12A				
2N1100	G	P		2N173	AP	50W	C	95	100	65	O	25	50	5.0A	0.7	12A				
2N1101	G	N			A	180M		75	20	15	R	25	50	35M	0.5	100M			10K	E
2N1102	G	N			A	180M		75	40	25	R	25	50	35M	0.5	100M			10K	E
2N1103	S	N			A	125M	A	150	45	35	O	30	65	10M	1.5	10M	20	E	10M	B
2N1104	S	N			A	125M	A	150	45	35	O	45	150	10M	1.5	10M	40	E	20M	B
2N1105	S	N			A	800M	A	200	60	60	O	12	36	200M	5.0	200M				
2N1106	S	N			A	800M	A	200	100	100	O	12	36	200M	5.0	200M				
2N1107	G	P			AH	30M	C		16										40M	B
2N1108	G	P			AH	30M	C		16										35M	B
2N1109	G	P			AH	30M	C		16										35M	B
2N1110	G	P			AH	30M	C		16										35M	B
2N1111	G	P			AH	30M	C		16										35M	B
2N1114	G	N			S	150M		100	25	15	R	40	180	20M					7.0M	B
2N1115	G	P			S	150M	A	85	20	15	O				0.35	60M			5.0M	B
2N1115A	G	P			S	150M	A	85	20	15	O				0.35	60M			5.0M	B
2N1116	S	N			AH	600M	C	200	60	60	O	40	150	0.5A	5.0	0.5A			6.0M	T
2N1117	S	N			AH	600M	C	200	60	60	O	40	150	0.2A	4.0	0.2A			4.0M	T
2N1118	S	P			AH	150M	A	140	25	25	U						15	E	8.0M	M
2N1118A	S	P			AH	150M	A	140	25	25	U		25	15M			15	E	8.0M	M
2N1119	S	P			S	150M	A	140	10	10	U	15		15M	0.15	5.0M			7.2M	T
2N1120	G	P		2N1120	AP	45W	C	95	80	70	S	20	50	10A	1.0	10A	30	E	3.0K	E
2N1121	G	N			AH	65M	C	85	15	15	O	34		1.0M						
2N1122	G	P	2N961	2N956	SH	25M	A	100	12	11	S	25		10M	0.1	8.0M	35	E	40M	
2N1122A	G	P	2N960	2N956	SH	25M	A	100	15	14	S	25		10M	0.1	8.0M	35	E	40M	
2N1123	G	P	2N3427	2N3427	SH	10M	C	100	45	40	S	40		100M	0.2	10M			3.0M	B
2N1124	G	P	2N651	2N650	A	300M	A	85	40	35	V				0.2	100M	40	E	400K	B
2N1125	G	P	2N651	2N650	SH	300M	A	85	40	40	V	50	150	500M	0.3	500M			1.0M	B
2N1126	G	P	2N651	2N650	S	1.0W	C	85	40	35	V				0.2	100M	40	E	400K	B
2N1127	G	P	2N3428	2N3427	S	1.0W	C	85	40	40	V	50	150	500M	0.3	500M			1.0M	B
2N1128	G	P	2N1192	2N1191	A	150M	A	85	25	18	S						70	E		
2N1129	G	P	2N3427	2N3427	A	150M	A	85	25	25	V	100	200	100M	0.25	100M				
2N1130	G	P	2N1193	2N1191	A	150M	A	85	30			50	165	100M	0.25	100M				
2N1131	S	P		2N1131	S	600M	A	175	50	35	O	20	45	150M	1.5	150M	15	E	50M	T
2N1131A	S	P	2N2800	2N2800	S	0.6W	A	175	60	40	O	20	45	0.15A	1.5	0.15A	15	E	50M	T
2N1132	S	P		2N722	S	600M	A	175	50	35	O	30	90	150M	1.5	150M	25	E	60M	T
2N1132A	S	P		2N722	S	0.6W	A	175	60	40	O	30	90	0.15A	1.5	0.15A	25	E	60M	T
2N1132B	S	P			S	0.6W	A	175	70	45	O	30	90	0.15A	1.5	0.15A	25	E	60M	T
2N1135	S	P			S	100M	A	140	12	12	O								5.6M	T
2N1135A	S	P			S	100M	A	140	12	12	O								5.6M	T
2N1136	G	P	MP249		AP			100	60	35	R	50	100	3.0A	1.0	3.0A			4.0K	E
2N1136A	G	P	MP249A		AP			100	90	35	R	50	100	3.0A	1.0	3.0A			4.0K	E

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N1136B	G	P	MP249B		AP			100	100	75	R	50	100	3.0A	1.0	3.0A			4.0K	E
2N1137	G	P	MP438		AP			100	60	25	O	75	150	3.0A	1.0	3.0A				
2N1137A	G	P	MP438A		AP			100	90	55	O	75	150	3.0A	1.0	3.0A				
2N1137B	G	P	MP438B		AP			100	100	65	O	75	150	3.0A	1.0	3.0A				
2N1138	G	P	MP280		AP			100	60	25	O	100	200	3.0A	1.0	3.0A				
2N1138A	G	P	MP281		AP			100	90	55	O	100	200	3.0A	1.0	3.0A				
2N1138B	G	P	MP282		AP			100	100	65	O	100	200	3.0A	1.0	3.0A				
2N1139	S	N			SH	6.6M	A	175	15	15	O	20	200	10M	0.7	10M			100M	T
2N1141	G	P		2N1141	AH	750M	C	100	35			10		10M	2.0	50M	12	E		
2N1141A	G	P			AH	750M	C	100	35	25	S	15		10M	2.0	50M	0.94	B	500M	T
2N1142	G	P		2N1141	AH	750M	C	100	30			10		10M	2.0	50M	0.98	B	600M	B
2N1142A	G	P			AH	750M	C	100	30	25	S	15		10*	2.0	50M	0.94	B	400M	T
2N1143	G	P		2N1141	AH	750M	C	100	25			10		10M	2.0	50M	0.98	B	480M	B
2N1143A	G	P			AH	750M	C	100	30	25	S	15		10M	2.0	50M	0.94	B	400M	T
2N1144	G	P	2N321	2N319	A	175M	A	85	16	16	R	34	90	20M					1.0M	B
2N1145	G	P	2N1414	2N1413	A	175M	A	85	16	16	R	25	90	20M					1.0M	B
2N1146	G	P			SP	87W	C	95	40	20	O	60	150	5.0A	1.0	15A			0.15M	E
2N1146A	G	P			SP	87W	C	95	60	30	O	60	150	5.0A	1.0	15A			0.15M	E
2N1146B	G	P			SP	87W	C	95	80	40	O	60	150	5.0A	1.0	15A			0.15M	E
2N1146C	G	P			SP	87W	C	95	100	50	O	60	150	5.0A	1.0	15A			0.15M	E
2N1147	G	P			SP	87W	C	95	40	20	O	60	150	5.0A	1.0	15A			0.15M	E
2N1147A	G	P			SP	87W	C	95	60	30	O	60	150	5.0A	1.0	15A			0.15M	E
2N1147B	G	P			SP	87W	C	95	80	40	O	60	150	5.0A	1.0	15A			0.15M	E
2N1147C	G	P			SP	87W	C	95	100	50	O	60	150	5.0A	1.0	15A			0.15M	E
2N1149	S	N			A	150M	A	175	45			9.0	20	25M			0.9	B	4.0M	B
2N1150	S	N			A	150M	A	175	45			18	40	25M			0.948	B	5.0M	B
2N1151	S	N			A	150M	A	175	45			18	90	25M			0.948	B	8.0M	B
2N1152	S	N			A	150M	A	175	45			36	90	25M			0.973	B	6.0M	B
2N1153	S	N			A	150M	A	175	45			76	333	25M			0.987	B	7.0M	B
2N1154	S	N			A	750M	C	150	50			9.0		60M			0.9	B		
2N1155	S	N			A	750M	C	150	80			9.0		50M			0.9	B		
2N1156	S	N			A	750M	C	150	120			9.0		40M			0.9	B		
2N1157	G	P	MP501	MP500	SP	187W	J	100	60	45	O	38	84	10A	0.8	40A			75K	T
2N1157A	G	P	MP502	MP500	SP	187W	J	100	80	50	O	38	84	10A	0.8	40A			75K	T
2N1158	G	P	2N1143	2N1141	AH	60M	A	100	20	20	S						5.7	E		
2N1158A	G	P	2N1142	2N1141	AH	75M	A	100	20	20	S						9.0	E		
2N1159	G	P	2N3616	2N3615	SP	35W	C	95	80	60	O	30	75	3.0A	1.0	3.0A				
2N1160	G	P	2N3616	2N3615	SP	35W	C	95	80	60	O	20	50	5.0A	1.0	5.0A				
2N1162	G	P		2N1162	SP	90W	C	100	50	35	S	15	65	25A	0.8	25A			1.0K	E
2N1162A	G	P		2N1162	SP	90W	C	100	50	35	S	15	65	25A	0.8	25A			3.0K	E
2N1163	G	P		2N1162	SP	90W	C	100	50	35	S	15	65	25A	0.8	25A			1.0K	E
2N1163A	G	P		2N1162	SP	90W	C	100	50	35	S	15	65	25A	0.8	25A			3.0K	E
2N1164	G	P		2N1162	SP	90W	C	100	80	60	S	15	65	25A	0.8	25A			1.0K	E
2N1164A	G	P		2N1162	SP	90W	C	100	80	60	S	15	65	25A	0.8	25A			3.0K	E
2N1165	G	P		2N1162	SP	90W	C	100	80	60	S	15	65	25A	0.8	25A			1.0K	E
2N1165A	G	P		2N1162	SP	90W	C	100	80	60	S	15	65	25A	0.8	25A			3.0K	E
2N1166	G	P		2N1162	SP	90W	C	100	100	75	S	15	65	25A	0.8	25A			1.0K	E
2N1166A	G	P		2N1162	SP	90W	C	100	100	75	S	15	65	25A	0.8	25A			3.0K	E
2N1167	G	P		2N1162	SP	90W	C	100	100	75	S	15	65	25A	0.8	25A			1.0K	E
2N1167A	G	P		2N1162	SP	90W	C	100	100	75	S	15	65	25A	0.8	25A			3.0K	E
2N1168	G	P	2N3614	2N3611	AP	45W	C	95	50	30	R									
2N1169	G	N			S	120M	A	71	40	20	O	20		200M	0.3	200M			4.5M	B
2N1170	G	N			S	120M	A	71	40	20	O	20		200M	0.3	200M			4.5M	B
2N1171	G	P			S	170M	A	85	30	12	O	30		30M					10M	B
2N1172	G	P	2N2137	2N2137	SP			95	40	30	O	30	90	100M						
2N1173	G	N			S	0.25W	A	100	35	20	O	50	200	10M	0.075	10M	50	E		
2N1174	G	P			S	0.25W	A	100	35	20	O	50	200	10M	0.075	10M	50	E		
2N1175	G	P		2N1413	A	200M	A	85	35	25	R	70	140	20M					1.5M	B
2N1176	G	P	2N1189	2N1189	A	0.3W	C	85	10	10	R				0.3	0.1A	20	E		
2N1177	G	P	2N2957	2N2955	AH	80M	A	71	30											
2N1178	G	P	2N2955	2N2955	AH	80M	A	71	30											
2N1179	G	P	2N2956	2N2955	AH	80M	A	71	30											
2N1180	G	P	2N2956	2N2955	AH	80M	A	71	30											
2N1182	G	P	2N2140	2N2137	SP	106W	C	100	50	60	O	30	85	0.5A	0.9	2.0A			5.0K	E
2N1183	G	P	2N2140	2N2137	SP	7.5W	C	100	45	20	O	20	60	400M	0.5	400M			500K	B
2N1183A	G	P	2N2140	2N2137	SP	7.5W	C	100	60	30	O	20	60	400M	0.5	400M			500K	B
2N1183B	G	P	2N2141	2N2137	SP	7.5W	C	100	80	40	O	20	60	400M	0.5	400M			500K	B
2N1184	G	P	2N2144	2N2137	SP	7.5W	C	100	45	20	O	40	120	400M	0.5	400M			500K	B
2N1184A	G	P	2N2145	2N2137	SP	7.5W	C	100	60	30	O	40	120	400M	0.5	400M			500K	B
2N1184B	G	P	2N2146	2N2137	SP	7.5W	C	100	80	40	O	40	120	400M	0.5	400M			500K	B
2N1185	G	P		2N1175	A	200M	A	100	45	30	R	130		10M			190	E	1.7M	B
2N1186	G	P		2N1175	A	200M	A	100	60	45	R	33		10M			30	E	0.75M	B
2N1187	G	P		2N1175	A	200M	A	100	60	45	R	45		10M			50	E	1.0M	B
2N1188	G	P		2N1175	A	200M	A	100	60	45	R	80		10M			100	E	1.2M	B
2N1189	G	P		2N1189	A	200M	A	100	45	30	R	60		10M	0.22	50M	75	E	1.7M	B
2N1190	G	P		2N1189	A	200M	A	100	45	30	R	100		10M	0.22	50M	125	E	2.2M	B
2N1191	G	P		2N1191	A	200M	A	100	40	25	R	20	80	10M			30	E		
2N1192	G	P		2N1191	A	200M	A	100	40	25	R	40	135	10M			50	E		
2N1193	G	P		2N1191	A	200M	A	100	40	25	R	70	300	10M			100	E		
2N1194	G	P		2N1191	A	200M	A	100	40	25	R	125	600	10M			190	E		
2N1195	G	P		2N1141	AH	225M	A	100	30								0.96	B	400M	T
2N1196	S	P			AH	0.35W	A	200	70	70	O	5.0	30	2.0M			0.85	B		
2N1197	S	P			AH	0.35W	A	200	70	70	O	5.0	30	2.0M			0.85	B		
2N1198	G	N			SH	65M	A	85	25	25	O	17	90	8.0M			0.952	B	5.0M	B
2N1199	S	N	2N835	2N834	SH	150M	A	150	20	15	O	12	60	20M	0.25	10M			75M	T
2N1199A	S	N	2N835	2N834	SH	150M	A	150	20	15	O	12	60	20M	0.25	10M			75M	T
2N1200	S	N			AH	100M	A	150	20	15	O	7.0	200	1.5M			9.0	E		
2N1201	S	N			AH	100M	A	150	20	15	O	7.0	200	1.5M			9.0	E		

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N1202	G	P	2N2145	2N2137	SP	34W	J	95	80	60	O	40	120	500M	0.3	500M			200K	T
2N1203	G	P	2N2146	2N2137	SP	34W	J	95	120	70	O	25	75	2.0A	0.6	2.0A			200K	T
2N1204	G	P		2N1204	SH	200M	A	100	20	15	O	15		400M	0.5	200M			220M	T
2N1204A	G	P		2N1204	SH	200M	A	100	20	15	O	25		200M	0.4	200M			220M	T
2N1206	S	N			AH	3.0M	A	200	60	60	O	20	80				25	E	10M	T
2N1207	S	N			AH	3.0M	A	200	125	125	O	20	80				25	E	10M	T
2N1208	S	N	2N3487	2N3485	AP	45W	C	200	60	60	O	15		2.0A	5.0	2.0A				
2N1209	S	N	2N3487	2N3485	AHP	45W	C	200	45	45	O	20	80	2.0A	5.0	2.0A			3.0M	T
2N1210	S	N	2N3713	2N3713	AHP	30W	C	175	60	60	O	15	75	2.0A	2.0	2.0A			3.0M	T
2N1211	S	N	2N3445	2N3445	AHP	30W	C	175	80	80	V	15	75	2.0A	2.0	2.0A			3.0M	T
2N1212	S	N	2N3487	2N3485	AHP	45W	C	200	60	60	O	12	36	1.0A	5.0	1.0A			3.0M	T
2N1213	G	P			SH	75M	A	71	25											
2N1214	G	P			SH	75M	A	71	25											
2N1215	G	P			SH	75M	A	71	25											
2N1216	G	P			SH	75M	A	71	25											
2N1217	G	N			SH	75M	A	85	20	20	O	40	100	500*					6.0M	B
2N1218	G	N			AP	20W	C	90	45	45	R	30	120	1.0A	1.0	1.0A			7.0K	E
2N1219	S	P			A	0.25W	A	175	30	25	O	18		5.0M					5.0M	B
2N1220	S	P			A	0.25W	A	175	30	25	O	9.0		5.0M					2.0M	B
2N1221	S	P			A	0.25W	A	175	30	25	O						18	E	5.0M	B
2N1222	S	P			A	0.25W	A	175	30	25	O						9.0	E	2.0M	B
2N1223	S	P			A	0.25W	A	175	40	40	O						6.0	E		
2N1224	G	P			SH	120M	A	85	40											
2N1225	G	P			AH	120M	A	85	40											
2N1226	G	P			AH	120M	A	85	60											
2N1227	G	P	2N3611	2N3611	AP	50W	C	95	35	20	O	50	350	0.5A	0.8	1.5A	25	E	3.0K	E
2N1228	S	P			S	0.4W	A	160	15	15	O				0.2	10M	14	E		
2N1229	S	P			S	0.4W	A	160	15	15	O				0.2	10M	28	E		
2N1230	S	P			S	0.4W	A	160	35	35	O				0.2	10M	14	E		
2N1231	S	P			S	0.4W	A	160	35	35	O				0.2	10M	28	E		
2N1232	S	P			S	0.4W	A	160	60	60	O				0.2	10M	14	E		
2N1233	S	P			S	0.4W	A	160	60	60	O				0.2	10M	28	E		
2N1234	S	P			S	0.4W	A	160	110	110	O				0.2	10M	14	E		
2N1235	S	N			AP	85W	C	200	120	120	R	12	60	1.0A	5.0	1.0A			50K	E
2N1238	S	P			S	1.0W	A	160	15	15	O				0.2	10M	14	E		
2N1239	S	P			S	1.0W	A	160	15	15	O				0.2	10M	28	E		
2N1240	S	P			S	1.0W	A	160	35	35	O				0.2	10M	14	E		
2N1241	S	P			S	1.0W	A	160	35	35	O				0.2	10M	28	E		
2N1242	S	P			S	1.0W	A	160	60	60	O				0.2	10M	14	E		
2N1243	S	P			S	1.0W	A	160	60	60	O				0.2	10M	28	E		
2N1244	S	P			S	1.0W	A	160	110	110	O				0.2	10M	14	E		
2N1245	G	P			AP	20W	C	85	30	25	R	50		0.5A						
2N1246	G	P			AP	20W	C	85	30	25	R	50		0.5A						
2N1247	S	N			A	30M	A	150	6.0	6.0	O	15		5.0*						
2N1248	S	N			A	30M	A	150	6.0	6.0	O	15		20*						
2N1249	S	N			A	30M	A	150	6.0	6.0	O	20		30*						
2N1250	S	N	2N3713	2N3713	AP	85W	C	200	60	60	O	15		2.0A	5.0	2.0A				
2N1251	G	N			A	150M		85	20	15	R				0.5	100M	70	E	7.5K	E
2N1252	S	N	2N2537	2N2537	S	600M	A	175	30	20	R	15	45	150M	1.5	150M			40M	T
2N1252A	S	N	2N2537	2N2537	S	800M	A	300	60	30	O	15	45	150M	1.5	150M			40M	T
2N1253	S	N	2N2537	2N2537	S	600M	A	175	30	20	R	30	90	150M	1.5	150M			50M	T
2N1253A	S	N	2N2537	2N2537	S	800M	A	300	60	30	O	30	90	150M	1.5	150M			50M	T
2N1254	S	P			SH	275M	A	200	30	30	O	25	50	10M	0.3	10M			30M	T
2N1255	S	P			SH	275M	A	200	30	30	O	40	80	10M	0.3	10M			50M	T
2N1256	S	P			SH	275M	A	200	40	40	O	25	50	10M	0.3	10M			30M	T
2N1257	S	P			SH	275M	A	200	40	40	O	40	80	10M	0.3	10M			50M	T
2N1258	S	P			SH	275M	A	200	30	30	O	75	150	10M	0.6	10M			50M	T
2N1259	S	P			SH	275M	A	200	50	50	O	25	100	10M	0.3	10M			40M	T
2N1260	S	N			AP	85W	C	200	120	120	R	12	60	1.0A	10	1.0A			50K	E
2N1261	G	P	2N1531	2N1529	SP	34W	J	95	80	45		20	50	2.0A	0.6	2.0A			200K	T
2N1262	G	P	2N1531	2N1529	SP	34W	J	95	80	45	O	30	75	2.0A	0.6	2.0A			200K	T
2N1263	G	P	2N3617	2N3615	SP	34W	J	95	80	45	O	45	113	2.0A	0.6	2.0A			200K	T
2N1264	G	P	2N1191	2N1191	AH	50M	A	75	20								15	E		
2N1265	G	P	2N1192	2N1191	AH	50M	A	85	12	10	R				0.5	100M	25	E	600K	B
2N1266	G	P	2N1191	2N1191	AH	80M	A	85	10								10	E		
2N1267	S	N			AH	150M	A	150	20	15	O	4.0	16	1.5M			6.0	E		
2N1268	S	N			AH	150M	A	150	20	15	O	7.0	30	1.5M			11	E		
2N1269	S	N			AH	150M	A	150	20	15	O	20	80	1.5M			28	E		
2N1270	S	N			AH	150M	A	150	20	15	O	4.0	16	1.5M			6.0	E		
2N1271	S	N			AH	150M	A	150	20	15	O	7.0	30	1.5M			11	E		
2N1272	S	N			AH	150M	A	150	20	15	O	20	80	1.5M			28	E		
2N1273	G	P			A	250M	A	100	15	15	R	27	165	50M	1.0	100M	20	E		
2N1274	G	P			A	250M	A	100	25	25	R	27	165	50M	1.0	100M	20	E		
2N1275	S	P			AM	250M	A	160	100	80	O	9.0	25	1.0M	0.3	5.0M			100K	B
2N1276	S	N	2N2501	2N2501	A	150M	A	150	40	30	O				1.0	5.0M	9.0	E	15M	B
2N1277	S	N			A	150M	A	150	40	30	O				1.0	5.0M	18	E	15M	B
2N1278	S	N	2N2501	2N2501	A	150M	A	150	40	30	O				1.0	5.0M	37	E	15M	B
2N1279	S	N	2N2501	2N2501	A	150M	A	150	40	30	O				1.0	5.0M	76	E	15M	B
2N1280	G	P			S	0.2W	A	85	16	16	O	40		20M					5.0M	B
2N1281	G	P			S	0.2W	A	85	16	12	O	60		20M					7.0M	B
2N1282	G	P			S	0.2W	A	85	16	6.0	O	70		20M					10M	B
2N1284	G	P			S	0.15W	A	85	20	15	O	30	150	10M	0.2	10M			5.0M	B
2N1285	G	P			AH	240M	A	71	40	40	V	30	100	1.5M						
2N1287	G	P	2N651	2N650	A	0.3W	C	85	25	25	R				0.5	20M	40	E		
2N1287A	G	P	2N652	2N650	A	0.3W	C	85	25	25	R				0.5	20M	60	E		
2N1288	G	N			SH	75M	A	100	15	10	R	50	300	10M	0.3	10M				
2N1289	G	N			SH	75M	A	85	20	15	O	50	300	10M	0.3	10M			40M	B
2N1291	G	P	2N1529	2N1529	AP	20W	C	85	35	30	S	40		0.5A	1.0	1.0A				

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N1292	G	N			AP	25W	C	100	35	30	S	30		0.5A	1.0	1.0A				
2N1293	G	P	2N1531	2N1529	AP	20W	C	85	60	60	S	40		0.5A	1.0	1.0A				
2N1294	G	N			AP	25W	C	100	60	45	S	30		0.5A	1.0	1.0A				
2N1295	G	P	2N1532	2N1529	AP	20W	C	85	80	80	S	40		0.5A	1.0	1.0A				
2N1296	G	N			AP	25W	C	100	80	60	S	30		0.5A	1.0	1.0A				
2N1297	G	P	2N1533	2N1529	AP	20W	C	85	100	100	S	40		0.5A	1.0	1.0A				
2N1298	G	N			AP	25W	C	100	100	80	S	30		0.5A	1.0	1.0A				
2N1299	G	N			S	150M		100	40	20	R	35	110	50M	0.17	15M			4.0M	B
2N1300	G	P			SH	150M	A	85	13	12	O	30		10M					25M	T
2N1301	G	P			SH	150M	A	85	13	12	O	30		10M					35M	T
2N1302	G	N			S	150M	A	85	25			20		10M	0.2	10M			3.0M	B
2N1303	G	P	2N1192	2N1191	S	150M	A	85	30			20		10M	0.2	10M			3.0M	B
2N1304	G	N			S	150M	A	85	25			40	200	10M	0.2	10M			5.0M	B
2N1305	G	P			S	150M	A	85	30			40	200	10M	0.2	10M			5.0M	B
2N1306	G	N			S	150M	A	85	25			60	300	10M	0.2	10M			10M	B
2N1307	G	P			S	150M	A	85	30			60	300	10M	0.2	10M			10M	B
2N1308	G	N			S	150M	A	85	25			80		10M	0.2	10M			15M	B
2N1309	G	P			S	150M	A	85	30			80		10M	0.2	10M			15M	B
2N1309A	G	P			S	0.15W	A	85	35	15	O	80		10M	0.2	10M			15M	B
2N1310	G	N	MP2373-1		AL	120M	A	85	90			20		5.0M						
2N1311	S	N	MP2373-3		AL	120M	A	85	75	75		15		5.0M						
2N1312	G	N			S	120M	A	85	50	50		20		20M		20M				
2N1313	G	P	MP2373-4		S	0.18W	A	100	30	15	O	40	125		0.28	0.3A			6.0M	B
2N1314	G	P	2N3611	2N3611	AP	125W	C	90	40	40	R	20	55	1.0A						
2N1315	G	P	2N3611	2N3611	AP	125W	C	90	32	16		45	135	1.0A						
2N1316	G	P			S	0.2W	A	85	30	15	O	50	200						10M	B
2N1317	G	P			S	0.2W	A	85	20	12	O	45	180						10M	B
2N1318	G	P			S	0.2W	A	85	10	6.0	O	40	150						10M	B
2N1319	G	P	MP2372-1		S	120M	A	71	20	20	V	15		0.4A	0.3	0.4A			3.0M	T
2N1320	G	P	MP2372-2		AP	20W	C	85	35	30	S	40		0.5A	1.0	1.0A				
2N1321	G	N	MP2372-3		AP	25W	C	100	35	30	S	30		0.5A	1.0	1.0A				
2N1322	G	P	MP2372-4		AP	20W	C	85	60	60	S	40		0.5A	1.0	1.0A				
2N1323	G	N			AP	25W	C	100	60	45	S	30		0.5A	1.0	1.0A				
2N1324	G	P			AP	20W	C	85	80	80	S	40		0.5A	1.0	1.0A				
2N1325	G	N			AP	25W	C	100	80	60	S	30		0.5A	1.0	1.0A				
2N1326	G	P			AP	20W	C	85	100	100	S	40		0.5A	1.0	1.0A				
2N1327	G	N			AP	25W	C	100	100	80	S	30		0.5A	1.0	1.0A				
2N1328	G	P			AP	20W	C	85	35	30	S	40		0.5A	1.0	1.0A				
2N1329	G	N			AP	25W	C	100	35	30	S	30		0.5A	1.0	1.0A				
2N1330	G	N			AP	25W	C	100	60	45	S	30		0.5A	1.0	1.0A				
2N1331	G	P			AP	20W	C	85	80	80	S	40		0.5A	1.0	1.0A				
2N1332	G	N			AP	25W	C	100	80	60	S	30		0.5A	1.0	1.0A				
2N1333	G	P			AP	20W	C	85	100	100	S	40		0.5A	1.0	1.0A				
2N1334	G	N			AP	25W	C	100	100	80	S	30		0.5A	1.0	1.0A				
2N1335	S	N			AHP	0.8W	A	175	120	45	O	10	150	30M					70M	T
2N1336	S	N			AHP	0.8W	A	175	120	45	O	10	150	30M					70M	T
2N1337	S	N			AHP	0.8W	A	175	120	45	O	10	150	30M					70M	T
2N1338	S	N			AHP	0.8W	A	175	80	25	O	10	150	30M					70M	T
2N1339	S	N			AHP	0.8W	A	175	120	50	O	10	150	30M					70M	T
2N1340	S	N			AHP	0.8W	A	175	120	50	O	10	150	30M					70M	T
2N1341	S	N			AHP	0.8W	A	175	120	50	O	10	150	30M					70M	T
2N1342	S	N			AHP	0.8W	A	175	150	65	O	10	150	30M					70M	T
2N1343	G	P			S	0.15W	A	85	20	16	O	15		50M					4.0M	B
2N1344	G	P			S	0.15W	A	85	15	10	O	60		20M					7.0M	B
2N1345	G	P			S	0.15W	A	85	10	8.0	O	30	100	0.4A					10M	B
2N1346	G	P			S	0.15W	A	85	12	10	O	40	250	0.35M	0.13	12M			10M	B
2N1347	G	P			S	0.15W	A	85	20	12	O	30		10M	0.2	10M			5.0M	B
2N1352	G	P	2N651	2N650	A	0.15W	A	85	30	20	O	40	100							
2N1353	G	P			S	0.2W	A	85	15	10	O	25	150	10M	0.2	50M			1.5M	B
2N1354	G	P			S	0.2W	A	85	30	15	O	25	150	10M	0.2	50M			3.0M	B
2N1355	G	P			S	0.2W	A	85	30	20	O	30	150	10M	0.2	50M			5.0M	B
2N1356	G	P			S	0.2W	A	100	30	20	O	40	140	10M	0.2	50M			5.0M	B
2N1357	G	P			S	0.2W	A	85	30	15	O	40	150	10M	0.2	50M			10M	B
2N1358	G	P		2N173	SP	90W		95	80	40	O	40	80	1.2A	0.7	12A			100K	B
2N1358A	G	P		2N173	SP	150W	C	100	100	60	O	40	80	1.2A	0.7	12A			100K	B
2N1359	G	P		2N350A	AP	90W	J	100	50	40	S	35	90	1.0A	0.1	2.0A			5.0K	E
2N1360	G	P		2N350A	AP	90W	J	100	50	40	S	60	140	1.0A	1.0	2.0A			5.0K	E
2N1361	G	P			S	0.15W	A	100	25	20	O	40	100	25M					4.0M	B
2N1361A	G	P			S	0.2W	A	100	25	20	O	40	100	25M					4.0M	B
2N1362	G	P		2N350A	AP	90W	J	100	100	75	S	35	90	1.0A	1.0	2.0A			5.0K	E
2N1363	G	P		2N350A	AP	90W	J	100	100	75	S	60	140	1.0A	1.0	2.0A			5.0K	E
2N1364	G	P		2N350A	AP	90W	J	100	120	100	S	35	90	1.0A	1.0	2.0A			5.0K	E
2N1365	G	P		2N350A	AP	90W	J	100	120	100	S	60	140	1.0A	1.0	2.0A			5.0K	E
2N1366	G	N			A	100M	A	85	18	18	R	20		1.0M			10	E	5.0M	T
2N1367	G	N			A	100M	A	85	18	18	R	10		1.0M			5.0	E	2.5M	T
2N1370	G	P			A	250M	A	100	25	25	R	45	165	50M	1.0	100M	40	E		
2N1371	G	P			A	250M	A	100	45	45	R	45	165	50M	1.0	100M	40	E		
2N1372	G	P			A	250M	A	100	25	25	R	27	105	50M	1.0	100M	20	E		
2N1373	G	P			A	250M	A	100	45	45	R	27	105	50M	1.0	100M	20	E		
2N1374	G	P			A	250M	A	100	25	25	R	45	165	50M	1.0	100M	40	E		
2N1375	G	P			A	250M	A	100	45	45	R	45	165	50M	1.0	100M	40	E		
2N1376	G	P			A	250M	A	100	25	25	R	67	165	50M	1.0	100M	60	E		
2N1377	G	P			A	250M	A	100	45	45	R	67	165	50M	1.0	100M	60	E		
2N1378	G	P			A	250M	A	100	12	12	R	85	330	50M	1.0	100M	75	E		
2N1379	G	P			A	250M	A	100	25	25	R	85	330	50M	1.0	100M	75	E		
2N1380	G	P			A	250M	A	100	12	12	R	27	330	50M	1.0	100M	20	E		
2N1381	G	P			A	250M	A	100	25	25	R	27	330	50M	1.0	100M	20	E		
2N1382	G	P			A	250M	A	100	25	25	R	45	165	50M	1.0	100M	40	E		

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N1383	G	P			A	250M	A	100	25	25	R	27	165	50M	1.0	100M	20	E		
2N1384	G	P			SH	240M	A	85	30	30	O	20		200M					20M	T
2N1385	G	P			SH	750M	A	100	25	10	O	10		10M					250M	T
2N1386	S	N	2N2218	2N2218	S	300M	A	175	25	25	O	30	90	10M	0.6	5.0M				
2N1387	S	N	2N2218	2N2218	S	300M	A	175	30	30	O	20	40	10M	0.5	5.0M				
2N1388	S	N	2N2218	2N2218	AH	300M	A	175	45	25	O	15	55	10M			30	E	50M	B
2N1389	S	N	2N2218	2N2218	AH	300M	A	175	50	50	O				0.8	5.0M			24M	T
2N1390	S	N	2N2218	2N2218	AH	300M	A	175	20	20	O	30	150	10M			10	E	20M	B
2N1391	G	N			A	150M	A	100	25	18	O	40	160	20M			35	E	3.0M	E
2N1392	G	P			AL	50M	A	85	20	20	R									
2N1393	G	P			AL	50M	A	85	20	10	R									
2N1394	G	P			AL	50M	A	85	10	6.0	R									
2N1395	G	P	2N2955	2N2955	AH	120M	A	100	40	40	O	50	175	1.5M					30M	B
2N1396	G	P	2N3323	2N3323	AH	120M	A	100	40	40	O	50	175	1.5M					30M	B
2N1397	G	P	2N3323	2N3323	AH	120M	A	100	40	40	O	50	175	1.5M					120M	B
2N1398	G	P			AH	50M	A	85	30	20	O	10		0.5M	0.75	10M			140M	T
2N1399	G	P			AH	50M	A	85	30	20	O	3.5		0.5M	0.75	10M			140M	T
2N1400	G	P			AH	50M	A	85	30	20	O	5.0	12	0.5M	0.75	10M			100M	T
2N1401	G	P			AH	50M	A	85	30	20	O	5.0		0.5M	0.75	10M			120M	T
2N1402	G	P			AH	50M	A	85	30	20	O	3.5	12	1.5M	0.75	10M			100M	T
2N1403	G	P			AH	250M	A	100	15	12	O	25	250	7.0M	0.75	10M			200M	T
2N1404	G	P			S	150M	A	85	25						0.15	12M			4.0M	B
2N1404A	G	P			S	150M	A	85	25	15	O	30	200	12M	0.15	12M			3.0M	T
2N1405	G	P			AH	75M	A	100	30	20	O	10	200	2.0M			10	E	250M	T
2N1406	G	P			AH	75M	A	100	30	20	O	10	200	2.0M			10	E	250M	T
2N1407	G	P			AH	75M	A	100	30	20	O	10	200	2.0M			10	E	200M	T
2N1408	G	P			S	150M	A	100	50	50	S	10					10	E		
2N1409	S	N	2N2537	2N2537	SH	600M	A	200	30	25	O	15	45	150M					200M	T
2N1409A	S	N	2N2537	2N2537	SH	800M	A	200	30	25	O	15	45	150M					200M	T
2N1410	S	N	2N2537	2N2537	SH	600M	A	200	45	30	O	39	90	150M					130M	T
2N1410A	S	N	2N2537	2N2537	SH	800M	A	200	30	30	O	30	90	150M					130M	T
2N1411	G	P	2N962	2N956	S	25M	A	85	5.0	5.0	S	20		50M	0.45	10M			25M	T
2N1412	G	P		2N1412	SP	70W	C	95	100	65	O	25	50	5.0A	0.7	12A				
2N1413	G	P		2N1413	S	200M	A	85	35	25	R	25	42	20M			20	E	800K	B
2N1414	G	P		2N1413	S	200M	A	85	35	25	R	34	65	20M			30	E	1.0M	B
2N1415	G	P		2N1413	S	200M	A	85	35	25	R	53	90	20M			44	E	1.3M	B
2N1416	G	P	2N1193	2N1191	A	100M	A	65		18	U						39	E		
2N1417	S	N			A	0.15W	A	150	15	15	O						30	E		
2N1418	S	N			A	0.15W	A	150	30	30	O						30	E		
2N1419	G	P	2N1164	2N1162	SP	87W	C	95	80	40	O	40	100	25A	0.7	25A				
2N1420	S	N		2N718	AH	600M	A	175	60	30	R	100	300	150M	1.5	150M			50M	T
2N1420A	S	N	2N2219	2N2218	AH	800M	A	200	60	40	R	100	300	150M	1.5	150M			60M	T
2N1421	S	N			AHP	30W	C	200	60	60	S	20	80	1.0A	3.0	1.0A	20	E	10M	T
2N1422	S	N			AHP	30W	C	200	60	60	S	20	80	1.0A	3.0	1.0A	20	E	10M	T
2N1423	S	N			AHP	60W	C	200	60	60	S	20	80	2.0A	5.0	2.0A	20	E	10M	T
2N1424	S	N			AHP	60W	C	200	60	60	S	20	80	2.0A	5.0	2.0A	20	E	10M	T
2N1425	G	P			A	80M	A	85	24										10M	B
2N1426	G	P			A	80M	A	85	24								17	E	10M	B
2N1427	G	P	2N962	2N956	SH	25M	A	100	6.0	6.0	S	20		50M	0.2	50M	40	E	50M	T
2N1428	S	P			S	100M	A	140	6.0	6.0	O	12		5.0M	0.1	5.0M	25	E	16M	T
2N1429	S	P			S	100M	A	140	6.0	6.0	O	12		5.0M	0.1	5.0M	25	E	16M	T
2N1430	G	P			SP	70W	C	110	120	100	O	30	90	5.0A	0.4	10A			0.6M	T
2N1431	G	N			A	180M	A	75	20	15	R	75	150	35M					10K	E
2N1432	G	P			A	100M	A	100	45	45	R						30	E		
2N1433	G	P			AP			95	80	50	O	20	50	2.0A	1.5	2.0A			5.0K	E
2N1434	G	P			AP			95	80	50	O	45	115	2.0A	1.0	2.0A			5.0K	E
2N1435	G	P			AP			95	80	50	O	30	75	2.0A	0.6	2.0A			5.0K	E
2N1436	G	P			SH	50M	A	100	15	12	S	20		10M	0.2	10M				
2N1437	G	P			AP	23W	C	95	100	90	S	20		0.5A	1.0	1.0A			4.0K	E
2N1438	G	P			AP	23W	C	95	100	90	S	20		0.5A	1.0	1.0A			4.0K	E
2N1439	S	P			A	0.4W	A	200	50	50	O				0.25	5.0M	9.0	E	0.5M	B
2N1440	S	P			A	0.4W	A	200	60	50	O				0.25	5.0M	9.0	E	1.0M	B
2N1441	S	P			A	0.4W	A	200	50	35	O				0.25	5.0M	18	E	1.0M	B
2N1442	S	P			A	0.4W	A	200	50	30	O				0.25	5.0M	30	E	1.0M	B
2N1443	S	P			A	0.4W	A	200	50	15	O				0.25	5.0M	50	E	1.0M	B
2N1444	S	N			SH	0.5W	A	150	60	20	O	20		0.25A	1.5	0.25A				
2N1445	S	N			AP	4.0W	C	200	120	120	O	20	80	200M	4.0	200M			75K	E
2N1446	G	P	2N1191	2N1191	A	0.2W	A	85	45	25	O	16	45	20M			16	E	0.8M	B
2N1447	G	P	2N1191	2N1191	A	0.2W	A	85	45	25	O	35	65	20M			30	E	1.5M	B
2N1448	G	P	2N1192	2N1191	A	0.2W	A	85	45	25	O	50	90	20M			45	E	2.0M	B
2N1449	G	P	2N1189	2N1189	A	0.2W	A	85	45	25	O	70	125	20M			60	E	2.5M	B
2N1450	G	P	2N2955	2N2955	S	0.12W	A	85	30	20	O	20		10M	0.25	10M				
2N1451	G	P	2N464	2N464	A	0.2W	A	85	45	20	O	20	65	20M						
2N1452	G	P	2N1191	2N1191	A	0.2W	A	85	45	20	O	30	90	20M						
2N1453	G	P			AP			90	30	20	O	40	90	1.0A	1.0	3.0A			5.0K	E
2N1454	G	P			AP			90	30	20	O	70	150	1.0A	1.0	3.0A			5.0K	E
2N1455	G	P			AP			90	60	40	O	40	90	1.0A	1.0	3.0A			5.0K	E
2N1456	G	P			AP			90	60	40	O	70	150	1.0A	1.0	3.0A			5.0K	E
2N1457	G	P			AP			90	80	60	O	40	90	1.0A	1.0	3.0A			5.0K	E
2N1458	G	P			AP			90	80	60	O	70	150	1.0A	1.0	3.0A			5.0K	E
2N1461	G	P			AP			90	30	20	O	40	90	1.0A	1.0	3.0A			5.0K	E
2N1462	G	P			AP			90	30	20	O	70	150	1.0A	1.0	3.0A			5.0K	E
2N1463	G	P			AP			90	60	40	O	40	90	1.0A	1.0	3.0A			5.0K	E
2N1464	G	P			AP			90	60	40	O	70	150	1.0A	1.0	3.0A			5.0K	E
2N1465	G	P			AP	20W	C	85	120	70	O	20		0.5A	0.75	1.0A			4.0K	E
2N1466	G	P			AP	20W	C	85	120	70	O	20		0.5A	0.75	1.0A			4.0K	E
2N1469	S	P			A	0.25W	A	175	40	35	U						36	E	2.0M	B
2N1470	S	N			AP	55W	C	200	60	60	S	15		1.0A	3.0	1.0A				

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N1471	G	P			S	200M	A	85	12	15	R						100	E	3.0M	B
2N1472	S	N			SH	150M	A	150	25	25	O	20		10M	0.25	10M			75M	T
2N1473	G	N			S	167M	A	75	40	20	O	25	50	400M					4.0M	B
2N1474	S	P			A	0.25W	A	175	60	60	U						12	E	1.0M	B
2N1474A	S	P			A	0.25W	A	175	60	60	U						18	E	2.0M	B
2N1475	S	P			A	0.25W	A	175	60	60	U						36	E	1.0M	B
2N1476	S	P			A	0.25W	A	175	100	100	U						12	E	1.0M	B
2N1477	S	P			A	0.25W	A	175	100	100	U						30	E	1.0M	B
2N1478	G	P	2N3427	2N3427	S	250M	A	100	30	20	S	40		100M	0.2	10M			3.0M	B
2N1479	S	N	2N4237	2N4237	SP	5.0W	C	200	60	60	V	20	60	200M	1.4	200M				
2N1480	S	N	2N4238	2N4237	SP	5.0W	C	200	100	100	V	20	60	200M	1.4	200M				
2N1481	S	N	2N4239	2N4237	SP	5.0W	C	200	60	60	V	35	100	200M	1.4	200M				
2N1482	S	N	2N4238	2N4237	SP	5.0W	C	200	100	100	V	35	100	200M	1.4	200M				
2N1483	S	N	2N3766	2N3766	SP	25W	C	200	60	60	V	20	60	750M	2.0	750M				
2N1484	S	N	2N3766	2N3766	SP	25W	C	200	100	100	V	20	60	750M	2.0	750M				
2N1485	S	N	2N3766	2N3766	SP	25W	C	200	60	60	V	35	100	750M	0.75	750M				
2N1486	S	N	2N3766	2N3766	SP	25W	C	200	100	100	V	35	100	750M	0.75	750M				
2N1487	S	N	2N4913	2N4913	SP	75W	C	200	60	60	V	15	45	200M	3.0	1.5A				
2N1488	S	N	2N4914	2N4913	SP	75W	C	200	100	100	V	15	45	200M	3.0	1.5A				
2N1489	S	N	2N4913	2N4913	SP	75W	C	200	60	60	V	25	75	1.5A	1.0	1.5A				
2N1490	S	N	2N4914	2N4913	SP	75W	C	200	100	100	V	25	75	1.5A	1.0	1.5A				
2N1491	S	N			AH	3.0W	C	175	30								15	E		
2N1492	S	N			AH	3.0W	C	175	60								15	E		
2N1493	S	N			AH	3.0W	C	175	100			4.0					15	E		
2N1494	G	P		2N1204	SH	400M	A	100	20	15	O	15		400M	0.5	200M			220M	T
2N1494A	G	P		2N1204	SH	400M	A	100	20	15	O	25		200M	0.4	200M			220M	T
2N1495	G	P		2N1204	SH	300M	A	100	40	25	O	25		200M	0.3	200M			150M	T
2N1495A	G	P			SH	0.25W	A	100	40	25	O	25		0.2A	0.3	0.2A			150M	T
2N1496	G	P		2N1204	SH	500M	A	100	40	25	O	25		200M	0.3	200M			150M	T
2N1499	G	P			SH	25M	A	85	20	15	S	20		10M	0.2	10M				
2N1499A	G	P			SH	60M	A	100	20	20	S	30		10M	0.2	10M			100M	T
2N1499B	G	P			SH	75M	A	100	30	20	O	40		10M	0.2	10M			150M	T
2N1500	G	P			SH	60M	A	100	15	12	S	20		10M	0.2	10M			120M	T
2N1501	G	P	2N2144	2N2137	SP	34W	J	95	60	40		25	100	2.0A	0.6	2.0A			200K	T
2N1502	G	P	2N2143	2N2137	SP	34W	J	95	40	40		25	100	2.0A	0.6	2.0A			200K	T
2N1504	G	P			AP	25W	C	95	80	60	O	21		0.5A	0.75	1.0A			4.0K	E
2N1505	S	N			AHP	0.8W	A	175	50	20	O	7.0	100	0.1A	2.0	0.15A			70M	T
2N1506	S	N			AHP	0.8W	A	175	60	20	O	10	100	0.1A	1.5	0.15A			140M	T
2N1506A	S	N			AHP	0.8W	A	200	80	50	O	10	100	0.1A	0.6	0.15A			140M	T
2N1507	S	N	2N2219	2N2218	S	600M	A	175	60	30	R	100	300	150M	1.5	150M			50M	T
2N1508	S	N			S	1.0W	A	175	100	55	O	20	60	600M	3.6	600M			50M	T
2N1509	S	N			S	1.0W	A	175	60	35	O	20	60	600M	3.6	600M			50M	T
2N1510	G	N			AL	75M	A	85	75	70	R	8.0	90	1.0M	0.8	4.0M				
2N1511	S	N	2N3445	2N3445	SP	75W	C	200	60	60	V	4.0		6.0A	7.2	6.0A			0.3M	T
2N1512	S	N	2N3445	2N3445	SP	75W	C	200	100	100	V	7.0		6.0A	6.0	6.0A			0.3M	T
2N1513	S	N	2N3445	2N3445	SP	75W	C	200	60	60	V	7.0		6.0A	6.0	6.0A			0.3M	T
2N1514	S	N	2N3445	2N3445	SP	75W	C	200	100	100	V								0.3M	T
2N1516	G	P			AH	83M	A	75	25			20		1.0M						
2N1518	G	P	MP943		SP	50W	C	95	50	40		15	60	15A	0.7	25A				
2N1519	G	P	MP943A		SP	50W	C	95	80	60		15	60	15A	0.7	25A				
2N1520	G	P	MP944		SP	50W	C	95	50	40		17	68	15A	0.6	35A				
2N1521	G	P	MP944A		SP	50W	C	95	80	60		17	68	15A	0.6	35A				
2N1522	G	P	MP945		SP	50W	C	95	50	40	B	25	100	15A	0.5	50A				
2N1523	G	P	MP945A		SP	50W	C	95	80	60	B	25	100	15A	0.5	50A				
2N1524	G	P	2N3325	2N3323	AH	80M	A	85	24								17	E		
2N1525	G	P	2N3325	2N3323	AH	80M	A	85	24								17	E		
2N1526	G	P	2N3325	2N3323	AH	80M	A	85	24								27	E		
2N1527	G	P	2N3325	2N3323	AH	80M	A	85	24								27	E		
2N1528	S	N	2N2218	2N2218	AH	150M	A	175	25	25	S						10	E		
2N1529	G	P		2N1529	AP	90W	C	100	40	30	S	20	40	3.0A	1.5	3.0A				
2N1529A	G	P		2N1529	AP	90W	C	100	40	20	O	20	40	3.0A	1.5	3.0A			5.0K	E
2N1530	G	P		2N1529	AP	90W	C	100	60	45	S	20	40	3.0A	1.5	3.0A				
2N1530A	G	P		2N1529	AP	90W	C	100	60	30	O	20	40	3.0A	1.5	3.0A			5.0K	E
2N1531	G	P		2N1529	AP	90W	C	100	80	60	S	20	40	3.0A	1.5	3.0A				
2N1531A	G	P		2N1529	AP	90W	C	100	80	40	O	20	40	3.0A	1.5	3.0A			5.0K	E
2N1532	G	P		2N1529	AP	90W	C	100	100	75	S	20	40	3.0A	1.5	3.0A				
2N1532A	G	P		2N1529	AP	90W	C	100	100	50	O	20	40	3.0A	1.5	3.0A			5.0K	E
2N1533	G	P		2N1529	AP	90W	C	100	120	90	S	20	40	3.0A	1.5	3.0A				
2N1534	G	P		2N1529	AP	90W	C	100	40	30	S	35	70	3.0A	1.2	3.0A				
2N1534A	G	P		2N1529	AP	90W	C	100	40	20	O	35	70	3.0A	1.2	3.0A			5.0K	E
2N1535	G	P		2N1529	AP	90W	C	100	60	45	S	35	70	3.0A	1.2	3.0A				
2N1535A	G	P		2N1529	AP	90W	C	100	60	30	O	35	70	3.0A	1.2	3.0A			5.0K	E
2N1536	G	P		2N1529	AP	90W	C	100	80	60	S	35	70	3.0A	1.2	3.0A				
2N1536A	G	P		2N1529	AP	90W	C	100	80	40	O	35	70	3.0A	1.2	3.0A			5.0K	E
2N1537	G	P		2N1529	AP	90W	C	100	100	75	S	35	70	3.0A	1.2	3.0A				
2N1537A	G	P		2N1529	AP	90W	C	100	100	50	O	35	70	3.0A	1.2	3.0A			5.0K	E
2N1538	G	P		2N1529	AP	90W	C	100	120	90	S	35	70	3.0A	1.2	3.0A				
2N1539	G	P		2N1539	AP	90W	C	100	40	30	S	50	100	3.0A	0.3	3.0A				
2N1539A	G	P		2N1539	AP	90W	C	100	40	20	O	50	100	3.0A	0.3	3.0A			3.0K	E
2N1540	G	P		2N1539	AP	90W	C	100	60	45	S	50	100	3.0A	0.3	3.0A				
2N1540A	G	P		2N1539	AP	90W	C	100	60	30	O	50	100	3.0A	0.3	3.0A			3.0K	E
2N1541	G	P		2N1539	AP	90W	C	100	80	60	S	50	100	3.0A	0.3	3.0A				
2N1541A	G	P		2N1539	AP	90W	C	100	80	40	O	50	100	3.0A	0.3	3.0A			3.0K	E
2N1542	G	P		2N1539	AP	90W	C	100	100	75	S	50	100	3.0A	0.3	3.0A				
2N1542A	G	P		2N1539	AP	90W	C	100	100	50	O	50	100	3.0A	0.3	3.0A			3.0K	E
2N1543	G	P		2N1539	AP	90W	C	100	120	90	S	50	100	3.0A	0.3	3.0A				
2N1544	G	P		2N1539	AP	90W	C	100	40	30	S	75	150	3.0A	0.2	3.0A			1.0K	E
2N1544A	G	P		2N1539	AP	90W	C	100	40	30	S	75		3.0A	0.2	3.0A			3.0K	E

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} @ I_C (min)	(max)	Units	$V_{CE(SAT)}$ @ I_C (volts)	Units	h_{f-}	Subscript	f_- Units	Subscript
2N1545	G	P		2N1539	AP	90W	C	100	60	45	S	75	150	3.0A	0.2	3.0A			1.0K	E
2N1545A	G	P		2N1539	AP	90W	C	100	60	45	S	75		3.0A	0.2	3.0A			3.0K	E
2N1546	G	P		2N1539	AP	90W	C	100	80	60	S	75	150	3.0A	0.2	3.0A			1.0K	E
2N1546A	G	P		2N1539	AP	90W	C	100	80	60	S	75		3.0A	0.2	3.0A			3.0K	E
2N1547	G	P		2N1539	AP	90W	C	100	100	75	S	75	150	3.0A	0.2	3.0A			1.0K	E
2N1547A	G	P		2N1539	AP	90W	C	100	100	75	S	75		3.0A	0.2	3.0A			3.0K	E
2N1548	G	P		2N1539	AP	90W	C	100	120	90	S	75	150	3.0A	0.2	3.0A			1.0K	E
2N1549	G	P		2N1539	AP	90W	C	100	40	30	S	10	30	10A	1.0	10A				
2N1549A	G	P		2N1539	AP	90W	C	100	40	30	S	10	30	10A	1.0	10A			5.0K	E
2N1550	G	P		2N1539	AP	90W	C	100	60	45	S	10	30	10A	1.0	10A				
2N1550A	G	P		2N1539	AP	90W	C	100	60	45	S	10	30	10A	1.0	10A			5.0K	E
2N1551	G	P		2N1539	AP	90W	C	100	80	60	S	10	30	10A	1.0	10A				
2N1551A	G	P		2N1539	AP	90W	C	100	80	60	S	10	30	10A	1.0	10A			5.0K	E
2N1552	G	P		2N1539	AP	90W	C	100	100	75	S	10	30	10A	1.0	10A				
2N1552A	G	P		2N1539	AP	90W	C	100	100	75	S	10	30	10A	1.0	10A			5.0K	E
2N1553	G	P		2N1539	AP	90W	C	100	40	30	S	30	60	10A	0.5	10A			1.0K	E
2N1553A	G	P		2N1539	AP	90W	C	100	40	20	O	30	60	10A	0.5	10A			3.0K	E
2N1554	G	P		2N1539	AP	90W	C	100	60	45	S	30	60	10A	0.5	10A			1.0K	E
2N1554A	G	P		2N1539	AP	90W	C	100	60	30	O	30	60	10A	0.5	10A			3.0K	E
2N1555	G	P		2N1539	AP	90W	C	100	80	60	S	30	60	10A	0.5	10A			1.0K	E
2N1555A	G	P		2N1539	AP	90W	C	100	80	40	O	30	60	10A	0.5	10A			3.0K	E
2N1556	G	P		2N1539	AP	90W	C	100	100	75	S	30	60	10A	0.5	10A			1.0K	E
2N1556A	G	P		2N1539	AP	90W	C	100	100	50	O	30	60	10A	0.5	10A			3.0K	E
2N1557	G	P		2N1539	AP	90W	C	100	40	30	S	50	100	10A	0.4	10A			1.0K	E
2N1557A	G	P		2N1539	AP	90W	C	100	40	20	O	50	100	10A	0.5	10A			3.0K	E
2N1558	G	P		2N1539	AP	90W	C	100	60	45	S	50	100	10A	0.4	10A			1.0K	E
2N1558A	G	P		2N1539	AP	90W	C	100	60	30	O	50	100	10A	0.5	10A			3.0K	E
2N1559	G	P		2N1539	AP	90W	C	100	80	60	S	50	100	10A	0.4	10A			1.0K	E
2N1559A	G	P		2N1539	AP	90W	C	100	80	40	O	50	100	10A	0.5	10A			3.0K	E
2N1560	G	P		2N1539	AP	90W	C	100	100	75	S	50	100	10A	0.4	10A			1.0K	E
2N1560A	G	P		2N1539	AP	90W	C	100	100	50	O	50	100	10A	0.5	10A			3.0K	E
2N1561	G	P		2N1561	AH	250M	A	100	25	15	O				3.0	200M				
2N1562	G	P		2N1561	AH	250M	A	100	25	15	O				4.0	200M				
2N1564	S	N	2N2218	2N2218	A	600M	A	175	80	60	O	15	50	5.0M	1.0	10M	20	E		
2N1565	S	N	2N2218	2N2218	A	600M	A	175	80	60	O	30	100	5.0M	1.0	10M	40	E		
2N1566	S	N	2N2219	2N2218	A	600M	A	175	80	60	O	60	200	5.0M	1.0	10M	80	E		
2N1566A	S	N	2N2219	2N2218	A	600M	A	175	80	60	O	60	200	5.0M	0.95	10M	80	E	100M	T
2N1572	S	N			A	600M	A	175	125	80	O	15	50	5.0M	1.0	10M	20	E		
2N1573	S	N			A	600M	A	175	125	80	O	30	100	5.0M	1.0	10M	40	E		
2N1574	S	N			A	600M	A	175	125	80	O	60	200	5.0M	1.0	10M	80	E		
2N1585	G	N			A	750M	A	100	25	10	O	20		10M						
2N1586	S	N			A	125M	A	85	15	10	O	5.0	27	1.0M	1.5	5.0M	9.0	E	5.0M	B
2N1587	S	N			A	125M	A	85	30	20	O	5.0	27	1.0M	1.5	5.0M	9.0	E	5.0M	B
2N1588	S	N			A	125M	A	85	60	40	O	5.0	27	1.0M	1.5	5.0M	9.0	E	5.0M	B
2N1589	S	N			A	125M	A	85	15	10	O	20	75	1.0M	1.5	5.0M	25	E	5.0M	B
2N1590	S	N			A	125M	A	85	30	20	O	20	75	1.0M	1.5	5.0M	25	E	5.0M	B
2N1591	S	N			A	125M	A	85	60	40	O	20	75	1.0M	1.5	5.0M	25	E	5.0M	B
2N1592	S	N			A	125M	A	85	15	10	O	40	210	1.0M	1.5	5.0M	70	E	5.0M	B
2N1593	S	N			A	125M	A	85	30	20	O	40	210	1.0M	1.5	5.0M	70	E	5.0M	B
2N1594	S	N			A	125M	A	85	60	40	O	40	210	1.0M	1.5	5.0M	70	E	5.0M	B
2N1595 thru 2N1604	Thyristors, see Table on Page 164																			
2N1605	G	N			S	150M	A	100	25	24	O	40		20M	0.15	12M			4.0M	B
2N1605A	G	N			S	0.2W	A	100	40	40		40		20M	0.15	12M			4.0M	B
2N1606	S	P			SH	100M	A	140	10	10	S	6.0	30	15M	0.15	5.0M			7.2M	T
2N1607	S	P			SH	100M	A	140	10	10	S	6.0	30	15M	0.15	5.0M			10M	T
2N1608	S	P			SH	100M	A	140	10	10	S	6.0	30	15M	0.15	5.0M			25M	T
2N1609	G	P	2N2140	2N2137	AP			95	80	60	O	30	75	100M	1.0	500M				
2N1610	G	P	2N2145	2N2137	AP			95	80	60	O	50	125	100M	0.6	500M				
2N1611	G	P	2N2138	2N2137	AP			95	60	40	O	30	75	100M	1.0	500M				
2N1612	G	P	2N2143	2N2137	AP			95	60	40	O	50	125	100M	0.6	500M				
2N1613	S	N		2N718A	S	800M	A	200	75	50	R	40	120	150M	1.5	150M	30	E	60M	T
2N1613A	S	N	2N2218	2N2218	S	1.0W	A	200	75	50	R	40	120	150M	1.0	150M	30	E	60M	T
2N1613B	S	N			S	1.0W	A	200	120	55	R	40	120	150M	0.2	150M	30	E	60M	T
2N1614	G	P	2N1924	2N1924	S	240M	A	100	65	40	R	18	43	20M	0.13	20M			500K	B
2N1615	S	N			AH	5.5M	A	200	100	100	O	25		5.0M	5.0	50M			2.0M	T
2N1616	S	N	2N3487	2N3485	AHP	60W	C	175	60	60	O	15	75	2.0A	2.0	2.0A			3.0M	T
2N1616A	S	N	2N3487	2N3485	AP	85W	C	200	60	60	O	20	60	2.0A	1.0	2.0A			3.0M	T
2N1617	S	N	2N3487	2N3485	AHP	60W	C	175	80	80	V	15	75	2.0A	2.0	2.0A			3.0M	T
2N1617A	S	N	2N3487	2N3485	AP	85W	C	200	80	70	O	20	60	2.0A	1.0	2.0A			3.0M	T
2N1618	S	N	2N3488	2N3485	AHP	60W	C	175	100	100	V	15	75	2.0A	2.0	2.0A			3.0M	T
2N1618A	S	N	2N3488	2N3485	AP	85W	C	200	100	80	O	20	60	2.0A	1.0	2.0A			3.0M	T
2N1620	S	N	2N3446	2N3445	AHP	60W	C	175	100	100	V	15	75	2.0A	2.0	2.0A			3.0M	T
2N1622	G	N			A	0.12W	A	85	90	90	S	40		5.0M		5.0M				
2N1623	S	P			A	250M	A	160	50	20	O	9.0	40	1.0M	0.3	5.0M			100K	B
2N1624	G	N			S	0.15W	A	100	25	20	R	60	180	30M					5.0M	B
2N1631	G	P	2N3325	2N3323	AH	80M	A	85	34								40	E		
2N1632	G	P	2N3325	2N3323	AH	80M	A	85	34								40	E		
2N1633	G	P			AH	80M	A	85	34								27	E		
2N1634	G	P			AH	80M	A	85	34								27	E		
2N1635	G	P			AH	80M	A	85	34								40	E		
2N1636	G	P			AH	80M	A	85	34								40	E		
2N1637	G	P	2N3325	2N3323	AH	80M	A	85	34								40	E		
2N1638	G	P	2N3325	2N3323	AH	80M	A	85	34								70	E		
2N1639	G	P	2N3325	2N3323	AH	80M	A	85	34								40	E		
2N1640	S	P			SC	250M	A	160	30	20	U	6.0		100*						
2N1641	S	P			SC	250M	A	160	30	10	U	10		100*						

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N1642	S	P			SC	250M	A	160	30	6.0	U	15		100*						
2N1643	S	P			A	250M	A	160	25	25	U	10	25	100*						
2N1644	S	N	2N2218	2N2218	S	2.0W	C	175	60	40	R	40	120	150M	1.5	150M			50M	T
2N1645	G	P			AHP	1.0W	A	100	35	20	O	20		0.2A	4.0	0.2A	25	E	450M	T
2N1646	G	N			SH	150M	A	100	15	12	S	20		10M						
2N1647	S	N	2N3445	2N3445	AHP	267M	C	175	80	80	V	15	45	0.5A	3.0	1.0A			3.0M	T
2N1648	S	N	2N3446	2N3445	AHP	267M	C	175	120	80	O	15	45	0.5A	3.0	1.0A			2.0M	T
2N1649	S	N	2N3447	2N3445	AHP	267M	C	175	80	80	V	30	90	0.5A	3.0	1.0A			3.0M	T
2N1650	S	N	2N3448	2N3445	AHP	267M	C	175	120	80	O	30		0.5A	3.0	1.0A			2.0M	T
2N1651	G	P		2N1651	AP	100W	C	110	60	60	S	35	140	10A	0.65	25A	20	E		
2N1652	G	P		2N1651	AP	100W	C	110	100	100	S	35	140	10A	0.65	25A	20	E		
2N1653	G	P		2N1651	AP	100W	C	110	120	120	S	35	140	10A	0.65	25A	20	E		
2N1654	S	N			AP	250M	A	160	100	80	O	20	45	1.0M	0.3	5.0M			100K	B
2N1655	S	N			AP	250M	A	160	125	100	O	10	22	1.0M	0.3	5.0M			100K	B
2N1656	S	N			AP	250M	A	160	125	100	O	20	45	1.0M	0.3	5.0M			100K	B
2N1657	S	N			AP		C	200	60	60	S	7.5	30	0.85A	4.5	0.85A			2.0M	B
2N1660	S	N			AP	85W	C	200	60	60	R	45	135	1.0A	4.0	1.0A			25M	T
2N1661	S	N			AP	85W	C	200	80	80	R	45	135	1.0A	4.0	1.0A			25M	T
2N1662	S	N			AP	85W	C	200	100	100	R	45	135	1.0A	4.0	1.0A			25M	T
2N1663	S	N			SH	150M	A	150	20	15	O	30	150	20M	0.25	10M			100M	T
2N1664	G	P			A	0.2W	A	100	45	40	R	45	120	10M	0.5	0.1A	50	E	0.1M	B
2N1665	G	P			AH	150M	A	85	15	12	O	5.0	100	10M					300M	T
2N1666	G	P	2N3616	2N3615	SP	30W	C	90	80	60	V	15	30	6.0A	0.5	6.0A			2.0K	E
2N1667	G	P	2N3618	2N3615	SP	30W	C	90	60	48	X	35	80	6.0A	0.5	6.0A			2.0K	E
2N1668	G	P	2N3616	2N3615	SP	30W	C	90	60	48	X	20	45	6.0A	0.5	6.0A			2.0K	E
2N1669	G	P	2N3616	2N3615	SP	30W	C	90	80	60	X	20	65	6.0A	0.5	6.0A			2.0K	E
2N1670	G	P			S	0.12W	A	85	100			15		10M						
2N1671	Unijunction Transistors, see Table on Page 184																			
2N1672	G	N			AL	120M	A	85	40	40	X	20		1.0M			15	E	2.0M	B
2N1672A	G	N			AL	120M	A	85	40	40	X	20		1.0M			15	E	2.0M	B
2N1673	G	P			AH	80M	A	85	35								20	E		
2N1674	S	N			A	0.2W	A	200	45	45	O				1.5	5.0M	50	E	20M	T
2N1675	S	N			SHP	50W	C	150	100	100	S	25	100	1.0A	2.5	5.0A			120M	T
2N1676	S	P			SC	100M	A	140	4.5	4.5	U				0.1	5.0M			16M	T
2N1677	S	P			SC	100M	A	140	4.5	4.5	U				0.1	5.0M	25	E	16M	T
2N1678	G	P			S	120M	A	85	60	60	S	25		20M		20M			25M	B
2N1679	S	N			S	1.0W	A	175	100	55	O	40	120	600M	3.6	600M			50M	T
2N1680	S	N			S	1.0W	A	175	60	35	O	40	120	600M	3.6	600M			50M	T
2N1681	G	P			S	0.18W	C	100	30	15	O	30	120	10M	0.1	10M			5.0M	B
2N1682	S	N			S	500M	A	175	25	20	R	20		10M	0.6	10M			200M	T
2N1683	G	P			SH	150M	A	85	13	12	O	50		40M	12	1.0A			50M	T
2N1684	G	P			S	100M	A	100	25	25	X				0.15	12M			4.0M	B
2N1685	G	P			S	100M	A	100	25	20	R	60	180	30M		100M			8.0M	B
2N1686 thru 2N1689	Thyristors, see Table on Page 164																			
2N1690	S	N	2N4912	2N4910	AP	40W	C	200	80	80	O	20	60	500M	7.5	500M			90K	E
2N1691	S	N			AP	40W	C	200	120	120	O	20	60	500M	7.5				90K	E
2N1692	G	P		2N1561	AH	350M	A	100	25	15	O				3.0	200M				
2N1693	G	P		2N1561	AH	350M	A	100	25	25	S				4.0	200M				
2N1694	G	N			S	75M	A	85	20	20	O	17	50	1.0M					3.0M	B
2N1699	G	P			AH	100M	A	100	40	40	X	20	175	1.5M			20	E		
2N1700	S	N			S	5.0W	C	200	60	60	V	20	80	100M	12.5	2.5A			0.4M	B
2N1701	S	N	2N3766	2N3766	S	25W	C	200	60	60	V	20	80	300M	20	5.0A			0.35M	B
2N1702	S	N	2N4913	2N4913	S	75W	C	200	60	60	V	15	60	800M	20	5.0A			0.3M	B
2N1703	S	N	2N4913	2N4913	S	75W	C	200	60	60	V	15	60	800M					0.3M	B
2N1704	S	N	2N2218	2N2218	S	3.3M	J	175	45	45	O	50	200	1.0M	1.0	10M	40	E	5.0M	B
2N1705	G	P		2N1692	A	0.2W	A	100	18	12	R						70	E		
2N1706	G	P		2N1692	A	0.2W	A	100	25	18	R	60	120	20M			50	E		
2N1707	G	P		2N1692	A	0.2W	A	100	30	25	R	30	150	10M			40	E		
2N1708	S	N		2N1708	SH	1.0W	C	175	25	12	O	20		10M	0.22	10M			200M	T
2N1708A	S	N			SH	300M	A	175	40	20	R	30	120	10M	0.22	10M			300M	T
2N1709	S	N			AHP	15W	C	175	75	30	O	7.5	75	0.35A	5.0	1.0A			175M	T
2N1710	S	N			AHP	15W	C	175	60	30	O	4.0	100	0.35A	5.0	1.0A			140M	T
2N1711	S	N	2N2219A	2N2218A	S	800M	A	200	75	50	R	100	300	150M	1.5	150M	50	E	70M	T
2N1711A	S	N	2N2219A	2N2218A	AH	1.0W	A	200	75	50	R	100	300	150M	1.0	150M	50	E	70M	T
2N1711B	S	N	2N2219A	2N2218A	AH	1.0W	A	200	120	55	R	100	300	150M	0.2	150M	50	E	70M	T
2N1713	G	P				80M	A	85	30	12	O	20		1.5M			40	E	100M	B
2N1714	S	N			AP	20W	C	175	90	60	O	20	60	200M	2.0	200M			16M	T
2N1715	S	N			AP	20W	C	175	150	100	O	20	60	200M	2.0	200M			16M	T
2N1716	S	N			AP	20W	C	175	90	60	O	40	120	200M	2.0	200M			16M	T
2N1717	S	N			AP	20W	C	175	150	100	O	40	120	200M	2.0	200M			16M	T
2N1718	S	N	2N3766	2N3766	AP	20W	C	175	90	60	O	20	60	200M	2.0	200M			16M	T
2N1719	S	N	2N3767	2N3766	AP	20W	C	175	150	100	O	20	60	200M	2.0	200M			16M	T
2N1720	S	N	2N3766	2N3766	AP	20W	C	175	90	60	O	40	120	200M	2.0	200M			16M	T
2N1721	S	N	2N3767	2N3766	AP	20W	C	175	150	100	O	40	120	200M	2.0	200M			16M	T
2N1722	S	N	2N3446	2N3445	AP	50W	C	175	120	80	O	20	90	2.0A	1.0	2.0A			10M	T
2N1722A	S	N			AP	50W	C	175	180	120	O	30	90	2.0A	0.6	2.0A			10M	T
2N1723	S	N	2N3448	2N3445	AP	50W	C	175	120	80	O	50	150	2.0A	1.0	2.0A			10M	T
2N1724	S	N		2N1724	AP	50W	C	175	120	80	O	20	90	2.0A	1.0	2.0A			10M	T
2N1724A	S	N			AP	50W	C	175	180	120	O	30	90	2.0A	0.6	2.0A			10M	T
2N1725	S	N		2N1724	AP	50W	C	175	120	80	O	50	150	2.0A	1.0	2.0A			10M	T
2N1726	G	P	2N3323	2N3323	AH	60M	A	100	20	20	S	50		1.0M					100M	M
2N1727	G	P	2N3324	2N3323	AH	60M	A	100	20	20	S	20		1.0M					100M	M
2N1728	G	P	2N3324	2N3323	AH	60M	A	100	20	20	S	20		1.0M					100M	M
2N1729	G	P			S	150M	A	85	25	15	X	30		100M	0.35	200M				
2N1730	G	N			S	150M	A	85	20	15	X	30		100M	0.35	200M				
2N1731	G	P			A	150M	A	85	30	30	X	40		10M					5.0M	B

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N1732	G	N			A	150M	A	85	30	30	X	40		10M					5.0M	B
2N1742	G	P		2N499	AH	60M	A	125	20	20	S	10		2.0M						
2N1743	G	P	2N3284	2N3283	AH	60M	A	125	20	20	S	10		2.0M						
2N1744	G	P	2N3284	2N3283	AH	60M	A	125	20	20	S	10		2.0M						
2N1745	G	P	2N3285	2N3283	AH	60M	A	100	20	20	S	10		2.0M						
2N1746	G	P	2N3323	2N3323	AH	60M	A	100	20	20	S	10		1.0M					100M	M
2N1747	G	P	2N3324	2N3323	AH	60M	A	100	20	20	S	10		1.0M						
2N1748	G	P	2N3324	2N3323	AH	60M	A	100	25	25	S						30	E	80M	T
2N1748A	G	P	2N3323	2N3323	AH	60M	A	100	25	25	S						50	E	100M	T
2N1749	G	P	2N3323	2N3323	AH	75M	A	100	40	40	S						30	E	80M	T
2N1750	G	P			A	15M	A	75	14	6.0	S	18	40	500*					30M	M
2N1751	G	P		2N2832	AP			110	80	80	S	30	90	20A	0.5	20A	20	E	1.5M	B
2N1752	G	P	2N3325	2N3323	A	60M	A	100	12	12	S						50	E	50M	M
2N1753	G	P			AH	30M	A	85	30	18	O	50	220	100*						
2N1754	G	P			SH	50M	A	85	13	13	S	20		10M	0.2	10M				
2N1755	G	P	2N2137	2N2137	SP	28W	C	95	40	35	S	30	75	0.5A	0.7	3.0A			15K	E
2N1756	G	P	2N2138	2N2137	SP	28W	C	95	60	50	S	30	75	0.5A	0.7	3.0A				
2N1757	G	P	2N2139	2N2137	SP	28W	C	95	80	65	S	30	75	0.5A	0.7	3.0A			15K	E
2N1758	G	P	2N2140	2N2137	SP	28W	C	95	100	75	S	30	75	0.5A	0.7	3.0A			15K	E
2N1759	G	P	2N2142	2N2137	SF	28W	C	95	40	35	S	60	150	0.5A	0.5	3.0A			15K	E
2N1760	G	P	2N2143	2N2137	SP	28W	C	95	60	50	S	60	150	0.5A	0.5	3.0A			15K	E
2N1761	G	P	2N2144	2N2137	SP	28W	C	95	80	65	S	60	150	0.5A	0.5	3.0A			15K	E
2N1762	G	P	2N2145	2N2137	SP	28W	C	95	100	75	S	60	150	0.5A	0.5	3.0A			15K	E
2N1763	S	N			S	0.3W	A	175	40	25	O				1.5	10M				
2N1764	S	N			S	0.3W	A	175	20	15	O				1.5	10M				
2N1765	Thyristors, see Table on Page 164																			
2N1768	S	N	2N3445	2N3445	S	40W	C	200	60	40	O	35	100	750M	0.75	750M			600K	B
2N1769	S	N	2N3445	2N3445	S	40W	C	200	100	55	O	35	100	750M	0.75	750M			600K	B
2N1770 thru 2N1778	Thyristors, see Table on Page 164																			
2N1779	G	P			S	100M	A	100	25	20	R	20	60	30M						
2N1780	S	P			S	100M	A	100	25	25	R	30	110	30M					4.0M	B
2N1781	G	P			S	100M	A	100	25	25	X	40		20M	0.15	12M			4.0M	B
2N1782	G	P			S	100M	A	100	30	20	X	30	150	10M	0.20	50M			5.0M	B
2N1783	G	P			S	100M	A	100	30	15	O	20		10M	0.32	200M	30	E	5.0M	B
2N1784	G	P			S	100M	A	100	30	20	O	20		10M	0.32	200M			10M	B
2N1785	G	P	2N3324	2N3323	AH	45M	A	85	10	10	S	40		1.0M					50M	M
2N1786	G	P	2N3323	2N3323	AH	45M	A	85	10	10	S	15		1.0M					50M	M
2N1787	G	P	2N3324	2N3323	AH	45M	A	85	15	15	S	25		1.0M					50M	M
2N1788	G	P	2N3324	2N3323	AH	50M	A	100	35	35	S	50		1.0M					100M	M
2N1789	G	P	2N3325	2N3323	AH	60M	A	100	35	35	S	20		1.0M					100M	M
2N1790	G	P	2N3323	2N3323	AH	60M	A	100	35	35	S	40		1.0M					100M	M
2N1792 thru 2N1807	Thyristors, see Table on Page 164																			
2N1808	G	N			S	150M	A	85	25						0.15	12M			4.0M	B
2N1809	S	N			SP	250W	C	175	50	50	V	10		10A	1.5	10A				
2N1810	S	N			SP	250W	C	175	100	100	V	10		10A	1.5	10A				
2N1811	S	N			SP	250W	C	175	150	150	V	10		10A	1.5	10A				
2N1812	S	N			SP	250W	C	175	200	200	V	10		10A	1.5	10A				
2N1813	S	N			SP	250W	C	175	250	250	V	10		10A	1.5	10A				
2N1814	S	N			SP	250W	C	175	300	300	V	10		10A	1.5	10A				
2N1816	S	N			SP	250W	C	175	50	50	V	10		15A	1.5	15A				
2N1817	S	N			SP	250W	C	175	100	100	V	10		15A	1.5	15A				
2N1818	S	N			SP	250W	C	175	150	150	V	10		15A	1.5	15A				
2N1819	S	N			SP	250W	C	175	200	200	V	10		15A	1.5	15A				
2N1820	S	N			SP	250W	C	175	250	250	V	10		15A	1.5	15A				
2N1821	S	N			SP	250W	C	175	300	300	V	10		15A	1.5	15A				
2N1823	S	N			SP	250W	C	175	50	50	V	10		20A	1.5	20A				
2N1824	S	N			SP	250W	C	175	100	100	V	10		20A	1.5	20A				
2N1825	S	N			SP	250W	C	175	150	150	V	10		20A	1.5	20A				
2N1826	S	N			SP	250W	C	175	200	200	V	10		20A	1.5	20A				
2N1827	S	N			SP	250W	C	175	250	250	V	10		20A	1.5	20A				
2N1828	S	N			SP	250W	C	175	300	300	V	10		20A	1.5	20A				
2N1830	S	N			SP	250W	C	175	50	50	V	10		25A	1.5	25A				
2N1831	S	N			SP	250W	C	175	100	100	V	10		25A	1.5	25A				
2N1832	S	N			SP	250W	C	175	150	150	V	10		25A	1.5	25A				
2N1833	S	N			SP	250W	C	175	200	200	V	10		25A	1.5	25A				
2N1834	S	N			SP	250W	C	175	250	250	V	10		25A	1.5	25A				
2N1835	S	N			SP	250W	C	175	300	300	V	10		25A	1.5	25A				
2N1837	S	N	2N2218	2N2218	SH	800M	A	300	80	30	O	40	120	150M	0.8	150M			140M	T
2N1837A	S	N	2N2218	2N2218	SH	0.8W	A	175	80	30	O	40	120	0.15A	0.8	0.15A			140M	T
2N1837B	S	N			SH	0.8W	A	200	80	30	O	40	120	0.15A	0.8	0.15A			140M	T
2N1838	S	N	2N2218	2N2218	SH	0.6W	A	175	45	20	O	40	150	0.1A	1.4	0.1A			90M	T
2N1839	S	N	2N2218	2N2218	SH	0.6W	A	175	45	20	O	12	50	0.1A	1.4	0.15A			90M	T
2N1840	S	N	2N2218	2N2218	SH	0.6W	A	175	25	15	O	10	100	0.15A	1.4	0.15A			90M	T
2N1841	S	N			AHP	2.0W	A	150	100	50	O	15	50	15M	1.0	1.0A			60M	E
2N1842 thru 2N1850	Thyristors, see Table on Page 164																			
2N1853	G	P			SH	150M	A	85	18	6.0	O	30		6.0M	0.2	6.0M				
2N1854	G	P			SH	150M	A	85	18	6.0	O	40		20M	0.2	20M			40M	T
2N1864	G	P	2N3324	2N3323	AH	60M	A	100	20	20	S	10		1.0M			20	E	50M	M
2N1865	G	P	2N3325	2N3323	AH	60M	A	100	20	20	S	40		1.0M						
2N1866	G	P	2N3323	2N3323	AH	60M	A	100	35	35	S	40		1.0M						
2N1867	G	P	2N3324	2N3323	AH	60M	A	100	35	35	S	10		1.0M						
2N1868	G	P	2N3325	2N3323	AH	60M	A	100	20	20	S	10		2.0M						

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N1869 thru 2N1885	Thyristors, see Table on Page 164																			
2N1886	S	N	2N4914	2N4913	AHP	20W	C	175	60	60	0	20	80	0.5A	5.0	1.0A			2.0M	T
2N1889	S	N	2N3498	2N3498	AH	800M	A	200	100	80	R	40	120	150M	5.0	150M	30	E	50M	T
2N1890	S	N	2N3499	2N3498	AH	800M	A	200	100	80	R	100	300	150M	5.0	150M	50	E	60M	T
2N1891	G	N			SH	150M	A	85	25	15	0	25		100M	0.15	100M			5.0M	B
2N1892	G	P			S	150M	A	85	30	15	0	40	200	10M	0.2	10M	30	E	5.0M	B
2N1893	S	N	2N3498	2N3498	AH	800M	A	200	120	100	R	40	120	150M	5.0	150M	30	E	50M	T
2N1893A	S	N	2N3498	2N3498	AHP	0.8W	A	200	140	80	0	40	120	0.15A	2.0	0.15A	30	E	100M	T
2N1894	S	N			AP			200	60	60	R	12	60	1.0A	5.0	1.0A				
2N1895	S	N			AP			200	80	80	R	12	60	1.0A	10	1.0A				
2N1896	S	N			AP			200	60	60	R	45	135	1.0A	4.0	1.0A			25M	T
2N1897	S	N			AP			200	80	80	R	45	135	1.0A	4.0	1.0A			25M	T
2N1898	S	N			AP			200	100	100	R	45	135	1.0A	4.0	1.0A			25M	T
2N1899	S	N			SHP	125W	C	150	140	50	0	10	30	10A	1.0	10A			50M	T
2N1900	S	N			AHP	125W	C	150	140	50	0	8.0		10A	2.0	10A			50M	T
2N1901	S	N			SHP	125W	C	150	140	50	0	20	60	10A	1.0	10A			50M	T
2N1902	S	N			SHP	125W	C	150	140	50	0	10	30	10A	1.0	10A			50M	T
2N1903	S	N			AHP	125W	C	150	140	50	0	8.0		10A	2.0	10A			50M	T
2N1904	S	N			SHP	125W	C	150	140	50	0	20	60	10A	1.0	10A			50M	T
2N1905	G	P	2N2832	2N2832	AP	30W	C	100	100	50	0	50	150	1.0A	1.0	5.0A	30	E		
2N1906	G	P	2N2832	2N2832	AP	30W	C	100	130	60	0	75	250	1.0A	5.0	5.0A	50	E		
2N1907	G	P	MP1907		AHP	60W	C	100	100	40	0				1.0	15A			10M	T
2N1907A	G	P			AHP	60W	C		100	40	0	30	170	10A	0.7	10A	2.0	E		
2N1908	G	P	MP1910		AHP	60W	C	100	130	50	0				1.0	15A			10M	T
2N1908A	G	P			AHP	60W	C		130	50	0	30	170	10A	0.7	10A	2.0	E		
2N1909 thru 2N1916	Thyristors, see Table on Page 164																			
2N1917	S	P			SC	0.25W	A	175	25	8.0	0						25	E	16M	T
2N1918	S	P			SC	0.25W	A	175	25	8.0	0						25	E	10M	T
2N1919	S	P			SC	0.25W	A	175	40	18	0				0.003				1.0M	B
2N1920	S	P			SC	0.25W	A	175	40	18	0				0.004				1.0M	B
2N1921	S	P			SC	0.25W	A	175	50	50	0				0.005				1.0M	B
2N1922	S	P			SC	0.25W	A	175	80	80	0				0.005				1.0M	B
2N1923	S	N			A	750M	A	150	85	85	0	4.0	90		7.0	20M	28	E		
2N1924	G	P		2N1924	A	225M	A	100	60	40	R	34	65	20M	0.11	20M	30	E	1.0M	B
2N1925	G	P		2N1924	A	225M	A	100	60	40	R	53	90	20M	0.11	20M	44	E	1.3M	B
2N1926	G	P		2N1924	A	225M	A	100	60	40	R	72	121	20M	0.11	20M	60	E	1.5M	B
2N1929 thru 2N1935	Thyristors, see Table on Page 164																			
2N1936	S	N			AP	150W	C	175	125	60	0	7.0	50	10A	0.75	10A	15	E	4.0M	T
2N1937	S	N			AP	150W	C	175	125	80	0	7.0	50	10A	0.75	10A	15	E	4.0M	T
2N1940	G	P			AHP	3.5W	C	100	30	15	0	5.0		40M	1.8	200M				
2N1941	S	N			A	0.6W	A	175	45	30	R	30	150	10M	1.5	5.0M	40	E	60M	T
2N1942	G	P			S	0.2W	A	85	20	10	0	20	60	0.2A					5.0M	B
2N1943	S	N			A	800M	A	200	60	60	0	30	90	200M	5.0	200M	12	E		
2N1944	S	N			S	0.6W	A	175	20	20	R	150	450	1.0M			100	E	60M	T
2N1945	S	N			S	0.6W	A	175	30	30	R	150	450	1.0M			100	E	60M	T
2N1946	S	N			S	0.6W	A	175	40	40	R	150	450	1.0M			100	E	60M	T
2N1947	S	N			S	0.6W	A	175	20	20	R	500	800	0.1A			100	E	60M	T
2N1948	S	N			S	0.6W	A	175	30	30	R	500	800	0.1A			100	E	60M	T
2N1949	S	N			S	0.6W	A	175	40	40	R	500	800	0.1A			100	E	60M	T
2N1950	S	N			S	0.6W	A	175	20	20	R	250	500	0.1A			75	E	60M	T
2N1951	S	N			S	0.6W	A	175	30	30	R	250	500	0.1A			75	E	60M	T
2N1952	S	N			S	0.6W	A	175	40	40	R	250	500	0.1A			75	E	60M	T
2N1953	S	N			A	0.6W	A	175	20	20	S	15	150	10M			28	E	40M	T
2N1954	G	P	2N651	2N650	S	200M	A	100	60	20	0	30	120	20M	0.3	20M				
2N1955	G	P	2N1190	2N1189	S	200M	A	100	60	18	0	50	200	20M	0.175	20M				
2N1956	G	P	2N651	2N650	S	200M	A	100	60	16	0	30	120	20M	0.175	20M				
2N1957	G	P	2N1187	2N1175	S	200M	A	100	60	14	0	30	120	20M	0.175	20M				
2N1958	S	N	2N2537	2N2537	SH	600M	A	175	60	40	R	20	60	150M	0.45	150M			100M	T
2N1958A	S	N	2N2537	2N2537	SH	600M	A	175	60	40	R	20	60	150M	0.45	150M			100M	T
2N1959	S	N		2N1959	SH	600M	A	175	60	40	R	40	120	150M	0.45	150M	1.0	E		
2N1959A	S	N	2N2537	2N2537	SH	600M	A	175	60	40	R	40	120	150M	0.45	150M			100M	T
2N1960	G	P			SH	150M	A	100	15	15		25		10M	0.16	10M				
2N1961	G	P			SH	150M	A	100	12	12	S	20		10M	0.20	10M				
2N1962	S	N	2N834	2N834	SH	400M	A	175	40	20	R	20	60	10M	0.25	10M			200M	T
2N1963	S	N	2N834	2N834	SH	400M	A	175	30	15	R	25		10M	0.16	10M			200M	T
2N1964	S	N	2N2539	2N2537	SH	400M	A	175	60	40	R	20	60	150M	0.45	150M			100M	T
2N1965	S	N	2N2539	2N2537	SH	0.4W	A	175	60	40	R	40	120	0.15A	0.45	0.15A			100M	T
2N1966	G	P			AL	0.12W	A	75	35	15	R									
2N1967	G	P			AL	0.12W	A	75	35	15	R									
2N1968	G	P			AL	0.12W	A	75	35	18	R									
2N1969	G	P			S	150M	A	85	30	15	0	50	200	200*					10M	B
2N1970	G	P		2N1970	AP	150W	C	100	100	50	B	17	40	5.0A	1.0	12A			5.0K	E
2N1971	G	P	2N2140	2N2137	AP			100	80	40	0	25	60	0.5A	0.9	3.0A			15K	E
2N1972	S	N	2N2219	2N2218	AH	600M	A	175	60	30	R	110	350	50M	2.0	50M	40	E	50M	T
2N1973	S	N	2N2219	2N2218	A	800M	A	200	100	80	R	75		10M	1.2	50M	76	E	60M	T
2N1974	S	N	2N3498	2N3498	A	800M	A	200	100	80	R	35		10M	1.2	50M	36	E	50M	T
2N1975	S	N	2N3498	2N3498	A	800M	A	200	100	80	R	15		10M	1.2	50M	18	E	40M	T
2N1978	S	N			AHP	30W	C	200	60	40	R	20		500M	1.5	1.0A			40M	T
2N1980	G	P		2N1970	AP	170W	C	100	50	30	0	50	100	5.0A	0.5	5.0A			3.0K	E
2N1981	G	P		2N1970	AP	170W	C	100	70	40	0	50	100	5.0A	0.5	5.0A			3.0K	E
2N1982	G	P		2N1970	AP	170W	C	100	90	50	0	50	100	5.0A	0.5	5.0A			3.0K	E
2N1983	S	N	2N2218	2N2218	A	600M	A	150	50	25	0						70	E	40M	T

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N1984	S	N	2N2218	2N2218	A	600M	A	150	50	25	0						35	E	40M	T
2N1985	S	N	2N2218	2N2218	A	600M	A	150	50	25	0						15	E	40M	T
2N1986	S	N	2N2218	2N2218	AH	600M	A	150	50	25	0	60	240	150M	1.5	150M			40M	T
2N1987	S	N	2N2218	2N2218	AH	600M	A	150	50	25	0	20	80	150M	1.5	150M			40M	T
2N1988	S	N	2N2218A	2N2218A	AH	600M	A	150	100	45	0	35	120	30M	2.0	30M	20	E	40M	T
2N1989	S	N	2N2218A	2N2218A	AH	600M	A	150	100	45	0	20	60	30M	2.0	30M	10	E	40M	T
2N1990	S	N		2N1990	SP	600M	A	150	100			20		30M	0.5	2.0M				
2N1991	S	P		2N1131	AH	600M	A	150	30	20	0	15	60	150M	1.5	150M			40M	T
2N1992	S	N			SH	0.35W	A	200	15	15	0	30	120	1.0M	0.25	10M			300M	T
2N1993	G	N			S	150M	A	100	30	18	O	50	300	10M	0.2	10M			3.0M	B
2N1994	G	N			S	150M	A	85	30	15	0	15		10M	0.25	200M			3.0M	B
2N1995	G	N			S	150M	A	85	25	15	0	25		10M	0.25	200M			5.0M	B
2N1996	G	N			S	150M	A	85	20	15	0	35		10M	0.25	200M			8.0M	B
2N1997	G	P			S	250M	A	100	45	15	0	40	200	100M	0.2	10M			3.0M	B
2N1998	G	P			S	250M	A	100	35	15	0	70	225	100M	0.2	10M			5.6M	T
2N1999	G	P			S	250M	A	100	30	15	0	100	350	100M	0.2	10M			10M	T
2N2000	G	P			S	300M	A	100	50	15	0	50	300	100M	0.35	500M			2.0M	B
2N2001	G	P			S	300M	A	100	30	15	0	100		100M	0.2	100M			6.0M	B
2N2002	S	P			SC	0.25W	A	200	30	5.0	0									
2N2003	S	P			SC	0.25W	A	200	30	5.0	0									
2N2004	S	P			SC	0.25W	A	175	50	15	0	12		1.0M			15	E	0.5M	B
2N2005	S	P			SC	0.25W	A	200	50	15	0									
2N2006	S	P			SC	0.25W	A	200	60	35	0									
2N2007	S	P			SC	0.25W	A	200	60	35	0									
2N2008	S	N	2N3500	2N3498	A	800M	A	200	175	110	0	30	90	10M	2.5	25M	20	E	40M	T
2N2009 thru 2N2014	Thyristors, see Table on Page 164																			
2N2015	S	N	2N3715	2N3713	A	150W	C	200	100	50	0	15	50	5.0A	1.25	5.0A	12	E	12K	E
2N2016	S	N	2N3715	2N3713	A	150W	C	200	130	65	0	15	50	5.0A	1.25	5.0A	12	E	12K	E
2N2017	S	N			A	1.0W	A	200	60	60	0	50	200	200M			30	E		
2N2018	S	N	2N3738	2N3738	AHP	20W	C	175	150	150	V	20	60	0.5A	6.0	1.0A			2.0M	T
2N2019	S	N	2N3738	2N3738	AHP	20W	C	175	200	200	V	20	60	0.5A	6.0	1.0A			2.0M	T
2N2020	S	N	2N3738	2N3738	AHP	20W	C	175	150	125	O	40	90	0.5A	6.0	1.0A			3.0M	T
2N2021	S	N	2N3738	2N3738	AHP	20W	C	175	200	140	O	40	90	0.5A	6.0	1.0A			3.0M	T
2N2022	G	P			SH	0.15W	A	100	15	12	S	25	150	10M	1.2	50M			250M	T
2N2023 thru 2N2031	Thyristors, see Table on Page 164																			
2N2032	S	N	2N4914	2N4913	AHP	45W	C	200	45	45	O	20		2.0A	5.0	2.0A			3.0M	T
2N2033	S	N			SP	5.0W	C	200	80	60	O	20	60	500M	0.4	500M			1.0M	T
2N2034	S	N	2N4238	2N4237	SP	14W	C	200	80	60	O	20	60	1.0A	0.3	1.0A			1.0M	T
2N2035	S	N	2N4911	2N4910	SP	17W	C	200	80	60	O	20	60	1.5A	0.45	1.5A			1.0M	T
2N2036	S	N	2N4914	2N4913	SP	17.5W	C	200	80	60	O	20	60	2.0A	1.0	2.0A			1.0M	T
2N2038	S	N			AH	0.6W	A	200	45	45	O	12	36	0.2A	6.0	0.2A			2.0M	T
2N2039	S	N			AH	0.6W	A	200	75	75	O	12	36	0.2A	6.0	0.2A			2.0M	T
2N2040	S	N			AH	0.6W	A	200	45	45	O	30	90	0.2A	6.0	0.2A			2.0M	T
2N2041	S	N			AH	0.6W	A	200	75	75	O	30	90	0.2A	6.0	0.2A			2.0M	T
2N2042A	G	P			A	200M	A	100	105	105	S	20	50	5.0M	0.75	100M	20	E	0.5M	B
2N2043A	G	P			A	200M	A	100	105	105	S	40	100	5.0M	0.75	100M	45	E	0.75M	B
2N2044 thru 2N2047	Thyristors, see Table on Page 164																			
2N2048	G	P	2N2955	2N2955	SH	150M	A	100	20	15	O	50	300	10M	0.14	10M			150M	T
2N2048A	G	P			SH	150M	A	100	30	20	O	50	300	10M	0.14	10M			7.5K	E
2N2049	S	N	2N2219A	2N2218A	A	800M	A	200	75	50	R	100	300	150M	0.4	10M	75	E	50M	T
2N2059	G	P			S	60M	A	100	10	8.0	S	20		10M	0.2	10M			50M	T
2N2060	S	N		2N2060	AM	500M	A	200	100	80	R	50	150	10M	1.2	50M	50	E	60M	T
2N2060A	S	N		2N2060	AM	0.5W	A	200	100	60	O	50	150	10M	0.6	50M	50	E	60M	T
2N2060B	S	N							100											
2N2061	G	P			S	40W	C	85	20	10	O	10	60	0.5A	2.0	0.5A			2.0K	E
2N2061A	G	P			SP	90W	C	100	20	15	O	20	60	2.0A	1.0	5.0A			5.0K	E
2N2062	G	P			S	40W	C	85	20	10	O	20	200	2.0A	1.0	2.0A			2.0K	E
2N2062A	G	P			SP	90W	C	100	20	15	O	50	140	2.0A	0.7	5.0A			1.0K	E
2N2063	G	P			S	35W	C	95	40	15	O	10	200	2.0A	2.0	2.0A			2.0K	E
2N2063A	G	P			SP	90W	C	100	40	20	O	20	60	2.0A	1.0	5.0A			5.0K	E
2N2064	G	P			S	35W	C	95	40	15	O	20	200	2.0A	1.0	2.0A			2.0K	E
2N2064A	G	P			SP	90W	C	100	40	20	O	50	140	2.0A	0.7	5.0A			1.0K	E
2N2065	G	P			S	35W	C	95	80	25	O	10	200	2.0A	2.0	2.0A			2.0K	E
2N2065A	G	P			SP	90W	C	100	80	40	O	20	60	2.0A	1.0	5.0A			5.0K	E
2N2066	G	P			S	35W	C	95	80	25	O	20	200	2.0A	1.0	2.0A			2.0K	E
2N2066A	G	P			SP	90W	C	100	80	40	O	50	140	2.0A	0.7	5.0A			1.0K	E
2N2067	G	P	2N1536	2N1529	S	28W	C	95	40	25	O	20	100	0.5A	0.7	1.0A			7.0K	E
2N2068	G	P	2N1531	2N1529	S	28W	C	95	80	55	O	20	100	0.5A	0.7	1.0A			7.0K	E
2N2069	G	P	2N1539	2N1539	S	70W	C	95	40	30	S	30	200	5.0A	1.5	12A			1.5K	E
2N2070	G	P	2N1541	2N1539	S	70W	C	95	80	60	S	30	200	5.0A	1.5	12A			1.5K	E
2N2071	G	P	MP1539		S	70W	C	95	40	30	S	30	200	5.0A	1.5	12A			1.5K	E
2N2072	G	P	MP1541		S	70W	C	95	80	60	S	30	200	5.0A	1.5	12A			1.5K	E
2N2074	Thyristors, see Table on Page 164																			
2N2075	G	P		2N2075	AP	170W	C	110	80	80	S	20	40	5.0A	0.7	12A			5.0K	E
2N2075A	G	P		2N2075	AP	170W	C	110	80	80	S	20	40	5.0A	0.7	12A			5.0K	E
2N2076	G	P		2N2075	AP	170W	C	110	70	70	S	20	40	5.0A	0.7	12A			5.0K	E
2N2076A	G	P		2N2075	AP	170W	C	110	70	70	S	20	40	5.0A	0.7	12A			5.0K	E
2N2077	G	P		2N2075	AP	170W	C	110	50	50	S	20	40	5.0A	0.9	12A			5.0K	E
2N2077A	G	P		2N2075	AP	170W	C	110	50	50	S	20	40	5.0A	0.9	12A			5.0K	E
2N2078	G	P		2N2075	AP	170W	C	110	40	40	S	20	40	5.0A	0.9	12A			5.0K	E
2N2078A	G	P		2N2075	AP	170W	C	110	40	40	S	20	40	5.0A	0.9	12A			5.0K	E
2N2079	G	P		2N2075	AP	170W	C	110	80	80	S	35	70	5.0A	0.7	12A			5.0K	E

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N2079A	G	P		2N2075	AP	170W	C	110	80	80	S	35	70	5.0A	0.7	12A			5.0K	E
2N2080	G	P		2N2075	AP	170W	C	110	70	70	S	35	70	5.0A	0.7	12A			5.0K	E
2N2080A	G	P		2N2075	AP	170W	C	110	70	70	S	35	70	5.0A	0.7	12A			5.0K	E
2N2081	G	P		2N2075	AP	170W	C	110	50	50	S	35	70	5.0A	0.9	12A			5.0K	E
2N2081A	G	P		2N2075	AP	170W	C	110	50	50	S	35	70	5.0A	0.9	12A			5.0K	E
2N2082	G	P		2N2075	AP	170W	C	110	40	40	S	35	70	5.0A	0.9	12A			5.0K	E
2N2082A	G	P		2N2075	AP	170W		110	40	40	S	35	70	5.0A	0.9	12A			5.0K	E
2N2083	G	P			A	60M	A	85	30			25		1.0M					30M	T
2N2084	G	P			AH	125M	A	100	40	20	O	40	250	1.0M			40	E		
2N2085	G	N			A	150M	A	100	33	23	X	50	300	10M		10M	20	E	6.0M	B
2N2086	S	N			SH	600M	A	175	120	80	R	20		150M	0.7	150M			150M	T
2N2087	S	N			SH	600M	A	175	120	80	R	40	120	150M	0.5	150M			150M	T
2N2089	G	P			AH	0.1W	A	85	20	20	R	40		1.0M			40	E	44M	T
2N2090	G	P			AH	0.1W	A	85	20	20	R	40		1.0M			40	E	44M	T
2N2091	G	P			AH	0.1W	A	85	20	20	R	40		1.0M			40	E	44M	T
2N2092	G	P			AH	0.1W	A	85	20	20	R	40		1.0M			40	E	44M	T
2N2093	G	P			AH	0.1W	A	85	25	25	R	40		1.0M			40	E	30M	T
2N2095	G	P			AHP	1.0W	A	100	30	15	O								500M	T
2N2096	G	P		2N1204	SH	250M	A	100	25	12	O	15		400M	0.6	200M				
2N2097	G	P		2N1204	SH	250M	A	100	40	20	O	20		400M	0.5	200M				
2N2098	G	P			AH	1.0W	A	100	30	15	O								500M	T
2N2099	G	P		2N1204	SH	250M	A	100	25	12	O	15		400M	0.6	200M				
2N2100	G	P		2N1204	SH	250M	A	100	40	20	O	20		400M	0.5	200M				
2N2100A	G	P			SH	300M	A	100	40	20	O	20		400M	0.5	200M				
2N2101	S	N	2N3487	2N3485	AP	75W	C	200	60	40	O	15	60	1.0A	5.0	1.0A			25K	T
2N2102	S	N			SH	5.0W	C	200	120	80	R	35		10M	0.5	150M	35	E		
2N2102A	S	N			SH	1.0W	A	200	120	65	O	40	120	150M	0.3	150M	30	E		
2N2104	S	P			SH	3.5W	C	200	50	35	O	25	80	150M	1.5	150M			60M	T
2N2105	S	P			SH	3.5W	C	200	50	35	O	15	40	150M	1.5	150M			50M	T
2N2106	S	N	2N4238	2N2218	A	1.0W	A	150	60	60	R	12	36	200M	5.0	200M				
2N2107	S	N	2N4238	2N2218	A	1.0W	A	150	60	60	R	30	90	200M	2.0	200M				
2N2108	S	N	2N4238	2N2218	A	1.0W	A	150	60	60	R	75	200	200M	2.0	200M				
2N2109	S	N			SP	250W	C	175	50	50	V	10		10A	1.5	10A				
2N2110	S	N			SP	250W	C	175	100	100	V	10		10A	1.5	10A				
2N2111	S	N			SP	250W	C	175	150	150	V	10		10A	1.5	10A				
2N2112	S	N			SP	250W	C	175	200	200	V	10		10A	1.5	10A				
2N2113	S	N			SP	250W	C	175	250	250	V	10		10A	1.5	10A				
2N2114	S	N			SP	250W	C	175	300	300	V	10		10A	1.5	10A				
2N2116	S	N			SP	250W	C	175	50	50	V	10		15A	1.5	15A				
2N2117	S	N			SP	250W	C	175	100	100	V	10		15A	1.5	15A				
2N2118	S	N			SP	250W	C	175	150	150	V	10		15A	1.5	15A				
2N2119	S	N			SP	250W	C	175	200	200	V	10		15A	1.5	15A				
2N2120	S	N			SP	250W	C	175	250	250	V	10		15A	1.5	15A				
2N2121	S	N			SP	250W	C	175	300	300	V	10		15A	1.5	15A				
2N2123	S	N			SP	250W	C	175	50	50	V	10		20A	1.5	20A				
2N2124	S	N			SP	250W	C	175	100	100	V	10		20A	1.5	20A				
2N2125	S	N			SP	250W	C	175	150	150	V	10		20A	1.5	20A				
2N2126	S	N			SP	250W	C	175	200	200	V	10		20A	1.5	20A				
2N2127	S	N			SP	250W	C	175	250	250	V	10		20A	1.5	20A				
2N2128	S	N			SP	250W	C	175	300	300	V	10		20A	1.5	20A				
2N2130	S	N			SP	250W	C	175	50	50	V	10		25A	1.5	25A				
2N2131	S	N			SP	250W	C	175	100	100	V	10		25A	1.5	25A				
2N2132	S	N			SP	250W	C	175	150	150	V	10		25A	1.5	25A				
2N2133	S	N			SP	250W	C	175	200	200	V	10		25A	1.5	25A				
2N2134	S	N			SP	250W	C	175	250	250	V	10		25A	1.5	25A				
2N2135	S	N			SP	250W	C	175	300	300	V	10		25A	1.5	25A				
2N2137	G	P		2N2137	AP	62.5W	C	100	30	30	S	30	60	0.5A	0.5	2.0A			12K	E
2N2137A	G	P		2N2137	AP	62.5W	C	100	30	20	O	30	60	0.5A	0.5	2.0A			12K	E
2N2138	G	P		2N2137	AP	62.5W	C	100	45	45	S	30	60	0.5A	0.5	2.0A			12K	E
2N2138A	G	P		2N2137	AP	62.5W	C	100	45	30	O	30	60	0.5A	0.5	2.0A			12K	E
2N2139	G	P		2N2137	AP	62.5W	C	100	60	60	S	30	60	0.5A	0.5	2.0A			12K	E
2N2139A	G	P		2N2137	AP	62.5W	C	100	60	45	O	30	60	0.5A	0.5	2.0A			12K	E
2N2140	G	P		2N2137	AP	62.5W	C	100	75	75	S	30	60	0.5A	0.5	2.0A			12K	E
2N2140A	G	P		2N2137	AP	62.5W	C	100	75	60	O	30	60	0.5A	0.5	2.0A			12K	E
2N2141	G	P		2N2137	AP	62.5W	C	100	90	90	S	30	60	0.5A	0.5	2.0A			12K	E
2N2141A	G	P		2N2137	AP	62.5W	C	100	90	65	O	30	60	0.5A	0.5	2.0A			12K	E
2N2142	G	P		2N2137	AP	62.5W	C	100	30	30	S	50	100	0.5A	0.5	2.0A			12K	E
2N2142A	G	P		2N2137	AP	62.5W	C	100	30	20	O	50	100	0.5A	0.5	2.0A			12K	E
2N2143	G	P		2N2137	AP	62.5W	C	100	45	45	S	50	100	0.5A	0.5	2.0A			12K	E
2N2143A	G	P		2N2137	AP	62.5W	C	100	45	30	O	50	100	0.5A	0.5	2.0A			12K	E
2N2144	G	P		2N2137	AP	62.5W	C	100	60	60	S	50	100	0.5A	0.5	2.0A			12K	E
2N2144A	G	P		2N2137	AP	62.5W	C	100	60	45	O	50	100	0.5A	0.5	2.0A			12K	E
2N2145	G	P		2N2137	AP	62.5W	C	100	75	75	S	50	100	0.5A	0.5	2.0A			12K	E
2N2145A	G	P		2N2137	AP	62.5W	C	100	75	60	O	50	100	0.5A	0.5	2.0A			12K	E
2N2146	G	P		2N2137	AP	62.5W	C	100	90	90	S	50	100	0.5A	0.5	2.0A			12K	E
2N2146A	G	P		2N2137	AP	62.5W	C	100	90	65	O	50	100	0.5A	0.5	2.0A			12K	E
2N2147	G	P	2N2832	2N2832	AP	12.5W	C	100	75	50	O	100	300	1.0A	1.0	4.0A	75	E	3.0M	T
2N2148	G	P	2N2832	2N2800	AP	12.5W	C	100	60	40	O	40	160	1.0A	1.0	4.0A	30	E	2.0M	T
2N2150	S	N			AHP	30W	C	175	125	80	O	20	60	1.0A	1.0	1.0A	20	E	10M	T
2N2151	S	N			AHP	30W	C	175	125	80	O	40	120	1.0A	1.0	1.0A	40	E	10M	T
2N2152	G	P		2N2137	AP	170W	C	110	45	45	S	50	100	5.0A	0.1	5.0A			2.0K	E
2N2152A	G	P			AP	170W	C	110	45	30	O	50	100	5.0A	0.1	5.0A			2.0K	E
2N2153	G	P		2N2137	AP	170W	C	110	60	60	S	50	100	5.0A	0.1	5.0A			2.0K	E
2N2153A	G	P			AP	170W	C	110	60	45	O	50	100	5.0A	0.1	5.0A			2.0K	E
2N2154	G	P		2N2137	AP	170W	C	110	75	75	S	50	100	5.0A	0.1	5.0A			2.0K	E
2N2154A	G	P			AP	170W	C	110	75	60	O	50	100	5.0A	0.1	5.0A			2.0K	E
2N2155	G	P			AP	170W	C	110	90	90	S	50	100	5.0A	0.1	5.0A			2.0K	E
2N2155A	G	P			AP	170W	C	110	90	65	O	50	100	5.0A	0.1	5.0A			2.0K	E

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N2156	G	P		2N2137	AP	170W	C	110	45	45	S	80	160	5.0A	0.1	5.0A			2.0K	E
2N2156A	G	P			AP	170W	C	110	45	30	O	80	160	5.0A	0.1	5.0A			2.0K	E
2N2157	G	P		2N2137	AP	170W	C	110	60	60	S	80	160	5.0A	0.1	5.0A			2.0K	E
2N2157A	G	P			AP	170W	C	110	60	45	O	80	160	5.0A	0.1	5.0A			2.0K	E
2N2158	G	P		2N2137	AP	170W	C	110	75	75	S	80	160	5.0A	0.1	5.0A			2.0K	E
2N2158A	G	P			AP	170W	C	110	75	60	O	80	160	5.0A	0.1	5.0A			2.0K	E
2N2159	G	P			AP	170W	C	110	90	90	S	80	160	5.0A	0.1	5.0A			2.0K	E
2N2159A	G	P			AP	170W	C	110	90	65	O	80	160	5.0A	0.1	5.0A			2.0K	E
2N2160	Unijunction Transistors, see Table on Page 184																			
2N2161	S	N			SH	200M	A	150	55	35	O	60	160	10M	1.5	10M	75	E		
2N2162	S	P			SC	150M	A	140	30	30	O								14M	T
2N2163	S	P			SC	150M	A	140	15	15	O								14M	T
2N2164	S	P			SC	150M	A	140	12	8.0	O								24M	T
2N2165	S	P			SC	150M	A	140	30	30	O								10M	T
2N2166	S	P			SC	150M	A	140	15	15	O								10M	T
2N2167	S	P			SC	150M	A	140	12	8.0	O								16M	T
2N2168	G	P			SH	60M	A	100	20	15	O	50		10M	0.125	10M				
2N2169	G	P			SH	60M	A	100	15	15	O	40		10M	0.15	10M				
2N2170	G	P			SH	60M	A	100	15	10	O	20		10M	0.18	10M				
2N2171	G	P		2N381	A	0.2W	A	100	50	25	R	110	250	20M			120	E		
2N2172	G	P			S	200M	A	85	20	15	O	30	150	10M	0.2	10M	0.97	B	5.0M	B
2N2173	G	P			SH	240M	A	100	25	15	O	30		200M	0.4	200M				
2N2175	S	P			A	0.1W	A	175	6.0	6.0	O	30		20*					10M	T
2N2176	S	P			A	0.1W	A	175	6.0	6.0	O	30		20*					10M	T
2N2177	S	P			A	0.1W	A	160	6.0	6.0	O	15		5.0*			50	E	8.0M	B
2N2178	S	P			A	0.1W	A	160	6.0	6.0	O	15		5.0*			50	E	8.0M	B
2N2180	G	P			SH	50M	A	100	15	6.0	O	100		10M	0.08	10M	120	E	60M	T
2N2181	S	P			SC	150M	A	140	25	25	O	10		5.0M					6.0M	T
2N2182	S	P			SC	150M	A	140	25	25	O	10		5.0M					6.0M	T
2N2183	S	P			SC	150M	A	140	15	10	O	10		5.0M					6.0M	T
2N2184	S	P			SC	150M	A	140	15	10	O	10		5.0M					6.0M	T
2N2185	S	P			SC	150M	A	140	30	30	O								6.5M	T
2N2186	S	P			SC	150M	A	140	30	30	O								6.5M	T
2N2187	S	P			SC	150M	A	140	30	30	O								6.5M	T
2N2188	G	P	2N3323	2N3323	AH	125M	A	85	40	25	O	40	160	1.5M			40	E	60M	T
2N2189	G	P	2N3323	2N3323	AH	125M	A	85	40	25	O	60	180	1.5M			40	E	102M	T
2N2190	G	P	2N3323	2N3323	AH	125M	A	85	60	25	O	40	160	1.5M			40	E	60M	T
2N2191	G	P	2N3323	2N3323	AH	125M	A	85	60	25	O	60	180	1.5M			60	E	102M	T
2N2192	S	N		2N2192	SH	800M	A	200	60	40	O	100	300	150M	0.35	150M				
2N2192A	S	N		2N2192	SH	800M	A	200	60	40	O	100	300	150M	0.25	150M				
2N2192B	S	N		2N2192	SH	800M	A	200	60	40	O	100	300	150M	0.18	150M				
2N2193	S	N		2N2192	SH	800M	A	200	80	50	O	40	120	150M	0.35	150M				
2N2193A	S	N		2N2192	SH	800M	A	200	80	50	O	40	120	150M	0.25	150M				
2N2193B	S	N		2N2192	SH	800M	A	200	80	50	O	40	120	150M	0.18	150M				
2N2194	S	N		2N2192	SH	800M	A	200	60	40	O	20	60	150M	0.35	150M				
2N2194A	S	N		2N2192	SH	800M	A	200	60	40	O	20	60	150M	0.25	150M				
2N2194B	S	N		2N2192	SH	800M	A	200	60	40	O	20	60	150M	0.18	150M				
2N2195	S	N		2N2192	SH	800M	A	200	45	25	O	20		150M	0.35	150M				
2N2195A	S	N		2N2192	SH	800M	A	200	45	25	O	20		150M	0.25	150M				
2N2195B	S	N		2N2192	SH	800M	A	200	45	25	O	20		150M	0.18	150M				
2N2196	S	N	2N3766	2N3766	AP	2.0W	A	175	80	60	R	30	90	0.2A	2.0	0.2A	30	E		
2N2197	S	N	2N3766	2N3766	AP	2.0W	A	175	80	60	R	75	200	0.2A	2.0	0.2A	30	E		
2N2198	S	N			AH	5.5M	A	200	80	80	O	35	55	0.1A	6.0	0.2A			4.0M	T
2N2199	G	P			AH	75M	A	100	15	10	O	9.0		3.0M			20	E	120M	T
2N2200	G	P			AH	75M	A	100	15	10	O	9.0		3.0M					120M	T
2N2201	S	N	2N4239	2N4237	A	1.0W	C	175	120	100	O	25	90	200M	1.7	200M	30	E		
2N2202	S	N	2N4239	2N4237	A	1.0W	C	175	120	100	O	25	90	200M	1.7	200M	30	E		
2N2203	S	N	2N4239	2N4237	A	1.0W	C	175	120	100	O	25	90	200M	1.7	200M	30	E		
2N2204	S	N	2N4239	2N4237	A	1.0W	C	175	120	100	O	25	90	200M	1.7	200M	30	E		
2N2205	S	N	2N835	2N834	SH	1.0W	C	175	25	12	O	20		10M	0.22	10M	2.0	E		
2N2206	S	N	2N835	2N834	SH	1.0W	C	175	25	12	O	40	120	10M	0.22	10M	2.0	E		
2N2207	G	P			AH	0.26W	A	75	70	50	R	36	370	10M					140M	B
2N2208	G	P			AH	120M	A	85	40	10	O	15		1.5M			30	E		
2N2209	G	P			S	150M	A	85	30	12	O	50		24M	0.15	12M			6.0M	B
2N2210	G	P	2N2075	2N2075	AP	75W	C	100	100	65		25	50	5.0A	0.6	12A			5.0K	E
2N2211	G	P			AP	90W	C	100	80	60	S	60	140	1.0A	0.8	2.0A			5.0K	E
2N2212	G	P		2N2212	AHP	100W	C	110	120	120	R	50	120	5.0A	1.0	5.0A	30	E	0.45M	T
2N2214	S	N			SH	0.25W	C	150	25	15	O	25		10M	0.2	10M			200M	T
2N2216	S	P	2N3498	2N3498	SH	3.0W	C	200	150	100	O	25	120	50M	5.0	50M			50M	T
2N2217	S	N	2N2218	2N2218	SH	0.8W	A	175	60	30	O	20	60	150M	0.4	150M			250M	T
2N2218	S	N		2N2218	SH	0.8W	A	175	60	30	O	40	120	150M	0.4	150M			250M	T
2N2218A	S	N		2N2218A	SH	0.8W	A	175	75	40	O	40	120	0.15A	0.3	0.15A	30	E	250M	T
2N2219	S	N		2N2218	SH	0.8W	A	175	60	30	O	100	300	150M	0.4	150M			250M	T
2N2219A	S	N		2N2218A	SH	0.8W	A	175	75	40	O	100	200	0.15A	0.3	0.15A	50	E	300M	T
2N2220	S	N	2N2222	2N2218	SH	0.5W	A	175	60	30	O	20	60	150M	9.4	150M			250M	T
2N2221	S	N		2N2218	SH	0.5W	A	175	60	30	O	40	120	150M	0.4	150M			250M	T
2N2221A	S	N		2N2218A	SH	0.5W	A	175	75	40	O	40	120	0.15A	0.3	0.15A	30	E	250M	T
2N2222	S	N		2N2218	SH	0.5W	A	175	60	30	O	100	300	150M	0.4	150M			250M	T
2N2222A	S	N		2N2218A	SH	0.5W	A	175	75	40	O	100	300	0.15A	0.3	0.15A	50	E	300M	T
2N2222B	S	N			SH	1.8W	C		75	40	O	100	300	150M	0.3	150M	50	E	300M	T
2N2223	S	N		2N2060	AM	500M	A	200	100	80	R	50	200	10M	1.2	50M	40	E	50M	T
2N2223A	S	N		2N2060	AM	500M	A	200	100	80	R	50	200	10M	1.2	50M	40	E	50M	T
2N2224	S	N		2N2224	SH	0.8W	A	175	65	40	O	35	115	10M	0.4	150M			250M	T
2N2225	G	P			S	200M	A	100	15	4.0	O	100	300	100M	0.2	50M			25M	B
2N2226	S	N			AP	150W	C	150	50	50	V	100	500	9.0A	3.5	9.0A	50	E	7.0K	E
2N2227	S	N			AP	150W	C	150	100	100	V	100	500	9.0A	3.5	9.0A	50	E	7.0K	E
2N2228	S	N			AP	150W	C	150	150	150	V	100	500	9.0A	3.5	9.0A	50	E	7.0K	E
2N2229	S	N			AP	150W	C	150	200	200	V	100	500	9.0A	3.5	9.0A	50	E	7.0K	E

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N2230	S	N			AP	150W	C	150	50	50	V	350		9.0A	3.5	9.0A	100	E	4.0K	E
2N2231	S	N			AP	150W	C	150	100	100	V	350		9.0A	3.5	9.0A	100	E	4.0K	E
2N2232	S	N			AP	150W	C	150	150	150	V	350		9.0A	3.5	9.0A	100	E	4.0K	E
2N2233	S	N			AP	150W	C	150	200	200	V	350		9.0A	3.5	9.0A	100	E	4.0K	E
2N2234	S	N			SHP	12.5W	C	150	40	20	O	15	60	100M	0.25	100M			50M	T
2N2235	S	N			SHP	12.5W	C	150	40	20	O	40	125	100M	0.25	100M			100M	T
2N2236	S	N			SH	575M	A	150	40	20	O	15	60	100M	0.25	100M			50M	T
2N2237	S	N			SH	575M	A	150	40	20	O	40	125	100M	0.25	100M				
2N2238	G	P			AH	0.3W	A	100	30	30	S	10		10M			25	E	400M	T
2N2239	S	N	2N3766	2N3766	A	1.0W	A	150	60	50	R	30	200	200M	3.0	200M				
2N2240	S	N			SH	0.6W	A	200	25	20	O	40	100	1.0M	1.0	50M			50M	T
2N2241	S	N			SH	0.6W	A	200	25	20	O	100	200	1.0M	1.0	50M			50M	T
2N2242	S	N		2N2242	SH	360M	A	200	40	15	O	40	120	10M	0.7	100M			250M	T
2N2243	S	N	2N2219	2N2218	SH	0.8W	A	200	120	80	O	40	120	0.15A	0.35	0.15A			50M	T
2N2243A	S	N			SH	0.8W	A	200	120	80	O	40	120	0.15A	0.25	0.15A			50M	T
2N2244	S	N	2N835	2N834	A	0.5W	A	200	20	20	O	5.0	15	2.0*	0.2	1.0M	40	E	60M	T
2N2245	S	N	2N835	2N834	A	0.5W	A	200	20	20	O	10	30	2.0*	0.2	1.0M	80	E	60M	T
2N2246	S	N	2N835	2N834	A	0.5W	A	200	20	20	O	5.0	15	2.0*	0.2	1.0M	40	E	60M	T
2N2247	S	N	2N834	2N834	A	0.5W	A	200	45	45	O	5.0	15	2.0*	0.2	1.0M	40	E	60M	T
2N2248	S	N	2N834	2N834	A	0.5W	A	200	45	45	O	10	30	2.0*	0.2	1.0M	80	E	60M	T
2N2249	S	N	2N834	2N834	A	0.5W	A	200	45	45	O	20	60	2.0*	0.2	1.0M	150	E	60M	T
2N2250	S	N	2N835	2N834	A	0.5W	A	200	25	20	O	5.0	15	2.0*	0.2	1.0M	40	E	60M	T
2N2251	S	N	2N835	2N834	A	0.5W	A	200	25	20	O	10	30	2.0*	0.2	1.0M	80	E	60M	T
2N2252	S	N	2N834	2N834	A	0.5W	A	200	25	20	O	20	60	2.0*	0.2	1.0M	150	E	60M	T
2N2253	S	N	2N834	2N834	A	0.5W	A	200	45	50	O	5.0	15	2.0*	0.2	1.0M	40	E	60M	T
2N2254	S	N	2N834	2N834	A	0.5W	A	200	45	50	O	10	30	2.0*	0.2	1.0M	80	E	60M	T
2N2255	S	N	2N834	2N834	A	0.5W	A	200	45	50	O	20	60	2.0*	0.2	1.0M	150	E	60M	T
2N2256	S	N		2N2256	SH	300M	A	175	7.0	7.0	S	17		10M						
2N2257	S	N		2N2256	SH	300M	A	175	7.0	7.0	S	40		10M						
2N2258	G	P		2N2256	SH	150M	A	100	7.0	7.0	S	17		10M						
2N2259	G	P		2N2256	SH	150M	A	100	7.0	7.0	S	40		10M						
2N2260 thru 2N2262	Thyristors, see Table on Page 164																			
2N2266	G	P	2N2145	2N2137	SP	50W	J	125	100	55		40	120	500M	0.75	5.0A			200K	T
2N2267	G	P	2N2145	2N2137	SP	50W	J	125	120	55		40	120	500M	0.75	5.0A			200K	T
2N2268	G	P	2N2145	2N2137	SP	50W	J	125	100	55		40	120	500M	0.75	5.0A			200K	T
2N2269	G	P	2N2145	2N2137	SP	50W	J	125	120	55		40	120	500M	0.75	5.0A			200K	T
2N2270	S	N	2N2219	2N2218	A	5.0W	C	200	60	45	O	30		1.0M	0.9	150M	50	E		
2N2271		P			A	0.25W	A	100	20	15	R	50	100	35M					10K	E
2N2272	S	N			SH	360M	A	200	40	20	R	80	240	10M	0.7	200M	3.0	E		
2N2273	G	P		2N2273	AH	100M	A	100	25	15	O	20	150	1.0M						
2N2274	S	P			SC	150M	A	140	25	25	O	10		5.0M					6.0M	T
2N2275	S	P			SC	150M	A	140	25	25	O	10		5.0M					6.0M	T
2N2276	S	P			SC	150M	A	140	15	10	O	10		5.0M					6.0M	T
2N2277	S	P			SC	150M	A	140	15	10	O	10		5.0M					6.0M	T
2N2278	S	P			SC	150M	A	140	15	15	O								7.6M	T
2N2279	S	P			SC	150M	A	140	15	15	O								7.6M	T
2N2280	S	P			SC	150M	A	140	10	6.0	O				0.1	5.0M			16M	T
2N2281	S	P			SC	150M	A	140	10	6.0	O				0.1	5.0M			16M	T
2N2282	G	P			AHP	5.0W	C	110	60	30	O	15		3.0A	0.4	1.0A	40	E	20M	T
2N2283	G	P			AHP	5.0W	C	110	100	60	O	15		3.0A	0.4	1.0A	40	E	20M	T
2N2284	G	P			AHP	5.0W	C	110	200	100	O	15		3.0A	0.4	1.0A	40	E	20M	T
2N2285	G	P		2N1651	AP	100W	C	110	60	30	O	35	140	10A	0.65	25A			0.6M	T
2N2286	G	P		2N1651	AP	100W	C	110	100	60	O	35	140	10A	0.65	25A			0.6M	T
2N2287	G	P		2N1651	AP	100W	C	110	120	80	O	35	140	10A	0.65	25A			0.6M	T
2N2288	G	P		2N2288	AP	60W	C	110	40	40	R	20	60	5.0A	1.0	5.0A	25	E	0.45M	T
2N2289	G	P		2N2288	AP	60W	C	110	80	80	R	20	60	5.0A	1.0	5.0A	25	E	0.45M	T
2N2290	G	P		2N2288	AP	60W	C	110	120	120	R	20	60	5.0A	1.0	5.0A	25	E	0.45M	T
2N2291	G	P		2N2291	AP	60W	C	110	40	30	O	50	120	5.0A	1.0	5.0A	50	E	0.45M	T
2N2292	G	P		2N2291	AP	60W	C	110	80	70	O	50	120	5.0A	1.0	5.0A	50	E	0.45M	T
2N2293	G	P		2N2291	AP	60W	C	110	120	70	O	50	120	5.0A	1.0	5.0A	50	E	0.45M	T
2N2294	G	P			SP	70W	C	110	40	30	O	50	120	5.0A	1.0	5.0A	50	E	0.45M	T
2N2295	G	P			SP	70W	C	110	80	50	O	50	120	5.0A	1.0	5.0A	50	E	0.45M	T
2N2296	G	P			SP	70W	C	110	120	70	O	50	120	5.0A	1.0	5.0A	50	E	0.45M	T
2N2297	S	N	2N3252	2N3252	AH	800M	A	200	80	35	O	40	120	150M	0.2	150M			60M	T
2N2303	S	P	2N2801	2N2800	AH	600M	A	175	50	50	R	75	200	150M	1.5	150M	75	E	60M	T
2N2304	S	N	2N4910	2N4910	AP	25W	C	200	60	60	V	20	80	300M	0.9	300M				
2N2305	S	N	2N4913	2N4913	AP	75W	C	200	60	60	V	15	60	800M	1.2	600M				
2N2306	S	N			SHP	13W	C	175	75	50	O	12	75	0.35A	2.0	1.0A			175M	T
2N2307	Unijunction Transistors, see Table on Page 184																			
2N2308	S	N	2N4912	2N4910	AP	25W	C	200	100	80	O	20	60	1.0A	1.0	1.0A	15	E	30K	E
2N2309	S	N			A	600M	A	200	30	30	O	25	125	0.2M			40	E		
2N2310	S	N			A	350M	A	200	60	60	O	12	36	200M	5.0	200M				
2N2311	S	N			A	350M	A	200	100	100	O	12	36	200M	5.0	200M				
2N2312	S	N			A	350M	A	200	60	60	O	30	90	200M	5.0	200M				
2N2313	S	N			A	350M	A	200	100	100	O	30	90	200M	5.0	200M				
2N2314	S	N			A	350M	A	200	60	40	R	20	60	150M	5.0	150M	15	E	40M	T
2N2315	S	N			A	350M	A	200	60	40	R	40	120	150M	1.5	150M	25	E	50M	T
2N2316	S	N			A	350M	A	200	120	80	R	40	120	150M	5.0	150M	30	E	50M	T
2N2317	S	N			A	350M	A	200	75	50	R	40	120	150M	1.5	150M	30	E	60M	T
2N2318	S	N	2N834	2N834	SH	360M	A	200	30	25	S	15		0.1M	0.35	20M			300M	T
2N2319	S	N	2N834	2N834	SH	300M	A	200	30	25	S	15		0.1M	0.35	20M			300M	T
2N2320	S	N	2N834	2N834	SH	600M	A	200	30	25	S	15		0.1M	0.35	20M			300M	T
2N2322 thru 2N2329	Thyristors, see Table on Page 164																			
2N2330	S	N		2N2330	SC	0.8W	A	150	30	20	O	50		10M					100M	T

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N2331	S	N		2N2330	SC	0.5W	A	150	30	20	O	50		10M					100M	T
2N2332	S	P			SC	0.15W	A	200	15	15	O									
2N2333	S	P			SC	0.15W	A	200	15	5.0	O									
2N2334	S	P			SC	0.15W	A	200	30	15	O									
2N2335	S	P			SC	0.15W	A	200	30	15	O									
2N2336	S	P			SC	0.15W	A	200	50	35	O									
2N2337	S	P			SC	0.15W	A	200	50	35	O									
2N2338	S	N	2N3713	2N3713	AP	150W	C	200	60	40	O	7.0		6.0A	1.5	3.0A	12	E	15K	E
2N2339	S	N	2N4910	2N4910	AP	40W	C	200	60	40	O	6.0		1.5A	1.5	0.3A	12	E	0.7M	T
2N2340	S	N			AHP	15W	C	175	50	40	O	10	40	750M	4.0	750M			550K	E
2N2341	S	N			AHP	15W	C	175	50	40	O	40	100	750M	4.0	750M			350K	E
2N2342	S	N			AHP	15W	C	175	100	40	O	10	40	750M	3.0	750M			550K	E
2N2343	S	N			AHP	15W	C	175	100	40	O	40	100	750M	2.5	750M			350K	E
2N2344 thru 2N2348	Thyristors, see Table on Page 164																			
2N2349	S	N			A	150M	A	200	40	24	O	120	250	10M	1.5	10M	60	E		
2N2350	S	N			SH	400M	A	200	60	40	O	100	300	150M	0.35	150M	2.5	E		
2N2350A	S	N			SH	400M	A	200	60	40	O	100	300	150M	0.25	150M	2.5	E		
2N2351	S	N			SH	400M	A	200	80	50	O	40	120	150M	0.35	150M	2.5	E		
2N2351A	S	N			SH	400M	A	200	80	50	O	40	120	150M	0.25	150M	2.5	E		
2N2352	S	N			SH	400M	A	200	60	40	O	20	60	150M	0.35	150M	2.5	E		
2N2352A	S	N			SH	400M	A	200	60	40	O	20	60	150M	0.25	150M	2.5	E		
2N2353	S	N			SH	400M	A	200	45	25	O	20		150M	0.35	150M	2.5	E		
2N2353A	S	N			SH	400M	A	200	45	25	O	20		150M	0.25	150M	2.5	E		
2N2354		N			A	0.18W	A	85	20	15	R	50	150	35M						
2N2356	S	N			SC	0.6W	A	200	25	7.0	O								50M	T
2N2356A	S	N			SC	0.6W	A	200	25	7.0	O								50M	T
2N2357	G	P		2N2357	SP	170W	C	110	60	30	O	30	90	20A	0.9	50A	20	E	0.6M	T
2N2358	G	P		2N2357	SP	170W	C	110	100	60	O	30	90	20A	0.9	50A	20	E	0.6M	T
2N2359	G	P		2N2357	SP	170W	C	110	120	80	O	30	90	20A	0.9	50A	20	E	0.6M	T
2N2360	G	P	2N3283	2N3283	AH	60M	A	125	20	20	O	10		2.0M						
2N2361	G	P	2N3284	2N3283	AH	60M	A	125	20	20	O	10		2.0M						
2N2362	G	P	2N3284	2N3283	AH	60M	A	100	20	20	S	10		2.0M						
2N2363	G	P			AH	75M	A	100	30	20	O	10	200	2.0M			10	E	250M	T
2N2364	S	N			SH	400M	A	200	120	80	O	40	120	150M	0.35	150M			50M	T
2N2364A	S	N			SH	400M	A	200	120	80	O	40	120	150M	0.25	150M			50M	T
2N2368	S	N	2N3227	2N2369	SH	360M	A	200	40	40	S	20	60	10M	0.25	10M			400M	T
2N2369	S	N	2N3227	2N2369	SH	360M	A	200	40	40	S	40	120	10M	0.25	10M			500M	T
2N2369A	S	N	2N3227	2N2369	SH	360M	A	200	40	40	S		120	10M	0.2	10M			500M	T
2N2370	S	P			L	0.2W	A	200	15	15	O	15		25*			15	E		
2N2371	S	P			L	0.2W	A	200	15	15	O	20		25*			20	E		
2N2372	S	P			L	0.15W	A	200	15	15	O	15		25*			15	E		
2N2373	S	P			L	0.15W	A	200	15	15	O	20		25*			20	E		
2N2374	G	P			A	250M	A	100	35	35	S	100	300	100M			100	E		
2N2375	G	P			A	250M	A	100	35	35	S	35	110	100M			35	E		
2N2376	G	P	2N1193	2N1191	A	250M	A	100	35	35	S	35	110	100M			35	E		
2N2377	S	P			AH	150M	A	140	25	25	O	10	100	5.0M			15	E	8.0M	T
2N2378	S	P			AH	150M	A	140	10	10	O	15		15M					7.2M	T
2N2379	G	P			SP	150W	C	95	100	80	S	25	37	5.0A	1.0	15A			4.0K	E
2N2380	S	N			SH	600M	A	175	80	40	O	20	120	150M	1.3	150M			100M	T
2N2380A	S	N			SH	600M	A	175	80	40	O	20	120	150M	1.3	150M	60	E	100M	T
2N2381	G	P		2N2381	SH	300M	A	100	30	15	O	40		200M	0.40	200M			300M	T
2N2382	G	P		2N2381	SH	300M	A	100	45	20	O	40		200M	0.40	200M			300M	T
2N2383	S	N	2N4914	2N4913	AP	85W	C	180	80	60	O	20	60	1.5A	1.0	1.5A	15	E	30K	E
2N2384	S	N	2N4914	2N4913	AP	85W	C	180	80	60	O	20	60	1.5A	1.0	1.5A	15	E	30K	E
2N2386,A	Field-Effect Transistors, see Table on Page 176																			
2N2387	S	N			A	300M	A	175	45	45	O	40	120	10*	1.0	10M	60	E	30M	T
2N2388	S	N			A	300M	A	175	45	45	O	100	300	10*	1.0	10M	150	E	30M	T
2N2389	S	N			A	450M	A	200	75	50	R	40	120	150M	1.5	150M	30	E	60M	T
2N2390	S	N			A	450M	A	200	75	50	R	100	300	150M	1.5	150M	50	E	70M	T
2N2391	S	P			A	300M	A	175	25	20	O	15	45	10M	0.6	10M	15	E	140M	T
2N2392	S	P			A	300M	A	175	25	20	O	30	90	10M	0.6	10M	30	E	140M	T
2N2393	S	P			A	450M	A	175	50	35	O	20	45	150M	1.5	150M	15	E	50M	T
2N2394	S	P			A	450M	A	175	50	35	O	30	90	150M	1.5	150M	25	E	60M	T
2N2395	S	N			A	450M	A	200	60	40	O	20	60	150M	1.0	150M			40M	T
2N2396	S	N			A	450M	A	200	60	40	O	40	120	150M	1.0	150M			50M	T
2N2397	S	N			SH	300M	A	200	35	15	O	25	120	10M	0.30	10M			200M	T
2N2398	G	P	2N3284	2N3283	AH	60M	A	100	20	20	S	10		2.0M						
2N2399	G	P	2N3284	2N3283	AH	60M	A	100	20	20	S	10		2.0M						
2N2400	G	P	2N964	2N960	SH	150M	A	100	12	7.0	O	30		10M	0.22	10M			150M	T
2N2401	G	P	2N964	2N960	SH	150M	A	100	15	10	O	50		10M	0.2	10M			200M	T
2N2402	G	P	2N2956	2N2955	SH	150M	A	100	18	12	O	60		10M	0.2	10M			250M	T
2N2403	S	N			S	1.0W	A	200	60	60	O	20	60	0.6A	1.5	0.6A			147M	T
2N2404	S	N			S	1.0W	A	200	60	60	O	40	120	0.6A	1.5	0.6A			147M	T
2N2405	S	N	2N3498	2N3498	A	5.0W	C		120	90	O	60	200	150M	0.5	150M	50	E		
2N2410	S	N		2N2405	SH	800M	A	200	60	30	O	30	120	10M					200M	T
2N2411	S	P	2N3250	2N3250	SH	300M	A	200	25	20	O	20	60	10M	0.2	10M			140M	T
2N2412	S	P	2N3250	2N3250	SH	300M	A	200	25	20	O	40	120	10M	0.2	10M			140M	T
2N2413	S	N			AH	300M	A	175	40	18	O	30	120	10M	0.4	10M			300M	T
2N2414	S	N			AL	500M	A	200	60	40	R	50	250	10M	1.2	50M	50	E	50M	T
2N2415	G	P		2N2415	AH	75M	A	100	15	10	O	10	200	2.0M			15	E	500M	T
2N2416	G	P		2N2415	AH	75M	A	100	15	10	O	8.0	20	2.0M			10	E	400M	T
2N2417 thru 2N2422	Unijunction Transistors, see Table on Page 184																			
2N2423	G	P			SP	90W	C	100	100	80	V	20	100	2.0A	1.5	5.0A			3.0K	E
2N2424	S	P			S	375M	A	160	40	5.0	O	30	200	5.0M	0.3	15M			15M	B

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N2425	S	P			A	375M	A	160	50	10	O	25	110	5.0M	0.3	15M			10M	B
2N2426	G	N			A	150M	A	100	40	25	R				0.5	100M	35	E	25K	E
2N2427	S	N			AH	0.5W	A	200	40	40	O	20	60	10*			40	E	50M	T
2N2428	G	P	2N652	2N650	A	0.5W	A	75	32	32	S	50	150	2.0M			80	E	10K	E
2N2429	G	P	2N652	2N650	A	0.5W	A	75	32	32	S	65	300	2.0M			130	E	10K	E
2N2430	G	N			A	0.28W	A	75	32	32	R	60	210	0.1A					10K	E
2N2431	G	P			A	0.55W	A	90	32	32	R	60	175	0.3A					10K	E
2N2432	S	N			SC	300M	A	175	30	30	O	50		1.0M	0.15	10M			20M	T
2N2432A	S	N			SC	300M	A	175	45	45	O	50		1.0M					20M	T
2N2433	S	N			SH	500M	A	200	75	45	O	40	120	150M	1.5	150M	30	E	80M	T
2N2434	S	N			SH	500M	A	200	75	45	O	100	300	150M	1.5	150M	50	E	90M	T
2N2435	S	N			SH	500M	A	200	120	80	O	40	120	150M	3.0	150M	30	E	80M	T
2N2436	S	N			SH	500M	A	200	120	80	O	100	300	150M	3.0	150M	50	E	90M	T
2N2437	S	N			AH	500M	A	200	100	75	O	15		10M	0.2	10M	18	E	70M	T
2N2438	S	N			AH	500M	A	200	100	75	O	35		10M	0.4	50M	36	E	80M	T
2N2439	S	N			AH	500M	A	200	100	75	O	75		10M	0.4	50M	76	E	90M	T
2N2440	S	N			SH	300M	A	200	120	80	O	100	300	150M	0.4	50M	50	E	90M	T
2N2443	S	N			AH	800M	A	200	120	100	O	50	150	50M	1.2	50M	45	E	50M	T
2N2444	G	P			AP	85W	C	110	80	80	O	90	120	3.0A	1.0	5.0A	50	E	4.5M	T
2N2445	G	P			AP	90W	C	100	100	50	O	30	60	10A	1.0	10A	30	E	0.1M	T
2N2446	G	P			SP	90W	C	100	60	50	S	15	45	5.0A	1.5	7.0A			3.0K	E
2N2447	G	P	2N1187	2N1175	A	75M	A	85	45	24	O						25	E		
2N2448	G	P	2N1187	2N1175	A	75M	A	85	45	24	O						25	E		
2N2449	G	P	2N652	2N650	A	75M	A	85	35	20	O						50	E		
2N2450	G	P	2N652	2N650	A	75M	A	85	35	20	O						50	E		
2N2451	G	P			SH	25M	A	85	6.0	5.0	O	25		10M	0.1	10M	40	E	80M	T
2N2452	S	N			AL	500M	A	200	100	80	R									
2N2453	S	N		2N2453	AM	0.5W	A	200	60	30	O	150	600	1.0M	1.0	5.0M	150	E	60M	T
2N2453A	S	N		2N2453	AM	0.5W	A	200	80	50	O	150	600	1.0M	1.0	5.0M	150	E	60M	T
2N2454	Thyristors, see Table on Page 164																			
2N2455	G	P			SH	150M	A	100	15	15	S	20	100	2.0M	0.19	10M	30	E	600M	T
2N2456	G	P			SH	150M	A	100	15	15	S	20	100	2.0M	0.19	10M	30	E	1.0G	T
2N2459	S	N			A	0.4W	A	200	100	60	O	10		0.1M	0.3	10M	40	E	100M	T
2N2460	S	N			A	0.4W	A	200	100	60	O	20		0.1M	0.3	10M	70	E	120M	T
2N2461	S	N			A	0.4W	A	200	100	60	O	40		0.1M	0.3	10M	115	E	140M	T
2N2462	S	N			A	0.4W	A	200	100	60	O	60		0.1M	0.3	10M	160	E	160M	T
2N2463	S	N			A	0.5W	A	200	100	60	O	10		0.1M	0.3	10M	40	E	100M	T
2N2464	S	N			A	0.5W	A	200	100	60	O	20		0.1M	0.3	10M	70	E	120M	T
2N2465	S	N			A	0.5W	A	200	100	60	O	40		0.1M	0.3	10M	115	E	140M	T
2N2466	S	N			A	0.5W	A	200	100	60	O	60		0.1M	0.3	10M	160	E	160M	T
2N2467	G	P			AP	5.0W	C	110	60	30	O	30	90	0.5A	0.4	1.0A	40	E	20M	T
2N2468	G	P			AP	5.0W	C	110	100	60	O	30	90	0.5A	0.4	1.0A	40	E	20M	T
2N2469	G	P			AP	5.0W	C	110	200	100	O	30	90	0.5A	0.4	1.0A	40	E	20M	T
2N2472	S	N			AP	1.0W	A	175	120	100	O	30	90	0.2A	1.7	0.2A	30	E	10M	T
2N2473	S	N			AP	1.0W	A	175	120	100	O	30	90	0.2A	1.7	0.2A	30	E	10M	T
2N2474	S	P			AP	250M	A	160	30	15	O	8.0		100*	0.126	10M	8.0	E		
2N2475	S	N			SH	300M	A	200	15	6.0	O	20	20	50M			6.0	E		
2N2476	S	N		2N2476	SH	2.0W	C	200	60	20	O	20		150M	0.4	150M			250M	T
2N2477	S	N		2N2476	SH	2.0W	C	200	60	20	O	40		150M	0.4	150M			250M	T
2N2478	S	N	2N2218	2N2218	SH	600M	A	175	120	40	O	30		150M	0.7	150M			200M	T
2N2479	S	N	2N2218	2N2218	SH	600M	A	175	80	40	O	30	120	150M	0.85	150M	60	E	150M	T
2N2480	S	N		2N2060	AM	0.3W	A	200	75	40	O	30	350	1.0M	1.3	50M			50M	T
2N2480A	S	N		2N2060	AM	0.3W	A	200	80	40	O	50	200	1.0M	1.2	50M	50	E	50M	T
2N2481	S	N		2N2480	SH	1.2W	C	200	40	15	O	40	120	10M	0.25	10M			300M	T
2N2482	G	N			AH	150M	A		20	15	S	25	200	2.0M			15	E		
2N2483	S	N	MM2483	MM2483	A	360M	A	200	60	60	O	40	120	10*	0.35	1.0M	80	E	12M	T
2N2484	S	N	MM2484	MM2483	A	360M	A	200	60	60	O	100	500	10*	0.35	1.0M	150	E	15M	T
2N2484A	S	N			A	360M	A	200	60	60	O	100	500	10*	0.35	1.0M	150	E	60M	T
2N2485	S	N			AHP	8.8W	C	200	120	120	O	10		0.5A					100M	T
2N2486	S	N			AHP	8.8W	C	200	140	140	O	10		0.5A					100M	T
2N2487	G	P			SH	60M	A	100	15	10	O	20		10M	0.175	40M			360M	T
2N2488	G	P			SH	60M	A	100	15	10	O	20		50M	0.175	15M			360M	T
2N2489	G	P			SH	60M	A	100	20	15	O	20		10M	0.18	10M			300M	T
2N2490	G	P		2N2490	SP	170W	C	110	70	60	S	20	40	5.0A	0.7	12A			5.0K	E
2N2491	G	P		2N2490	SP	170W	C	110	60	50	S	35	70	5.0A	0.7	12A			5.0K	E
2N2492	G	P		2N2490	SP	170W	C	110	80	70	S	25	50	5.0A	0.5	12A			5.0K	E
2N2493	G	P		2N2490	SP	170W	C	110	100	85	S	25	50	5.0A	0.5	12A			5.0K	E
2N2494	G	P			AH	83M	A	75	20	20	V	25		1.0M						
2N2495	G	P			AH	125M	A	100	40	40	S	25		1.0M						
2N2496	G	P			AH	100M	A	100	40	20	V	25		1.0M						
2N2497 thru 2N2500	Field-Effect Transistors, see Table on Page 176																			
2N2501	S	N		2N2501	SH	0.36W	A	200	40	20	O	50	150	10M	0.2	10M			350M	T
2N2502 thru 2N2508	Thyristors, see Table on Page 164																			
2N2509	S	N			AH	1.2W	C	200	125	80	O	25		10*	1.0	5.0M			45M	T
2N2510	S	N			AH	1.2W	C	200	100	65	O	150	500	10M	1.0	5.0M			45M	T
2N2511	S	N	2N3444	2N3252	AH	1.2W	C	200	80	50	O	240	750	10M	1.0	5.0M			45M	T
2N2512	G	P			AH	0.15W	A	75	70	70	R	20		1.0M			40	E	140M	T
2N2514	S	N			A	0.4W	A	200	80	60	O	15	50	5.0M	0.5	10M	20	E	30M	T
2N2515	S	N			A	0.4W	A	200	80	60	O	30	100	5.0M	0.5	10M	40	E	60M	T
2N2516	S	N			A	0.4W	A	200	80	60	O	60	200	5.0M	0.5	10M	80	E	100M	T
2N2517	S	N			A	0.4W	A	200	125	80	O	15	50	5.0M	0.5	10M	20	E	30M	T
2N2518	S	N			A	0.4W	A	200	125	80	O	30	100	5.0M	0.5	10M	40	E	60M	T
2N2519	S	N			A	0.4W	A	200	125	80	O	60	200	5.0M	0.5	10M	80	E	100M	T
2N2520	S	N			A	0.4W	A	200	60	60	O	12		1.0M	0.5	10M	18	E	50M	B
2N2521	S	N			A	0.4W	A	200	60	60	O	25		1.0M	0.5	10M	36	E	50M	B

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N2522	S	N			A	0.4W	A	200	60	60	O	50		1.0M	0.5	10M	76	E	50M	B
2N2523	S	N			A	0.4W	A	200	60	45	O	40	120	10*	0.5	10M	60	E	45M	T
2N2524	S	N			A	0.4W	A	200	60	45	O	100	300	10*	0.5	10M	150	E	45M	T
2N2525	S	N			AHP	25W	C	200	100	80	O	10		0.35A	0.8	1.0A			154M	T
2N2526	G	P		2N2526	SHP	85W	C	110	80	80	O	20	50	3.0A	0.8	10A			30K	T
2N2527	G	P		2N2526	SHP	85W	C	110	120	120	O	20	50	3.0A	0.8	10A			30K	T
2N2528	G	P		2N2526	SHP	85W	C	110	160	160	O	20	50	3.0A	0.8	10A			30K	T
2N2529	S	N			A	150M	A	175	45	40	O	10	20	1.0M	2.0	10M	12	E	6.0M	B
2N2530	S	N			A	150M	A	175	45	40	O	12	35	1.0M	2.0	10M	18	E	10M	B
2N2531	S	N			A	150M	A	175	45	40	O	20	80	1.0M	2.0	10M	36	E	12M	B
2N2532	S	N			A	150M	A	175	45	40	O	45	185	1.0M	2.0	10M	76	E	16M	B
2N2533	S	N			A	150M	A	175	45	40	O	20	55	10M	1.5	10M	19	E	10M	B
2N2534	S	N			A	150M	A	175	45	40	O	45	150	10M	1.5	10M	39	E	20M	B
2N2535	G	P			A	10W	C	100	60	30	O	40	120	0.4A	0.5	1.0A	15	E	8.0K	E
2N2536	G	P			A	10W	C	100	80	40	O	40	120	0.4A	0.5	1.0A	15	E	8.0K	E
2N2537	S	N		2N2537	SH	0.8W	A	200	60	30	O	50	150	150M	0.45	150M			250M	T
2N2538	S	N		2N2537	SH	0.8W	A	200	60	30	O	100	300	150M	0.45	150M			250M	T
2N2539	S	N		2N2537	SH	0.5W	A	200	60	30	O	50	150	150M	0.45	150M			250M	T
2N2540	S	N		2N2537	SH	0.5W	A	200	60	30	O	100	300	150M	0.45	150M			250M	T
2N2541	G	P			S	215M	A	100	30	14	O	60	250	50M	0.25	50M			10M	B
2N2542 thru 2N2550	Thyristors, see Table on Page 164																			
2N2551	S	P			A	0.4W	A	200	150	150	O	15	45	0.1A	1.2	0.1A				
2N2552	G	P			AP	20W	C	100	40	40	V	20	60	1.0A	0.25	1.0A	18	E	225K	T
2N2553	G	P			AP	20W	C	100	60	60	V	20	60	1.0A	0.25	1.0A	18	E	225K	T
2N2554	G	P			AP	20W	C	100	80	80	V	20	60	1.0A	0.25	1.0A	18	E	225K	T
2N2555	G	P			AP	20W	C	100	100	100	V	20	60	1.0A	0.25	1.0A	18	E	225K	T
2N2556	G	P			AP	20W	C	100	40	40	V	20	60	1.0A	0.25	1.0A	18	E	225K	T
2N2557	G	P			AP	20W	C	100	60	60	V	20	60	1.0A	0.25	1.0A	18	E	225K	T
2N2558	G	P			AP	20W	C	100	80	80	V	20	60	1.0A	0.25	1.0A	18	E	225K	T
2N2559	G	P			AP	20W	C	100	100	100	V	20	60	1.0A	0.25	1.0A	18	E	225K	T
2N2560	G	P			AP	20W	C	100	40	40	V	20	60	3.0A	0.75	3.0A	25	E	250K	T
2N2561	G	P			AP	20W	C	100	60	60	V	20	60	3.0A	0.75	3.0A	25	E	250K	T
2N2562	G	P			AP	20W	C	100	80	80	V	20	60	3.0A	0.75	3.0A	25	E	250K	T
2N2563	G	P			AP	20W	C	100	100	100	V	20	60	3.0A	0.75	3.0A	25	E	250K	T
2N2564	G	P			AP	20W	C	100	40	40	V	20	60	3.0A	0.75	3.0A	25	E	250K	T
2N2565	G	P			AP	20W	C	100	60	60	V	20	60	3.0A	0.75	3.0A	25	E	250K	T
2N2566	G	P			AP	20W	C	100	80	80	V	20	60	3.0A	0.75	3.0A	25	E	250K	T
2N2567	G	P			AP	20W	C	100	100	100	V	20	60	3.0A	0.75	3.0A	25	E	250K	T
2N2568	G	N			AHP	1.0W	C	100	32	32	S	10	60	40M	0.75	100M			600M	T
2N2569	S	N			SC	300M	A	200	20	5.0	O	50		100*					100M	T
2N2570	S	N			SC	300M	A	200	20	5.0	O	50		100*					100M	T
2N2571	S	N			SC	300M	A	200	20	15	O	50		100M					100M	T
2N2572	S	N			SC	300M	A	200	20	15	O	50		100M						
2N2573 thru 2N2579	Thyristors, see Table on Page 164																			
2N2580	S	N			SP	150W	C	150	400	400	O	10	40	5.0A	0.7	5.0A			30K	E
2N2581	S	N			SP	150W	C	150	400	400	O	25	65	5.0A	1.0	10A			30K	E
2N2582	S	N			SP	150W	C	150	500	500	O	10	40	5.0A	0.7	5.0A			30K	E
2N2583	S	N			SP	150W	C	150	500	500	O	25	65	5.0A	1.0	10A			30K	E
2N2584	S	N			SP	150W	C	150	600	600	O	10	40	5.0A	0.7	5.0A			30K	E
2N2585	S	N			SP	150W	C	150	600	600	O	25	65	5.0A	1.0	10A			30K	E
2N2586	S	N			A	300M	A	175	60	45	O	120	360	10*	0.5	10M	150	E	1.5K	T
2N2587	G	P			AH	150M	A	100	30	30	S	15	100	8.0M	0.5	50M	0.95	B	320M	T
2N2588	G	P			AH	150M	A	100	40	20	O	50	150	1.5M			50	E	75M	T
2N2589	S	N			SP	150W	C	200	150	150	O	17	51	7.0A	1.05	7.0A	5.0	E	0.25M	T
2N2590	S	P			AH	0.4W	A	200	100	60	O	10		0.1M	0.4	10M	40	E	50M	T
2N2591	S	P			AH	0.4W	A	200	100	60	O	20		0.1M	0.4	10M	70	E	70M	T
2N2592	S	P			AH	0.4W	A	200	100	60	O	40		0.1M	0.4	10M	115	E	90M	T
2N2593	S	P			AH	0.4W	A	200	100	60	O	60		0.1M	0.4	10M	160	E	110M	T
2N2594	S	N			A	5.0W	C	200	80	90	R	50	150	100M	1.0	200M	15	E	40M	T
2N2595	S	P			AH	0.4W	A	200	80	60	O	15	60	5.0M	0.5	10M	20	E	30M	T
2N2596	S	P			AH	0.4W	A	200	80	60	O	30	120	5.0M	0.5	10M	40	E	40M	T
2N2597	S	P			AH	0.4W	A	200	80	60	O	60	240	5.0M	0.5	10M	80	E	60M	T
2N2598	S	P			AH	0.4W	A	200	125	80	O	15	60	5.0M	0.5	10M	20	E	30M	T
2N2599	S	P			AH	0.4W	A	200	125	80	O	30	120	5.0M	0.5	10M	40	E	40M	T
2N2599A	S	P			AH	0.4W	A	200	125	100	O	30	120	5.0M	0.5	10M	40	E	40M	T
2N2600	S	P			AH	0.4W	A	200	125	80	O	60	240	5.0M	0.5	10M	80	E	60M	T
2N2600A	S	P			AH	0.4W	A	200	125	100	O	60	240	5.0M	0.5	10M	80	E	60M	T
2N2601	S	P			AH	0.4W	A	200	60	60	O	12		1.0M	0.5	10M	18	E	20M	T
2N2602	S	P			AH	0.4W	A	200	60	60	O	25		1.0M	0.5	10M	36	E	40M	T
2N2603	S	P			AH	0.4W	A	200	60	60	O	50		1.0M	0.5	10M	76	E	60M	T
2N2604	S	P		2N2604	AH	0.4W	A	200	60	45	O	40		10*	0.5	10M	60	E	30M	T
2N2605	S	P	2N3798	2N2798	AH	0.4W	A	200	60	45	O	100		10*	0.5	10M	150	E	30M	T
2N2605A	S	P			AH	0.4W	A	200	60	45	O	50	200	1.0*	0.25	10M	200	E	45M	T
2N2606 thru 2N2609	Field-Effect Transistors, see Table on Page 176																			
2N2610	S	N			A	0.15W	A	150	45	40	O				1.0	5.0M	4.5	E		
2N2611	S	N	2N3766	2N3766	AP	2.0W	A	175	120	100	O	7.0	36	0.2A	1.7	0.2A	12	E	4.0M	T
2N2612	G	P	2N1559	2N1539	AP	75W	C	100	65	65	V	85	250	10A	1.0	10A				
2N2613	G	P	2N1193	2N1191	A	120M	A	100	30	25	R						120	E	4.0M	B
2N2614	G	P	2N1193	2N1191	A	120M	A	100	40	35	R						100	E	4.0M	B
2N2615	S	N			AL	300M	A	200	30	15	O	20	200	3.0M	0.5	3.0M			500M	T
2N2616	S	N	2N1559	2N1539	AL	300M	A	200	30	15	O	20	200	3.0M	0.4	10M			600M	T
2N2617	S	P			A	0.25W	A	150	25			15	80	20M			25	E		

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N2618	S	N			AH	0.6W	A	200	60	40	O	25		10M			30	E	200M	T
2N2619	Thyristors, see Table on Page 164																			
2N2620	Field-Effect Transistors, see Table on Page 176																			
2N2621	G	P			AH	150M	J	100	15	15	S	15		1.0M						
2N2622	G	P			AH	150M	J	100	24	24	S	15		1.0M						
2N2623	G	P			AH	150M	J	100	32	32	S	20		1.0M						
2N2624	G	P			AH	150M	J	100	15	15	S	20		1.0M						
2N2625	G	P			AH	150M	J	100	24	24	S	15		1.0M						
2N2626	G	P			AH	150M	J	100	32	32	S	20		1.0M						
2N2627	G	P			AH	150M	J	100	15	15	S	15		1.0M						
2N2628	G	P			AH	150M	J	100	24	24	S	15		1.0M						
2N2629	G	P			AH	150M	J	100	32	32	S	10		1.0M						
2N2630	G	P			SH	300M	A	100	18	10	O	25		100M	0.45	100M	3.0	E		
2N2631	S	N			A	8.75W	C	200	80	80	V	8.0		200M						
2N2632	S	N	2N3487	2N3485	AP	40W	C	175	90	60	O	40	120	1.0A	0.25	1.0A	40	E	20M	T
2N2633	S	N	2N3488	2N3485	AP	40W	C	175	120	80	O	40	120	1.0A	0.25	1.0A	40	E	20M	T
2N2634	S	N	2N3489	2N3485	AP	40W	C	175	150	100	O	40	120	1.0A	0.25	1.0A	40	E	20M	T
2N2635	G	P		2N2635	SH	150M	A	100	30	12	O	45	300	50M	0.2	10M			150M	T
2N2636	G	P			SP	100W	C	110	100	60	O	20	80	25A	0.65	25A			0.6M	T
2N2637	G	P			SP	100W	C	110	100	60	O	20	80	25A	0.65	25A			0.6M	T
2N2638	G	P			SP	100W	C	110	100	60	O	20	80	25A	0.65	25A			0.6M	T
2N2639	S	N		2N2639	AM	300M	A	200	45	45	O	50	300	10*	1.0	10M	65	E	35M	T
2N2640	S	N		2N2639	AM	300M	A	200	45	45	O	50	300	10*	1.0	10M	65	E	35M	T
2N2641	S	N		2N2639	AM	300M	A	200	45	45	O	50	300	10*	1.0	10M	65	E	35M	T
2N2642	S	N		2N2639	AM	300M	A	200	45	45	O	100	300	10*	1.0	10M	130	E	35M	T
2N2643	S	N		2N2639	AM	300M	A	200	45	45	O	100	300	10*	1.0	10M	130	E	35M	T
2N2644	S	N		2N2639	AM	300M	A	200	45	45	O	100	300	10*	1.0	10M	130	E	35M	T
2N2645	S	N			AM	500M	A	200	75	50	R	100	300	150M	0.4	10M	75	E	50M	T
2N2646 2N2647	Unijunction Transistors, see Table on Page 184																			
2N2648	G	P			S	5.0W	C	100	35	10	O	80	500	1.0A	0.4	1.0A			10M	T
2N2649	S	N			AHP	8.7W	C	200	65	65	O	10		0.5A					100M	T
2N2650	S	N			AHP	8.7W	C	200	140	140	O	10		0.5A					100M	T
2N2651	S	N	2N2501	2N2501	SH	360M	A	200	40	20	O	25		10M	0.25	10M			350M	T
2N2652	S	N		2N2652	AM	0.3W	A	200	100	60	O	50	200	1.0M	1.2	50M	50	E	60M	T
2N2652A	S	N		2N2652	AM	0.3W	A	200	100	60	O	50	200	1.0M	1.2	50M	50	E	60M	T
2N2653	Thyristors, see Table on Page 164																			
2N2654	G	P			AH	0.1W	A	75	25			25		1.0M						
2N2655	S	N			AP	15W	C	200	100	100	O	30	90	0.2A	2.0	0.2A	30	E	0.25M	E
2N2656	S	N			AH	0.36W	A	200	25	15	O	40	160	0.1M	0.5	10M			250M	T
2N2657	S	N	2N4238	2N4237	SP	1.25W	A	200	80	60	O	40	120	1.0A	0.5	1.0A			20M	T
2N2658	S	N	2N4239	2N4237	SP	1.25W	A	200	100	80	O	40	120	1.0A	0.5	1.0A			20M	T
2N2659	G	P			AP	15W	C	100	50	50	V	30	90	500M	0.2	500M	30	E	280K	T
2N2660	G	P			AP	15W	C	100	70	70	V	30	90	500M	0.2	500M	30	E	280K	T
2N2661	G	P			AP	15W	C	100	90	90	V	30	90	500M	0.2	500M	30	E	280K	T
2N2662	G	P			AP	15W	C	100	50	50	V	30	90	500M	0.2	500M	30	E	280K	T
2N2663	G	P			AP	15W	C	100	70	70	V	30	90	500M	0.2	500M	30	E	280K	T
2N2664	G	P			AP	15W	C	100	90	90	V	30	90	500M	0.2	500M	30	E	280K	T
2N2665	G	P			AP	15W	C	100	50	50	V	50	150	500M	0.2	500M	50	E	300K	T
2N2666	G	P			AP	15W	C	100	70	70	V	50	150	500M	0.2	500M	50	E	300K	T
2N2667	G	P			AP	15W	C	100	90	90	V	50	150	500M	0.2	500M	50	E	300K	T
2N2668	G	P			AP	15W	C	100	50	50	V	50	150	500M	0.2	500M	50	E	300K	T
2N2669	G	P			AP	15W	C	100	70	70	V	50	150	500M	0.2	500M	50	E	300K	T
2N2670	G	P			AP	15W	C	100	70	70	V	50	150	500M	0.2	500M	50	E	300K	T
2N2671	G	P			AH	0.1W	A	75	25			40		1.0M						
2N2672	G	P			AH	0.1W	A	90	25			40		1.0M						
2N2672A		P			AH	0.1W	A	90	32	32	S	40		1.0M						
2N2673	S	N			A	250M	A	200	60	45	O	8.0	22	1.0M	1.5	5.0M	9.0	E	2.5M	B
2N2674	S	N			A	250M	A	200	60	45	O	12	40	1.0M	1.5	5.0M	18	E	5.0M	B
2N2675	S	N			A	250M	A	200	60	45	O	22	76	1.0M	1.5	5.0M	37	E	10M	B
2N2676	S	N			A	250M	A	200	60	45	O	45	290	1.0M	1.5	5.0M	76	E	10M	B
2N2677	S	N			A	250M	A	200	45	35	O	20	55	1.0M	1.5	5.0M	19	E	10M	B
2N2678	S	N			A	250M	A	200	45	35	O	45	150	1.0M	1.5	5.0M	39	E	20M	B
2N2679 thru 2N2690	Thyristors, see Table on Page 164																			
2N2691	G	P			SP	100W	C	110	100	80	O	30	100	20A	0.65	20A			6.0M	T
2N2691A	G	P			SP	170W	C	125	120	80	O	50	100	20M						
2N2692	S	N			SH	300M	A	175	45	30	O	90	360	100*	0.12	100*			42M	T
2N2693	S	N			SH	300M	A	175	45	30	O	40		10*	0.12	100*			42M	T
2N2694	S	N			SH	300M	A	175	45	20	O	20		10*	0.12	100*			42M	T
2N2695	S	P			S	360M	A	200	25	25	O	30	130	50M	0.25	50M	25	E	100M	T
2N2696	S	P	2N2837	2N2800	S	360M	A	200	25	25	O	30	130	50M	0.25	50M	25	E	100M	T
2N2697	S	N			SP	18W	C	200	80	60	O	40	120	1.0A	0.5	1.0A			20M	T
2N2698	S	N			SP	18W	C	200	100	80	O	40	120	1.0A	0.5	1.0A			20M	T
2N2699	G	P	2N964	2N960	SH	150M	A	100	15	8.0	O	40	200	10M	0.18	10M			300M	T
2N2706	G	P			A	0.5W	A	75	32	32	S	65	120	20M			80	E	1.3M	B
2N2707	G	N,P	Matched Pair; 2N2430 (NPN) and 2N2706 (PNP)																	
2N2708	S	N		2N2708	AH	200M	A	200	35	20	O	30	200	2.0M			30	E		
2N2709	S	P	2N2800	2N2800	A	240M	A	160	50	35	O	10	22	0.2M	0.4	8.0M			200K	B
2N2710	S	N		2N2710	SH	360M	A	200	40	20	O	40		10M	0.25	10M			500M	T
2N2711	S	N	MPS2711	MPS2711	A	0.2W	A	125	18	18	O	30	90	2.0M			30	E		
2N2712	S	N	MPS2712	MPS2711	A	0.2W	A	125	18	18	O	75	225	2.0M			80	E		
2N2713	S	N	MPS2713	MPS2713	A	0.2W	A	125	18	18	O	30	90	2.0M	0.3	50M	30	E		
2N2714	S	N	MPS2714	MPS2713	A	0.2W	A	125	18	18	O	75	225	2.0M	0.3	50M	80	E		
2N2715	S	N	MPS2715		A	0.2W	A	125	18	18	O	30	90	2.0M			30	E		
2N2716	S	N	MPS2716		A	0.2W	A	125	18	18	O	75	225	2.0M			80	E		
2N2717	G	P			SH	0.1W	A	75	20	15	O	50		30M	0.35	10M			300M	T

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N2718	G	P			SH	240M	A	100	20	12	O	25		170M	0.27	170M			150M	T
2N2719	S	N			SH	300M	A	175	25	8.0	O	30		60M	0.40	60M			200M	T
2N2720	S	N		2N2720	AM	0.3W	A	200	80	60	O	30	120	0.1M	1.0	10M	30	E	80M	T
2N2721	S	N		2N2720	AM	0.3W	A	200	80	60	O	30	120	0.1M	1.0	10M	30	E	80M	T
2N2722	S	N		2N2722	AM	0.3W	A	200	45	45	O	50	250	1.0*	1.0	10M	100	E	100M	T
2N2723	S	N		2N2723	AL	0.5W	A	200	80	60	O	2K	10K	10M	1.0	10M	1500	E	100M	T
2N2724	S	N		2N2723	AL	0.5W	A	200	80	60	O	7K	50K	10M	1.0	10M	5000	E	100M	T
2N2725	S	N		2N2723	AL	0.5W	A	200	45	45	O	2K	10K	0.1M	1.0	10M	1500	E	100M	T
2N2726	S	N			AHP	1.0W	A	200	200	200	R	30	90	0.2A	2.0	0.2A	30	E	15M	T
2N2727	S	N			AHP	1.0W	A	200	200	200	R	75	150	0.2A	2.0	0.2A	75	E	15M	T
2N2728	G	P		2N2728	SHP	170W	C	110	15	5.0	O	40	130	20A	0.1	50A			3.0K	E
2N2729	S	N			AH	300M	A	200	30	15	O	20	200	3.0M	0.4	10M			600M	T
2N2730	G	P	MP506	MP500	SP	170W	C	110	80	60	O	30	120	25A	0.25	25A			200K	T
2N2731	G	P	MP505	MP500	SP	170W	C	110	60	45	O	30	120	25A	0.25	25A			200K	T
2N2732	G	P	MP504	MP500	SP	170W	C	110	40	30		30	120	25A	0.25	25A			200K	T
2N2733	G	P	MP506	MP500	SP	140W	C	110	80	60	O	30	120	25A	0.25	25A			200K	T
2N2734	G	P	MP505	MP500	SP	140W	C	110	60	45	O	30	120	25A	0.25	25A			200K	T
2N2735	G	P	MP504	MP500	SP	140W	C	110	40	30	O	30	120	25A	0.25	25A			200K	T
2N2736	G	P	MP506	MP500	SP	140W	C	110	80	60	O	30	120	25A	0.25	25A			200K	T
2N2737	G	P	MP505	MP500	SP	140W	C	110	60	45	O	30	120	25A	0.25	25A			200K	T
2N2738	G	P	MP504	MP500	SP	140W	C	110	40	30	O	30	120	25A	0.25	25A			200K	T
2N2739	S	N			SP	200W	C	175	50	50	V	10		10A	1.5	10A				
2N2740	S	N			SP	200W	C	175	100	100	V	10		10A	1.5	10A				
2N2741	S	N			SP	200W	C	175	150	150	V	10		10A	1.5	10A				
2N2742	S	N			SP	200W	C	175	200	200	V	10		10A	1.5	10A				
2N2743	S	N			SP	200W	C	175	250	250	V	10		10A	1.5	10A				
2N2744	S	N			SP	200W	C	175	300	300	V	10		10A	1.5	10A				
2N2745	S	N			SP	200W	C	175	50	50	V	10		15A	1.5	15A				
2N2746	S	N			SP	200W	C	175	100	100	V	10		15A	1.5	15A				
2N2747	S	N			SP	200W	C	175	150	150	V	10		15A	1.5	15A				
2N2748	S	N			SP	200W	C	175	200	200	V	10		15A	1.5	15A				
2N2749	S	N			SP	200W	C	175	250	250	V	10		15A	1.5	15A				
2N2750	S	N			SP	200W	C	175	300	300	V	10		15A	1.5	15A				
2N2751	S	N			SP	200W	C	175	50	50	V	10		20A	1.5	20A				
2N2752	S	N			SP	200W	C	175	100	100	V	10		20A	1.5	20A				
2N2753	S	N			SP	200W	C	175	150	150	V	10		20A	1.5	20A				
2N2754	S	N			SP	200W	C	175	200	200	V	10		20A	1.5	20A				
2N2755	S	N			SP	200W	C	175	250	250	V	10		20A	1.5	20A				
2N2756	S	N			SP	200W	C	175	300	300	V	10		20A	1.5	20A				
2N2757	S	N			SP	200W	C	175	50	50	V	10		10A	1.5	10A				
2N2758	S	N			SP	200W	C	175	100	100	V	10		10A	1.5	10A				
2N2759	S	N			SP	200W	C	175	150	150	V	10		10A	1.5	10A				
2N2760	S	N			SP	200W	C	175	200	200	V	10		10A	1.5	10A				
2N2761	S	N			SP	200W	C	175	250	250	V	10		10A	1.5	70A				
2N2762	S	N			SP	200W	C	175	300	300	V	10		10A	1.5	10A				
2N2763	S	N			SP	200W	C	175	50	50	V	10		15A	1.5	15A				
2N2764	S	N			SP	200W	C	175	100	100	V	10		15A	1.5	15A				
2N2765	S	N			SP	200W	C	175	150	150	V	10		15A	1.5	15A				
2N2766	S	N			SP	200W	C	175	200	200	V	10		15A	1.5	15A				
2N2767	S	N			SP	200W	C	175	250	250	V	10		15A	1.5	15A				
2N2768	S	N			SP	200W	C	175	300	300	V	10		15A	1.5	15A				
2N2769	S	N			SP	200W	C	175	50	50	V	10		20A	1.5	20A				
2N2770	S	N			SP	200W	C	175	100	100	V	10		20A	1.5	20A				
2N2771	S	N			SP	200W	C	175	150	150	V	10		20A	1.5	20A				
2N2772	S	N			SP	200W	C	175	200	200	V	10		20A	1.5	20A				
2N2773	S	N			SP	200W	C	175	250	250	V	10		20A	1.5	20A				
2N2774	S	N			SP	200W	C	175	300	300	V	10		20A	1.5	20A				
2N2775	S	N			SP	200W	C	175	50	50	V	10		25A	1.5	25A				
2N2776	S	N			SP	200W	C	175	100	100	V	10		25A	1.5	25A				
2N2777	S	N			SP	200W	C	175	150	150	V	10		25A	1.5	25A				
2N2778	S	N			SP	200W	C	175	200	200	V	10		25A	1.5	25A				
2N2779	S	N			SP	200W	C	175	250	250	V	10		25A	1.5	25A				
2N2780	S	N			SP	200W	C	175	300	300	V	10		25A	1.5	25A				
2N2781	S	N			AHP	200W	C	175	75	30	O	7.5	75	0.35A	5.0	1.0A			75M	T
2N2782	S	N			AHP	200W	C	175	100	40	O	7.5	75	0.35A	5.0	1.0A			75M	T
2N2783	S	N			AHP	200W	C	175	100	40	O	7.5	75	0.35A	5.0	1.0A			75M	T
2N2784	S	N			SH	200W	C	200	15	6.0	O	40		30M	0.26	3.0M			1.0G	T
2N2785	S	N		2N2785	AL	500M	A	175	60	40	O	2K	20K	0.1A	1.0	15M	600	E	10M	T
2N2786	G	P			AH	1.5W	C	90	35	20	O	33	200	0.1A						
2N2786A	G	P			AH	1.5W	C	90	35	20	O	33	200	0.1A						
2N2787	S	N	2N2218	2N2218	SH	800M	A	175	75	35	O	20	50	150M	0.4	150M	15	E	250M	T
2N2788	S	N	2N2218A	2N2218A	SH	800M	A	175	75	35	O	40	120	150M	0.4	150M	30	E	250M	T
2N2789	S	N	2N2219A	2N2218A	SH	800M	A	175	75	35	O	100	300	150M	0.4	150M	80	E	250M	T
2N2790	S	N	2N2218	2N2218	SH	500M	A	175	75	35	O	20	60	150M	0.4	150M	15	E	250M	T
2N2791	S	N	2N2221A	2N2218A	SH	500M	A	175	75	35	O	40	120	150M	0.4	150M	30	E	250E	T
2N2792	S	N	2N2222A	2N2218A	SH	500M	A	175	75	35	O	100	300	150M	0.4	150M	80	E	250E	T
2N2793	G	P			AHP	170W	C	110	75	60	O	50	100	15A	0.45	50A	20	E	2.0K	E
2N2794	Field-Effect Transistors, see Table on Page 176																			
2N2795	G	P			SH	75M	A	100	25	15	O	50		50M	0.125	50M			300M	T
2N2796	G	P			SH	75M	A	100	20	12	O	30		50M	0.25	50M			300M	T
2N2797	G	P			SH	75M	A	100	40	20	O	40		50M	0.2	50M			150M	T
2N2798	G	P			SH	75M	A	100	60	25	O	20		50M	0.25	50M			120M	T
2N2799	G	P			SH	75M	A	100	30	15	O	20		50M	0.25	50M			120M	T
2N2800	S	P		2N2800	SH	0.8W	A	200	50	35	O	30	90	150M	0.4	150M			120M	T
2N2801	S	P		2N2800	SH	0.8W	A	200	50	35	O	75	225	150M	0.4	150M			120M	T
2N2802	S	P		2N2802	AM	250M	A	200	25	20	O	20	120	100*	0.5	10M	20	E	60M	T
2N2803	S	P		2N2802	AM	250M	A	200	25	20	O	20	120	100*	0.5	10M	20	E	60M	T
2N2804	S	P		2N2802	AP	250M	A	200	25	20	O	20	120	100*	0.5	10M	20	E	60M	T

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N2805	S	P		2N2802	AM	250M	A	200	25	20	O	40	120	100*	0.5	10M	40	E	60M	T
2N2806	S	P		2N2802	AM	250M	A	200	25	20	O	40	120	100*	0.5	10M	40	E	60M	T
2N2807	S	P		2N2802	AP	250M	A	200	25	20	O	40	120	100*	0.5	10M	40	E	60M	T
2N2808	S	N			AH	300M	A	200	30	10	O	20	120	2.0M	0.25	4.0M	20	E	1.0G	T
2N2808A	S	N			AH	200M	A	200	30	10	O	20	120	2.0M	0.25	4.0M	7.0	E	1.5G	T
2N2809	S	N			AH	200M	A	200	30	15	O	20	120	2.0M	0.25	4.0M	20	E	600M	T
2N2809A	S	N			AH	200M	A	200	30	15	O	20	120	2.0M	0.25	4.0M	20	E	1.0G	T
2N2810	S	N			AH	200M	A	200	24	10	O	20	120	2.0M	0.25	4.0M	20	E	600M	T
2N2810A	S	N			AH	200M	A	200	24	10	O	20	120	2.0M	0.25	4.0M	20	E	1.0G	T
2N2811	S	N	2N3487	2N3485	AP	70W	J	200	80	60	O	20	60	5.0A	0.5	5.0A	20	E	15M	T
2N2812	S	N	2N3488	2N3485	AP	70W	J	200	80	60	O	40	120	5.0A	0.5	5.0A	40	E	15M	T
2N2813	S	N	2N3489	2N3485	AP	70W	J	200	120	80	O	20	60	5.0A	0.5	5.0A	20	E	15M	T
2N2814	S	N	2N3490	2N3485	AP	70W	J	200	120	80	O	40	120	5.0A	0.5	5.0A	40	E	15M	T
2N2815	S	N			SP	200W	C	200	80	80	O	10	50	10A	1.5	10A			0.6M	T
2N2816	S	N			SP	200W	C	200	100	100	O	10	50	10A	1.5	10A			0.6M	T
2N2817	S	N			SP	200W	C	200	150	150	O	10	50	10A	1.5	10A			0.6M	T
2N2818	S	N			SP	200W	C	200	200	200	O	10	50	10A	1.5	10A			0.6M	T
2N2819	S	N			SP	200W	C	200	80	80	O	10	50	15A	1.5	15A			0.6M	T
2N2820	S	N			SP	200W	C	200	100	100	O	10	50	15A	1.5	15A			0.6M	T
2N2821	S	N			SP	200W	C	200	150	150	O	10	50	15A	1.5	15A			0.6M	T
2N2822	S	N			SP	200W	C	200	200	200	O	10	50	15A	1.5	15A			0.6M	T
2N2823	S	N			SP	200W	C	200	80	80	O	10	40	20A	1.1	20A			0.6M	T
2N2824	S	N			SP	200W	C	200	100	100	O	10	40	20A	1.1	20A			0.6M	T
2N2825	S	N			SP	200W	C	200	150	150	O	10	40	20A	1.1	20A			0.6M	T
2N2826	G	P			AP	4.5W	C	95		15	O	75	200	100M	1.0	500M				
2N2827	G	P			AP	4.5W	C	95		30	O	75	200	100M	1.0	500M				
2N2828	S	N			SP	40W	C	200	80	60	O	20	60	0.5A	0.4	0.5A			1.0M	T
2N2829	S	N	2N4911	2N4910	SP	40W	C	200	80	60	O	20	60	1.0A	0.3	1.0A			1.0M	T
2N2831	S	N			AH	360M	A	200	40	12	O	25		10M	0.25	10M	40	E	250M	T
2N2832	G	P		2N2832	SP	85W	C	110	80	50	O	25	100	10A	0.5	20A			10M	T
2N2833	G	P		2N3832	SP	85W	C	110	120	75	O	25	100	10A	0.5	20A			10M	T
2N2834	G	P		2N2832	SP	85W	C	110	140	100	O	25	100	10A	0.5	20A				
2N2835	G	P			A	16W	C	90	32	32	R	30	100	1.0A	0.4	1.0A			0.3M	B
2N2836	G	P	2N3612	2N3611	AP	37.5W	C	100	55	55	R	30	100						250K	B
2N2837	S	P		2N2800	SH	0.5W	A	200	50	35	O	30	90	150M	0.4	150M			120M	T
2N2838	S	P		2N2800	SH	0.5W	A	200	50	35	O	75	225	150M	0.4	150M			120M	T
2N2840	Unijunction Transistors, see Table on Page 184																			
2N2841 thru 2N2844	Field-Effect Transistors, see Table on Page 176																			
2N2845	S	N		2N2845	S	360M	A	200	60	30	O	30	120	150M	0.4	150M			250M	T
2N2846	S	N		2N2845	S	800M	A	200	60	30	O	30	120	150M	0.4	150M			250M	T
2N2847	S	N		2N2845	S	360M	A	200	60	20	O	40	140	150M	0.4	150M			250M	T
2N2848	S	N		2N2845	S	800M	A	200	60	20	O	40	140	150M	0.4	150M			250M	T
2N2849	S	N			SH	850M	A	200	100	80	O	100	300	1.0A	0.4	1.0A			30M	T
2N2850	S	N			SH	850M	A	200	100	80	O	40	120	1.0A	0.25	1.0A			30M	T
2N2851	S	N			SH	850M	A	200	100	80	O	40	120	1.0A	0.4	1.0A			30M	T
2N2852	S	N			SH	850M	A	200	100	80	O	20	60	1.0A	0.4	1.0A			30M	T
2N2853	S	N			SH	850M	A	200	60	40	O	40		1.0A	1.5	5.0A			30M	T
2N2854	S	N			SH	850M	A	200	60	40	O	100	300	1.0A	0.4	1.0A			30M	T
2N2855	S	N			SH	850M	A	200	60	40	O	40	120	1.0A	0.4	1.0A			30M	T
2N2856	S	N			SH	850M	A	200	60	40	O	20	60	1.0A	0.4	1.0A			30M	T
2N2857	S	N		2N2857	AH	200M	A	200	30	15	O	30	150	3.0M			50	E	1.0G	T
2N2858	S	N			SP	0.6W	C	200	100	80	O	20	60	1.0A	0.3	1.0A			1.0M	T
2N2859	S	N			SP	0.6W	C	200	120	100	O	20	60	1.0A	0.3	1.0A			1.0M	T
2N2860	G	P			SH	150M	A	100	18	7.0	O	40		40M	0.4	36M			250M	T
2N2861	S	P			A	300M	A	200	25	20	O	30	120	10*	0.2	10M	50	E	60M	T
2N2862	S	P			A	300M	A	200	25	20	O	12	120	10*	0.2	10M	25	E	45M	T
2N2863	S	N			AH	800M	A	200	60	25	O	30	200	200M	1.0	500M			150M	T
2N2864	S	N			AH	800M	A	200	60	25	O	20	200	200M	1.0	500M			150M	T
2N2865	S	N			AH	200M	A	200	25	13	O	20	200	4.0M	0.4	10M	20	E	600M	T
2N2866	S	N			AHP	40W	C	175	120	80	O	20	60	0.5A	0.75	1.0A			10M	T
2N2867	S	N			AHP	40W	C	175	120	80	O	40	120	0.5A	0.75	1.0A			10M	T
2N2868	S	N	2N3252	2N3252	SH	0.8W	A	200	60	40	O	40	120	0.15A	0.25	0.15A			50M	T
2N2869	G	P	MP2015		AP	30W	C	100	60	50	O	50	165	1.0A	0.75	10A			200K	T
2N2870	G	P	MP2016		AP	30W	C	100	80	50	O	50	165	1.0A	0.5	10A			200K	T
2N2871	S	P			SC	0.4W	A	200	60	60	O	15		1.0M					0.2M	T
2N2872	S	P			SC	0.4W	A	200	110	110	O	15		1.0M					0.2M	T
2N2873	G	P			AH	115M	A	100	35	35	V	40		1.0M			40	E	300M	T
2N2874	S	N			AHP	2.0W	A	175	75	40	O	7.5	75	0.35A	5.0	1.0A			140M	T
2N2875	S	P			AHP	20W	C	200	60	50	O	15	60	50M	1.5	0.5A	20	E	25M	E
2N2876	S	N			AH	17.5W	C	200	80	60	O	5.0		2.5A	1.0	2.5A			150M	T
2N2877	S	N			AHP	53W	C	200	80	60	O	20	60	1.0A	0.25	1.0A	20	E	30M	T
2N2878	S	N			AHP	53W	C	200	80	60	O	40	120	1.0A	0.25	1.0A	40	E	50M	T
2N2879	S	N			AHP	53W	C	200	100	80	O	20	60	1.0A	0.25	1.0A	20	E	30M	T
2N2880	S	N			AHP	53W	C	200	100	80	O	40	120	1.0A	0.25	1.0A	40	E	50M	T
2N2881	S	P	2N4235	2N4234	AP	8.5W	C	200	60	60	O	20	60	0.5A	0.4	0.5A	10	E	25K	E
2N2882	S	P	2N4236	2N4234	AP	8.5W	C	200	100	100	O	20	60	0.5A	0.4	0.5A	10	E	25K	E
2N2883	S	N	2N3553	2N3375	AHP	800M	A	200	40	20	O	20		100M	0.5	100M			400M	T
2N2884	S	N	2N3553	2N3375	AHP	800M	A	200	40	20	O	20		100M	0.5	100M			400M	T
2N2885	S	N			SH	0.15W	A	175	40	15	O	30	120	10M	0.4	10M			300M	T
2N2886	S	N			A	800M	A	200	50	40	O	22	45	5.0M	1.2	8.0M				
2N2887	S	N			AHP	25W	C	200	100	80	O	15	80	0.35A	1.2	1.0A			140M	T
2N2888 2N2889	Thyristors, see Table on Page 164																			
2N2890	S	N	2N3507	2N3506	AP	800M	A	200	100	80	O	30	90	1.0A	0.5	1.0A	30	E	30M	T
2N2891	S	N	2N3507	2N3506	SP	800M	A	200	100	80	O	50	150	1.0A	0.5	1.0A	50	E	30M	T
2N2892	S	N			SP	30W	C	200	100	80	O	30	90	1.0A	0.5	1.0A	30	E	30M	T

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N2893	S	N			SP	30W	C	200	100	80	O	50	150	1.0A	0.5	1.0A	50	E	30M	T
2N2894	S	P		2N2894	S	360M	A	200	12	12	O	40	150	30M	0.15	10M			400M	T
2N2894A	S	P			SP	360M	A	200	12	12	S	40		30M					800M	T
2N2895	S	N		2N2895	S	500M	A	200	120	65	O	40	120	150M	0.6	150M	50	E	120M	T
2N2896	S	N		2N2895	S	500M	A	200	140	90	O	60	200	150M	0.6	150M	50	E	120M	T
2N2897	S	N		2N2895	S	500M	A	200	60	45	O	50	200	150M	1.0	150M	50	E	120M	T
2N2898	S	N			S	500M	A	200	120	65	O	40	120	150M	0.6	150M	50	E	120M	T
2N2899	S	N			S	500M	A	200	140	90	O	60	200	150M	0.6	150M	50	E	120M	T
2N2900	S	N			S	500M	A	200	60	45	O	50	200	150M	1.0	150M	50	E	120M	T
2N2901	S	N			SC	0.36W	A	200	20	10	O	30		10M	0.15	10M			300M	T
2N2902	S	N			AP	40W	C	200	120	120	O	30	90	500M	7.5	500M	30	E	2.0M	T
2N2903	S	N		2N2903	AM	600M	C	200	60	30	O	125	625	1.0M	1.0	5.0M	150	E	60M	T
2N2903A	S	N		2N2903	AM	600M	C	200	60	30	O	125	625	1.0M	1.0	5.0M	150	E	60M	T
2N2904	S	P		2N2904	SH	3.0W	C	200	60	40	O	40	120	150M	0.4	150M			200M	T
2N2904A	S	P		2N2904	SH	3.0W	C	200	60	60	O	40	120	150M	0.4	150M			200M	T
2N2905	S	P		2N2904	SH	3.0W	C	200	60	40	O	100	300	150M	0.4	150M			200M	T
2N2905A	S	P		2N2904	SH	3.0W	C	200	60	60	O	100	300	150M	0.4	150M			200M	T
2N2906	S	P		2N2904	SH	1.8W	C	200	60	40	O	40	120	150M	0.4	150M			200M	T
2N2906A	S	P		2N2904	SH	1.8W	C	200	60	60	O	40	120	150M	0.4	150M			200M	T
2N2907	S	P		2N2904	SH	1.8W	C	200	60	40	O	100	300	150M	0.4	150M			200M	T
2N2907A	S	P		2N2904	SH	1.8W	C	200	60	60	O	100	300	150M	0.4	150M			200M	T
2N2908	S	N			AP	75W	C	200	80	80	R	12	60	1.0A	10	1.0A	10	E	1.0M	E
2N2909	S	N			SH	0.4W	A	200	60	40	O	40	120	0.15A	0.25	0.15A			50M	T
2N2910	S	N	2N3409	2N3409	AM	0.3W	A	200	45	25	O	70		0.1M	1.0	10M	50	E	11M	T
2N2911	S	N	2N3766	2N3766	SP	5.0W	C	200	150	125	O	20	60	1.0A	0.3	1.0A			1.0M	T
2N2912	G	P		2N2912	SP	75W	C	110	15	6.0	O	75		10A	0.5	25A			20M	T
2N2913	S	N		2N2913	AM	300M	A	200	45	45	O	60	240	10*	0.35	1.0M			60M	T
2N2914	S	N		2N2913	AM	300M	A	200	45	45	O	150	600	10*	0.35	1.0M			60M	T
2N2915	S	N		2N2213	AM	300M	A	200	45	45	O	60	240	10*	0.35	1.0M			60M	T
2N2915A	S	N			A	300M	A	200	45	45	O						240	E	60M	T
2N2916	S	N		2N2913	AM	300M	A	200	45	45	O	150	600	10*	0.35	1.0M			60M	T
2N2916A	S	N			A	300M	A	200	45	45	O						600	E	60M	T
2N2917	S	N		2N2913	AM	0.3W	A	200	45	45	O	60	240	10*	0.35	1.0M			60M	T
2N2918	S	N		2N2913	AM	0.3W	A	200	45	45	O	150	600	10*	0.35	1.0M			60M	T
2N2919	S	N		2N2913	AM	0.3W	A	200	60	60	O	60	240	10*	0.35	1.0M			60M	T
2N2919A	S	N			A	300M	A	200	60	60	O						240	E	60M	T
2N2920	S	N		2N2913	AM	0.3W	A	200	60	60	O	150	600	10*	0.35	1.0M			60M	T
2N2920A	S	N			A	300M	A	200	60	60	O						600	E	60M	T
2N2921	S	N			A	0.2W	A	125	25	25	O						35	E		
2N2922	S	N	MPS6512	MPS6512	A	0.2W	A	125	25	25	O						55	E		
2N2923	S	N	MPS2923	MPS2923	A	0.2W	A	125	25	25	O						90	E		
2N2924	S	N	MPS2924	MPS2923	A	0.2W	A	125	25	25	O						150	E		
2N2925	S	N	MPS2925	MPS2923	A	0.2W	A	125	25	25	O						235	E		
2N2926	S	N	MPS2926	MPS2926	A	0.2W	A	125	18	18	O						35	E		
2N2927	S	P			S	800M	A	200	25	25	O	30	130	50M	0.25	50M	25	E	100M	T
2N2928	G	P			AH	150M	A	100	15	13	O	0.8	200	2.0M			0.10		400M	T
2N2929	G	P		2N2929	AH	750M	C	100	25	10	O	10	100	10M	0.5	50M	10	E	800M	T
2N2930	G	P	2N3427	2N3427	S	250M	A	100	30	12	O	60	420	10M	0.25	100M			4.0M	B
2N2931	S	N			A	50M	A	125	5.0	5.0	O	50		50M	0.45	50M	30	E	20M	T
2N2932	S	N			A	50M	A	125	5.0	5.0	O	70		50M	0.45	50M	70	E	20M	T
2N2933	S	N			A	50M	A	125	5.0	5.0	O	50		50M	0.45	50M	45	E	20M	T
2N2934	S	N			A	50M	A	125	45	30	O	50		50M	0.45	50M	30	E	20M	T
2N2935	S	N			A	50M	A	125	45	30	O	70		50M	0.45	50M	70	E	20M	T
2N2936	S	N			AP	300M	A	175	60	55	O	100	300	10*	0.3	2.0M	150	E	30M	T
2N2937	S	N			AP	300M	A	175	60	55	O	100	300	10*	0.3	2.0M	150	E	30M	T
2N2938	S	N			SH	300M	A	200	25	13	O	30		50M	0.4	50M			500M	T
2N2939	S	N			AHP	0.8W	A	300	75	60	O	60	240	0.15A	0.75	0.15A			150M	T
2N2940	S	N			AHP	0.8W	A	300	120	80	O	60	240	0.15A	0.75	0.15A			150M	T
2N2941	S	N			AHP	0.8W	A	200	150	100	O	60	240	0.15A					150M	T
2N2942	G	P			SH	150M	A	100	50	25	O	50		10M	0.15	10M			150M	T
2N2943	G	P			SH	150M	A	100	30	15	O	30		10M	0.2	10M			120M	T
2N2944	S	P		2N2944	SC	400M	A	175	15	10	O	80		1.0M					10M	T
2N2944A	S	P			SC	400M	A	200	15	10	O	100		1.0M					15M	T
2N2945	S	P		2N2944	SC	400M	A	175	25	20	O	40		1.0M					5.0M	T
2N2945A	S	P			SC	400M	A	200	25	20	O	100		1.0M					10M	T
2N2946	S	P		2N2944	SC	400M	A	175	40	35	O	30		1.0M					3.0M	T
2N2946A	S	P			SC	400M	A	200	40	35	O	50		1.0M					5.0M	T
2N2947	S	N		2N2947	AP	25W	C	175	60	60	S	2.5	55	0.4A	0.5	1.0A			100M	T
2N2948	S	N		2N2947	AP	25W	C	175	40	40	S	2.5	100	0.4A	0.5	1.0A			100M	T
2N2949	S	N		2N2949	AP	6.0W	C	175	60	60	S	5.0	100	40M	0.5	0.4A			100M	T
2N2950	S	N		2N2949	AP	6.0W	C	175	60	60	S	5.0	100	40M	0.5	0.4A			100M	T
2N2951	S	N		2N2951	AP	3.0W	C	175	60	60	S	20	150	10M	0.5	0.15A			200M	T
2N2952	S	N		2N2951	AP	1.8W	C	175	60	60	S	20	150	10M	0.5	0.15A			200M	T
2N2953	G	P	2N1194	2N1191	A	120M	A	100	30	25	R	100		50M			200	E		
2N2954	S	N			SH	200M	A	200	30	20	O	25	300	2.0M			25	E	300M	T
2N2955	G	P		2N2955	SH	0.15W	A	100	40			20	60	50M	0.2	10M			200M	T
2N2956	G	P		2N2955	SH	0.15W	A	100	40			40	120	50M	0.18	10M			250M	T
2N2957	G	P		2N2955	SH	0.15W	A	100	40			60		10M	0.15	10M			300M	T
2N2958	S	N		2N2958	SH	3.0W	C	200	60	20	O	40	120	150M	0.5	150M			250M	T
2N2959	S	N		2N2958	SH	3.0W	C	200	60	20	O	100	300	150M	0.5	150M			250M	T
2N2960	S	N			SH	3.0W	C	200	60	30	O	100	300	150M	0.5	150M			250M	T
2N2961	S	N			SH	3.0W	C	200	60	30	O	100	300	150M	0.5	150M			250M	T
2N2962	G	P			AP	350M	A	100	40	18	O								660M	T
2N2963	G	P			AP	350M	A	100	40	18	O								660M	T
2N2964	G	P			AP	350M	A	100	30	15	O								660M	T
2N2965	G	P			AHP	350M	A	100	30	15	O								660M	T
2N2966	G	P	2N3283	2N3283	AH	60M	A	100	20	20	O	8.0	100	3.0M					500M	T
2N2967	S	N			SH	300M	A	200	12	6.0	O	20	120	10M	0.3	3.0M			400M	T

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N2968	S	P			S	150M	A	140	30	10	O	15		100*	0.6	10M			8.0M	T
2N2969	S	P			S	150M	A	140	30	10	O	15		100*	0.6	10M			8.0M	T
2N2970	S	P			S	150M	A	140	30	20	O	10		100*	0.8	10M			4.0M	T
2N2971	S	P			S	150M	A	140	30	20	O	10		100*	0.8	10M			4.0M	T
2N2972	S	N		2N2913	AM	0.25W	A	200	45	45	O	60	240	10*	0.35	1.0M			60M	T
2N2973	S	N		2N2913	AM	0.25W	A	200	45	45	O	150	600	10*	0.35	1.0M			60M	T
2N2974	S	N		2N2913	AM	0.25W	A	200	45	45	O	60	240	10*	0.35	1.0M			60M	T
2N2975	S	N		2N2913	AM	0.25W	A	200	45	45	O	150	600	10*	0.35	1.0M			60M	T
2N2976	S	N		2N2913	AM	250M	A	200	45	45	O	60	240	10*	0.35	1.0M			60M	T
2N2977	S	N		2N2913	AM	250M	A	200	45	45	O	150	600	10*	0.35	1.0M			60M	T
2N2978	S	N		2N2913	AM	250M	A	200	60	60	O	60	240	10*	0.35	1.0M			60M	T
2N2979	S	N		2N2913	AM	0.25W	A	200	60	60	O	150	600	10*	0.35	1.0M			60M	T
2N2980	S	N	2N2060A	2N2060	AM	0.25W	A	200	100	60	O	25	75	10*	1.2	50M	50	E	60M	T
2N2981	S	N	2N2223	2N2060	AM	0.25W	A	200	100	60	O	50	200	10M	1.2	50M	40	E	50M	T
2N2982	S	N	2N2223A	2N2060	AM	0.25W	A	200	100	60	O	50	200	10M	1.2	50M	40	E	50M	T
2N2983	S	N			AP	1.0W	A	175	155	80	O	20	60	500M	0.6	1.0A	20	E	60M	T
2N2984	S	N			AP	1.0W	A	175	185	120	O	20	60	500M	0.8	200M	20	E	60M	T
2N2985	S	N			AP	1.0W	A	175	155	80	O	40	120	500M	0.8	200M	40	E	60M	T
2N2986	S	N			AP	1.0W	A	175	185	120	O	40	120	500M	0.8	200M	40	E	60M	T
2N2987	S	N			AP	1.0W	A	200	95	80	O	25	75	200M	0.8	200M	25	E	30M	T
2N2988	S	N			AP	1.0W	A	200	155	100	O	25	75	200M	0.8	200M	25	E	30M	T
2N2989	S	N			AP	1.0W	A	200	95	80	O	60	120	200M	0.8	200M	50	E	30M	T
2N2990	S	N			AP	1.0W	A	200	155	100	O	60	120	200M	0.8	200M	50	E	30M	T
2N2991	S	N			AP	2.0W	A	200	95	80	O	25	75	200M	0.8	200M	25	E	30M	T
2N2992	S	N			AP	2.0W	A	200	155	100	O	20		1.0M	0.8	200M	25	E	30M	T
2N2993	S	N			AP	2.0W	A	200	95	80	O	60	120	200M	0.8	200M	50	E	30M	T
2N2994	S	N			AP	2.0W	A	200	155	100	O	60	120	200M	0.8	200M	50	E	30M	T
2N2995	S	N			AHP	1.5W	A	175	120	100	O	25	90	0.2A	1.7	0.2A	30	E	10M	T
2N2996	G	P			AH	75M	A	100	15	10	O	25	500	4.0M			35	E	400M	T
2N2997	G	P			AH	75M	A	100	30	15	O	40	500	4.0M			50	E	400M	T
2N2998	G	P			AH	75M	A	100	15	12	O	15	300	3.0M			20	E	600M	T
2N2999	G	P	2N3283	2N3283	AH	75M	A	100	15	10	O	10		3.0M			15	E	1.4G	T
2N3001 thru 2N3008	Thyristors, see Table on Page 164																			
2N3009	S	N		2N3009	SH	360M	A	200	40	15	O	30	120	30M	0.18	30M			350M	T
2N3010	S	N		2N3010	SH	300M	A	200	15	6.0	O	25	125	10M	0.25	10M			600M	T
2N3011	S	N		2N3011	SH	360M	A	200	30	12	O	30	120	10M	0.2	10M			400M	T
2N3012	S	P	MM2894	MM2894	S	360M	A	200	12	12	O	30	120	30M	0.15	10M			400M	T
2N3013	S	N		2N3009	SH	360M	A	200	40	15	O	30	120	30M	0.18	30M			350M	T
2N3014	S	N		2N3009	SH	360M	A	200	40	20	O	30	120	30M	0.18	10M			350M	T
2N3015	S	N		2N3013	SH	800M	A	200	60	30	O	30	120	150M	0.4	150M			250M	T
2N3016	S	N			AHP	3.33W	C	150	100	50	O	60	150	1.0A	0.75	1.0A			200M	T
2N3017	S	N			AHP	3.33W	C	150	100	50	O	60	150	1.0A	0.75	5.0A			200M	T
2N3018	S	N			AHP	25W	C	150	100	50	O	60	150	1.0A	0.75	5.0A			200M	T
2N3019	S	N		2N3019	AH	0.8W	A	200	140	80	O	100	300	0.15A	0.2	0.15A	80	E	100M	T
2N3020	S	N		2N3019	AH	0.8W	A	200	140	80	O	40	120	0.15A	0.2	0.15A	30	E	80M	T
2N3021	S	P		2N3021	SHP	25W	C	175	30	30	O	20	60	1.0A	1.5	3.0A			60M	T
2N3022	S	P		2N3021	SHP	25W	C	175	45	45	O	20	60	1.0A	1.5	3.0A			60M	T
2N3023	S	P		2N3021	SHP	25W	C	175	60	60	O	20	60	1.0A	1.5	3.0A			60M	T
2N3024	S	P		2N3021	SHP	25W	C	175	30	30	O	50	180	1.0A	1.0	3.0A			60M	T
2N3025	S	P		2N3021	SHP	25W	C	175	45	45	O	50	180	1.0A	1.0	3.0A			60M	T
2N3026	S	P		2N3021	SHP	25W	C	175	60	60	O	50	180	1.0A	1.0	3.0A			60M	T
2N3027 thru 2N3032	Thyristors, see Table on Page 164																			
2N3033	S	N			AL	300M	A	175	100	100	R				1.0	100M				
2N3034	S	N			AL	300M	A	175	70	70	R				1.0	100M				
2N3035	S	N			AL	300M	A	175	50	50	R				1.0	100M				
2N3036	S	N			A	800M	A	200	120	80	O	50	150	150M	0.25	150M	40	E	50M	T
2N3037	S	N			A	360M	A	175	120	70	O	40	120	150M	0.2	10M	30	E	50M	T
2N3038	S	N			A	360M	A	175	100	60	O	80	240	150M	0.2	10M	60	E	50M	T
2N3039	S	P			A	360M	A	175	50	35	O	20	80	150M			20	E	50M	T
2N3040	S	P			A	360M	A	175	40	30	O	40	160	150M	0.2	10M	40	E	50M	T
2N3043	S	N		2N3043	AM	250M	A	200	45	45	O	100	300	10*	1.0	10M	130	E	30M	T
2N3044	S	N		2N3043	AM	250M	A	200	45	45	O	100	300	10*	1.0	10M	130	E	30M	T
2N3045	S	N		2N3043	A	250M	A	200	45	45	O	100	300	10*	1.0	10M	130	E	30M	T
2N3046	S	N		2N3043	AM	250M	A	200	45	45	O	50	200	10*	1.0	10M	65	E	30M	T
2N3047	S	N		2N3043	AM	250M	A	200	45	45	O	50	200	10*	1.0	10M	65	E	30M	T
2N3048	S	N		2N3043	A	250M	A	200	45	45	O	50	200	10*	1.0	10M	65	E	30M	T
2N3049	S	P		2N3049	AM	250M	A	200	25	20	O	20	120	10*	0.2	10M	30	E	60M	T
2N3050	S	P		2N3049	AM	250M	A	200	25	20	O	20	120	10*	0.2	10M	30	E	60M	T
2N3051	S	P			A	250M	A	175	25	20	O	20	120	10*	0.2	10M	30	E	60M	T
2N3052	S	N			SH	250M	A	175	35	15	O	25	130	10M	0.25	10M			200M	T
2N3053	S	N		2N3053	SH	5.0W	C	200	60	40	O	50	250	0.15A	1.4	0.15A			100M	T
2N3054	S	N			AP	25W	C	200	90	60	R	25	100	0.5A	1.0	0.5A	25	E	30K	E
2N3055	S	N		2N3055	AP	115W	C	200	100	70	R	20	70	4.0A	1.1	4.0A	15	E	20K	E
2N3055A	S	N			AP	175W	C	200	100	70	R	20	70	4.0A	0.8	4.0A	30	E		
2N3056	S	N			AH	0.4W	A	200	100	60	O	40	120	0.15A	0.25	0.15A	30	E	80M	T
2N3056A	S	N			AH	0.4W	A	200	140	80	O	40	120	0.15A	0.2	0.15A	30	E	80M	T
2N3057	S	N			AH	0.4W	A	200	100	60	O	100	300	0.15A	0.25	0.15A	80	E	100M	T
2N3057A	S	N			AH	0.4W	A	200	140	80	O	100	300	0.15A	0.2	0.15A	80	E	100M	T
2N3058	S	P			A	400M	A	200	6.0	6.0	O	40	120	100N			40	E		
2N3059	S	P			A	400M	A	200	10	10	O	100	300	10*			100	E		
2N3060	S	P			A	400M	A	200	70	60	O	30	90	1.0M			30	E		
2N3061	S	P			A	400M	A	200	70	60	O	60	180	1.0M			60	E		
2N3062	S	P			A	400M	A	200	90	80	O	20	80	1.0M			20	E		
2N3063	S	P			A	400M	A	200	90	80	O	50	150	1.0M			50	E		
2N3064	S	P			A	400M	A	200	110	100	O	15	45	1.0M			15	E		

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N3065	S	P			A	400M	A	200	110	100	O	30	90	1.0M			30	E		
2N3066,A thru 2N3071	Field-Effect Transistors, see Table on Page 176																			
2N3072	S	P			S	800M	A	200	60	60	O	30	130	50M	0.25	50M	25	E	130M	T
2N3073	S	P			S	360M	A	200	60	60	O	30	130	50M	0.25	50M	25	E	130M	T
2N3074	G	P			AH	0.14W	A	85	30	25	S	25	300	3.5M						
2N3075	G	P			AH	0.14W	A	85	35	25	S	20	250	3.0M						
2N3076	S	N			SHP	125W	C	175	140	50	O	30	90	7.0A	1.0	10A	60	E	50M	T
2N3077	S	N			A	0.36W	A	200	80	60	O	100	400	10*	0.35	1.0M	120	E	15M	T
2N3078	S	N			A	0.36W	A	200	80	60	O	40	120	10*	0.35	1.0M	50	E	15M	T
2N3079	S	N			SP	178W	C	150	200	200	O	7.0	40	5.0A	0.7	5.0A			30K	E
2N3080	S	N			SP	178W	C	150	300	300	O	7.0	40	5.0A	0.7	5.0A			30K	E
2N3081	S	P			SH	600M	A	200	70	50	O	20		500M	0.3	150M			150M	T
2N3082	S	N			SC	0.5W	A	200	25	7.0	O	100		0.25M					100M	T
2N3083	S	N			SC	0.5W	A	200	25	7.0	O	100		0.25M					100M	T
2N3084 thru 2N3089,A	Field-Effect Transistors, see Table on Page 176																			
2N3091 thru 2N3106	Thyristors, see Table on Page 164																			
2N3107	S	N			S	0.8W	A	200	100	60	O	100	300	0.15A	1.0	1.0A	60	E	70M	T
2N3108	S	N			S	800M	A	200	100	60	O	40	120	150M	0.25	150M			60M	T
2N3109	S	N			S	0.8W	A	200	80	40	O	100	300	0.15A	1.0	1.0A	60	E	70M	T
2N3110	S	N	2N2218A	2N2218A	S	800M	A	200	80	40	O	40	120	150M	0.25	150M			60M	T
2N3112 2N3113	Field-Effect Transistors, see Table on Page 176																			
2N3114	S	N		2N3114	AH	800M	A	200	150	150	O	30	120	30M	1.0	50M	25	E	40M	T
2N3115	S	N		2N2958	SH	0.4W	A	200	60	20	O	40	120	0.15A	0.5	0.15A			250M	T
2N3116	S	N		2N2958	SH	0.4W	A	200	60	20	O	100	300	0.15A	0.5	0.15A			250M	T
2N3117	S	N			A	360M	A	200	60	60	O	250	500	10*	0.35	1.0M	400	E	60M	T
2N3118	S	N			AH	1.0W	A	200	85	60	O	50	275	25M					250M	T
2N3119	S	N			SH	1.0W	A	200	100	80	O	50	200	100M	0.5	100M			250M	T
2N3120	S	P	2N2800	2N2800	S	800M	A	200	45	45	O	30	130	50M	0.25	50M	25	E	130M	T
2N3121	S	P	2N2837	2N2800	S	360M	A	200	45	45	O	30	130	50M	0.25	50M	25	E	130M	T
2N3122	S	N			A	800M	A	200	50	30	O	25	100	300M	1.5	300M			60M	T
2N3123	S	N			SH	0.8W	A	175	60	30	O	100	300	0.15A	0.4	0.15A			400M	T
2N3124	G	P			AP	90W	C	100	40	30	S	50	100	10A	0.5	10A	20	E	2.5K	E
2N3125	G	P			AP	90W	C	100	80	80	S	30	75	3.0A	1.5	3.0A	10	E	5.0K	E
2N3126	G	P			AP	90W	C	100	100	75	S	10	30	10A	1.0	10A	10	E	6.0K	E
2N3127	G	P		2N3127	AH	0.1W	A	100	30	20	O	20	75	3.0M	0.3	5.0M	20	E	400M	T
2N3128	S	N			A	0.15W	A	150	20	20	O	50	150	0.1M	0.25	1.0M	75	E	60M	T
2N3129	S	N			A	0.15W	A	150	45	45	O	100	300	10N	0.25	1.0M	160	E	60M	T
2N3130	S	N			A	0.15W	A	150	60	60	O	60	180	10N	0.25	1.0M	110	E	60M	T
2N3131	S	N			SH	0.15W	A	150	40	15	O	30	120	10M	0.25	10M			250M	T
2N3132	G	P			SP	90W	C	100	100	70	S	40	200	2.0A	1.5	5.0A			3.0K	E
2N3133	S	P		2N3133	SH	0.6W	A	200	50	35	O	40	120	0.15A	0.6	0.15A			200M	T
2N3134	S	P		2N3133	SH	0.6W	A	200	50	35	O	100	300	0.15A	0.6	0.15A			200M	T
2N3135	S	P		2N3133	SH	0.4W	A	200	50	35	O	40	120	0.15A	0.6	0.15A			200M	T
2N3136	S	P		2N3133	SH	0.4W	A	200	50	35	O	100	300	0.15A	0.6	0.15A			200M	T
2N3137	S	N		2N3137	AH	600M	A	200	40	20	O				0.3	50M			500M	T
2N3138	S	N	2N3766	2N3766	AHP	20W	C	200	65	65	O	10		1.0A					100M	T
2N3139	S	N			AHP	20W	C	200	140	140	O	10		1.0A					100M	T
2N3140	S	N			AHP	20W	C	200	65	65	O	10		1.0A					100M	T
2N3141	S	N			AHP	20W	C	200	140	140	O	10		1.0A					100M	T
2N3142	S	N			AHP	25W	C	200	65	65	O	10		1.0A					100M	T
2N3143	S	N			AHP	25W	C	200	140	140	O	10		1.0A					100M	T
2N3144	S	N			AHP	25W	C	200	65	65	O	10		1.0A					100M	T
2N3145	S	N			AHP	25W	C	200	140	140	O	10		1.0A					100M	T
2N3146	G	P	2N3616	2N3615	AP	150W	C	100	150	140	V	30	90	5.0A	0.4	5.0A	20	E	200K	T
2N3147	G	P	2N3616	2N3615	AP	150W	C	100	180	160	V	30	90	5.0A	0.4	5.0A	20	E	200K	T
2N3148	G	P			S	0.45M	A	100	11	6.0	O	70		20M	0.2	50M	80	E	25M	T
2N3149	S	N			SP	300W	C	200	80	80	O	10		50A	1.5	50A			0.1M	T
2N3150	S	N			SP	300W	C	200	100	100	O	10		50A	1.5	50A			0.1M	T
2N3151	S	N			SP	300W	C	200	150	150	O	10		50A	1.5	50A			0.1M	T
2N3152	S	N			SH	25M	C	200	120	120	O	40		30M			20	E	200M	T
2N3153	S	N			SC	0.3W	A	200	15	15	O								30M	T
2N3154	G	P			SP	37.5W	C	100	40	25	O	60	180	0.5A	1.1	3.0A			15K	E
2N3155	G	P			SP	37.5W	C	100	60	40	O	60	180	0.5A	1.1	3.0A			15K	E
2N3156	G	P			SP	37.5W	C	100	80	55	O	60	180	0.5A	1.1	3.0A			15K	E
2N3157	G	P			SP	37.5W	C	100	100	65	O	60	180	0.5A	1.1	3.0A			15K	E
2N3158	G	P			SP	37.5W	C	100	40	25	O	30	75	0.5A	1.4	3.0A			10K	E
2N3159	G	P			SP	37.5W	C	100	60	40	O	30	75	0.5A	1.4	3.0A			10K	E
2N3160	G	P			SP	37.5W	C	100	80	55	O	30	75	0.5A	1.4	3.0A			10K	E
2N3161	G	P			SP	37.5W	C	100	100	65	O	30	75	0.5A	1.4	3.0A			10K	E
2N3162	S	N	2N3411	2N3409	AM	300M	A	200	45	25	O	50	200	10M	0.5	10M			300M	T
2N3163	S	P			AHP	85W	C	200	40	40	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T
2N3164	S	P			AHP	85W	C	200	60	60	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T
2N3165	S	P			AHP	85W	C	200	80	80	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T
2N3166	S	P			AHP	85W	C	200	100	100	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T
2N3167	S	P	MJ2267	MJ2267	AHP	85W	C	200	40	40	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T
2N3168	S	P	2N3789	2N3789	AHP	85W	C	200	60	60	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T
2N3169	S	P	2N3790	2N3789	AHP	85W	C	200	80	80	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T
2N3170	S	P	2N3790	2N3789	AHP	85W	C	200	100	100	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T
2N3171	S	P			AHP	75W	C	200	40	40	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T
2N3172	S	P			AHP	75W	C	200	60	60	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T
2N3173	S	P			AHP	75W	C	200	80	80	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N3174	S	P			AHP	75W	C	200	100	100	O	12	36	1.0A	0.75	1.0A	10	E	1.0M	T
2N3175	S	P	MJ2267	MJ2267	AHP	85W	C	200	40	40	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3176	S	P	2N3789	2N3789	AHP	85W	C	200	60	60	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3177	S	P	2N3790	2N3789	AHP	85W	C	200	80	80	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3178	S	P	2N3790	2N3789	AHP	85W	C	200	100	100	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3179	S	P	MJ2267	MJ2267	AHP	85W	C	200	40	40	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3180	S	P	2N3789	2N3789	AHP	85W	C	200	60	60	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3181	S	P	2N3790	2N3789	AHP	85W	C	200	80	80	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3182	S	P	2N3790	2N3789	AHP	85W	C	200	100	100	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3183	S	P			AHP	75W	C	200	40	40	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3184	S	P			AHP	75W	C	200	60	60	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3185	S	P			AHP	75W	C	200	80	80	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3186	S	P			AHP	75W	C	200	100	100	O	10	30	2.0A	1.0	2.0A	10	E	1.0M	T
2N3187	S	P	MJ2267	MJ2267	AHP	85W	C	200	40	40	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3188	S	P	2N3789	2N3789	AHP	85W	C	200	60	60	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3189	S	P	2N3790	2N3789	AHP	85W	C	200	80	80	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3190	S	P	2N3790	2N3789	AHP	85W	C	200	100	100	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3191	S	P			AHP	85W	C	200	40	40	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3192	S	P	2N3789	2N3789	AHP	85W	C	200	60	60	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3193	S	P	2N3790	2N3789	AHP	85W	C	200	80	80	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3194	S	P	2N3790	2N3789	AHP	85W	C	200	100	100	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3195	S	P			AHP	75W	C	200	40	40	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3196	S	P			AHP	75W	C	200	60	60	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3197	S	P			AHP	75W	C	200	80	80	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3198	S	P			AHP	75W	C	200	100	100	O	10	30	3.0A	0.9	3.0A	10	E	1.0M	T
2N3199	S	P			AHP	40W	C	200	40	40	O	20	60	1.0A	0.3	1.0A	10	E	1.0M	T
2N3200	S	P	2N3740	2N3740	AHP	40W	C	200	60	60	O	20	60	1.0A	0.3	1.0A	10	E	1.0M	T
2N3201	S	P	2N3741	2N3740	AHP	40W	C	200	80	80	O	20	60	1.0A	0.3	1.0A	10	E	1.0M	T
2N3202	S	P			AHP	8.8W	C	200	40	40	O	20	60	1.0A	0.3	1.0A	10	E	1.0M	T
2N3203	S	P	2N3740	2N3740	AHP	8.8W	C	200	60	60	O	20	60	1.0A	0.3	1.0A	10	E	1.0M	T
2N3204	S	P	2N3741	2N3740	AHP	8.8W	C	200	80	80	O	20	60	1.0A	0.3	1.0A	10	E	1.0M	T
2N3205	S	P			AHP	40W	C	200	40	40	O	20	60	0.5A	0.4	0.5A	10	E	1.0M	T
2N3206	S	P	2N3740	2N3740	AHP	40W	C	200	60	60	O	20	60	0.5A	0.4	0.5A	10	E	1.0M	T
2N3207	S	P	2N3741	2N3740	AHP	40W	C	200	100	100	O	20	60	0.5A	0.4	0.5A	10	E	1.0M	T
2N3208	S	P	2N3740	2N3740	AHP	8.8W	C	200	40	40	O	20	60	0.5A	0.4	0.5A	10	E	1.0M	T
2N3209	S	P	MM2894	MM2894	S	0.36W	A	200	20	20	O	30	120	30M	0.2	30M			400M	T
2N3210	S	N		2N3210	SH	0.36W	A	200	40	15	O	30	120	10M	0.75	0.2A			300M	T
2N3211	S	N		2N3211	SH	0.36W	A	200	40	15	O	50	150	10M	0.2	10M			350M	T
2N3212	G	P			AP	14W	C	110	100	80	O	30	90	3.0A	0.5	5.0A	3.0	E		
2N3213	G	P			AP	14W	C	110	80	60	O	30	90	3.0A	0.5	5.0A	3.0	E		
2N3214	G	P			AP	14W	C	110	60	40	O	30	90	3.0A	0.5	5.0A	3.0	E		
2N3215	G	P			AP	14W	C	110	40	30	O	25	100	3.0A	0.5	5.0A	3.0	E		
2N3216	G	P			S	150M	A	100	20	10	O	60		200M	0.22	200M			10M	T
2N3217	S	P			SC	400M	A	200	15	10	O								1.0M	T
2N3218	S	P			SC	400M	A	200	25	20	O								1.0M	T
2N3219	S	P			SC	400M	A	200	40	35	O								1.0M	T
2N3220	S	N	2N3767	2N3766	AHP	6.0W	C	175	100	80	O	20	60	1.0A	1.25	1.0A	20	E	10M	T
2N3221	S	N	2N3767	2N3766	AHP	6.0W	C	175	100	80	O	40	120	1.0A	1.25	1.0A	40	E	10M	T
2N3222	S	N	2N3766	2N3766	AHP	6.0W	C	175	80	60	O	20	60	1.0A	1.25	1.0A	20	E	10M	T
2N3223	S	N	2N3766	2N3766	AHP	6.0W	C	175	80	60	O	40	120	1.0A	1.25	1.0A	40	E	10M	T
2N3224	S	P	2N3498	2N3498	AH	0.7W	A	200	100	100	O	20	60	50M			20	E	60M	T
2N3225	S	P	2N3498	2N3498	AH	0.7W	A	200	100	100	O	40	120	50M			40	E	80M	T
2N3226	S	N	2N4913	2N4913	AP	75W	C	200	35	35	O	20	50	2.0A	1.2	2.7A	20	E	30K	E
2N3227	S	N		2N2369	SH	0.36W	A	200	40	20	O	100	300	10M	0.25	10M			500M	T
2N3228	Thyristors, see Table on Page 164																			
2N3229	S	N			AHP	17.5W	C	200	105	60	O	5.0		2.5A	1.0	2.5A			150M	T
2N3230	S	N			SHP	25W	C	200	80	60	O	2K	20K	2.0A	1.4	2.0A			40M	T
2N3231	S	N			SHP	25W	C	200	100	80	O	2K	20K	2.0A	1.4	2.0A			40M	T
2N3232	S	N		2N3232	AHP	117W	C	200	80	60	O	18	55	3.0A	2.5	3.0A	10	E	1.0M	E
2N3233	S	N			AHP	117W	C	200	110	100	O	18	55	3.0A	2.5	3.0A	10	E	1.0M	E
2N3234	S	N			AHP	117W	C	200	160	160	O	18	55	3.0A	2.5	3.0A	10	E	1.0M	E
2N3235	S	N		2N3232	AHP	117W	C	200	65	55	O	20	70	4.0A	1.1	4.0A	10	E	1.0M	E
2N3236	S	N	2N3716	2N3713	AHP	150W	C	200	90	90	O	17	60	5.0A	1.1	5.0A	10	E	1.0M	E
2N3237	S	N			AHP	200W	C	200	90	75	O	12	36	10A	2.0	10A	10	E	1.0M	E
2N3238	S	N	2N3716	2N3713	AHP	150W	C	200	80	80	O	8.5	25	10A	3.0	10A	10	E	1.0M	E
2N3239	S	N	2N3716	2N3713	AHP	150W	C	200	80	80	O	8.5	25	10A	1.0	10A	10	E	1.0M	E
2N3240	S	N			AHP	150W	C	200	160	160	O	8.5	25	10A	1.0	10A	10	E	1.0M	E
2N3241	S	N			A	0.5W	A	175	30	25	O	50	300	10M			70	E	50M	T
2N3241A	S	N			A	500M	A	175	30	25	O						175	E	100M	T
2N3242	S	N			A	0.5W	A	175	30	25	O	75		10M			100	E	50M	T
2N3242A	S	N			A	500M	A	175	40	40	O						200	E	100M	T
2N3244	S	P		2N3227	SH	1.0W	A	200	40	40	O	50	150	0.5A	0.3	0.15A			175M	T
2N3245	S	P		2N3227	SH	1.0W	A	200	50	50	O	30	90	0.5A	0.35	0.15A			150M	T
2N3246	S	N			SH	0.35W	A	200	60	45	O	200	600	10*	0.5	5.0M	200	E	60M	T
2N3247	S	N			SH	0.15W	A	150	60	45	O	200	600	10*	0.5	5.0M	200	E	60M	T
2N3248	S	P		2N3248	SH	0.36W	A	200	15	12	O	50	150	0.1M	0.125	10M			250M	T
2N3249	S	P		2N3248	SH	0.36W	A	200	15	12	O	100	300	0.1M	0.125	10M			300M	T
2N3250	S	P		2N3250	SH	0.36W	A	200	50	40	O	50	150	10M	0.25	10M	50	E	250M	T
2N3250A	S	P		2N3250	SH	0.36W	A	200	60	60	O	50	150	10M	0.25	10M	50	E	250M	T
2N3251	S	P		2N3250	SH	0.36W	A	200	50	40	O	100	300	10M	0.25	10M	100	E	300M	T
2N3251A	S	P		2N3250	SH	0.36W	A	200	60	60	O	100	300	10M	0.25	10M	100	E	300M	T
2N3252	S	N		2N3252	SH	1.0W	A	200	60	30	O	30	90	0.5A	0.3	0.15A			200M	T
2N3253	S	N		2N3252	SH	1.0W	A	200	75	40	O	25	75	375M	0.35	0.15A			175M	T
2N3254 thru 2N3259	Thyristors, see Table on Page 164																			
2N3260	S	N			SP	200W	C	200	200	200	O	10	40	20A	1.5	20A			0.6M	T
2N3261	S	N			SH	0.3W	A	175	40	15	O	40	150	10M	0.35	0.1A			600M	T

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N3262	S	N			SH	8.75W	C	200	100	80	O	40		0.5A	0.6	1.0A			150M	T
2N3263	S	N			SP	75W	C	200	150	90	O	20	55	15A	1.0	20A			20M	T
2N3264	S	N			SP	75W	C	200	120	60	O	20	80	15A	1.6	20A			20M	T
2N3265	S	N			SP	125W	C	200	150	90	O	20	55	15A	1.0	20A			20M	T
2N3266	S	N			SP	125W	C	200	120	60	O	20	80	15A	1.6	20A			20M	T
2N3267	G	P			AH	75M	A	100	15	8.0	O	10	500	3.0M			15	E	900M	T
2N3268	S	N			A	0.15W	A	200	45	45	O	12	80	10M	1.0	5.0M	40	E	2.5M	B
2N3269 thru 2N3276	Thyristors, see Table on Page 164																			
2N3277 2N3278	Field-Effect Transistors, see Table on Page 176																			
2N3279	G	P		2N3279	AH	0.1W	A	100	30	20	O	10	70	3.0M	0.3	5.0M	10	E	400M	T
2N3280	G	P		2N3279	AH	0.1W	A	100	30	20	O	10	70	3.0M	0.3	5.0M	10	E	400M	T
2N3281	G	P		2N3279	AH	0.1W	A	100	30	15	O	10	100	3.0M	0.5	5.0M	10	E	300M	T
2N3282	G	P		2N3279	AH	0.1W	A	100	30	15	O	10	100	3.0M	0.5	5.0M	10	E	300M	T
2N3283	G	P		2N3283	AH	0.1W	A	100	25	25	S	10		3.0M			10	E	250M	T
2N3284	G	P		2N3283	AH	0.1W	A	100	25	25	S	10		3.0M			10	E	250M	T
2N3285	G	P		2N3283	AH	0.1W	A	100	20	20	S	5.0		3.0M			5.0	E	250M	T
2N3286	G	P		2N3283	AH	0.1W	A	100	20	20	S	5.0		3.0M			5.0	E	250M	T
2N3287	S	N		2N3287	AH	0.2W	A	200	40	20	O	15	100	2.0M	0.3	5.0M	15	E	350M	T
2N3288	S	N		2N3287	AH	0.2W	A	200	40	20	O	15	100	2.0M	0.3	5.0M	15	E	350M	T
2N3289	S	N		2N3287	AH	0.2W	A	200	30	15	O	10	150	2.0M	0.4	5.0M	10	E	300M	T
2N3290	S	N		2N3287	AH	0.2W	A	200	30	15	O	10	150	2.0M	0.4	5.0M	10	E	300M	T
2N3291	S	N		2N3291	AH	0.2W	A	200	25	25	S	10		2.0M			10	E	250M	T
2N3292	S	N		2N3291	AH	0.2W	A	200	25	25	S	10		2.0M			10	E	250M	T
2N3293	S	N		2N3291	AH	0.2W	A	200	20	20	S	10		2.0M			10	E	250M	T
2N3294	S	N		2N3291	AH	0.2W	A	200	20	20	S	10		2.0M			10	E	250M	T
2N3295	S	N		2N3295	AHP	800M	A	175	60	60	S	20	60	10M	0.5	0.15A			200M	T
2N3296	S	N		2N3296	AHP	700M	A	175	60	60	S	5.0	50	40M	0.5	0.4A			100M	T
2N3297	S	N		2N3297	AHP	25W	C	175	60	60	S	2.5	35	0.4A	0.5	1.0A			100M	T
2N3298	S	N		2N3298	AHP	1.0W	C	175	25	15	O	80	240	10M					200M	T
2N3299	S	N		2N3299	SH	0.8W	A	200	60	30	O	40	120	0.15A	0.22	0.15A			250M	T
2N3300	S	N		2N3299	SH	0.8W	A	200	60	30	O	100	300	0.15A	0.22	0.15A			250M	T
2N3301	S	N		2N3299	SH	0.36W	A	200	60	30	O	40	120	0.15A	0.22	0.15A			250M	T
2N3302	S	N		2N3299	SH	0.36W	A	200	60	30	O	100	300	0.15A	0.22	0.15A			250M	T
2N3303	S	N		2N3303	SH	0.6W	A	200	25	12	O	30	120	0.3A	0.33	0.3A			450M	T
2N3304	S	P		2N3304	S	0.3W	A	200	6.0	6.0	O	30	120	10M	0.16	10M			500M	T
2N3305	S	P			A	0.6W	A	200	50	40	O	40	120	0.1M	0.2	10M	40	E	20M	T
2N3306	S	P			A	0.6W	A	200	50	40	O	100	300	0.1M	0.2	10M	70	E	20M	T
2N3307	S	P		2N3307	AH	0.2W	A	200	40	35	O	40	250	2.0M	0.4	3.0M	40	E	300M	T
2N3308	S	P		2N3307	AH	0.2W	A	200	30	25	O	25	250	2.0M	0.4	3.0M	25	E	300M	T
2N3309	S	N	2N3553	2N3375	AHP	3.5W	C	175	50	50	S	5.0	100	30M	0.5	0.25A			300M	T
2N3309A	S	N	2N3553	2N3375	AHP	5.0W	C	200	60	60	S	8.0	80	50M	0.5	0.25A			300M	T
2N3310	S	N			AHP	0.3W	A	200	35	15	O	10		20M	0.5	20M			300M	T
2N3311	G	P		2N3311	AP	170W	C	110	30	30	S	60	120	3.0A	0.1	3.0A	30	E	1.0K	E
2N3312	G	P		2N3311	AP	170W	C	110	45	45	S	60	120	3.0A	0.1	3.0A	30	E	1.0K	E
2N3313	G	P		2N3311	AP	170W	C	110	60	60	S	60	120	3.0A	0.1	3.0A	30	E	1.0K	E
2N3314	G	P		2N3311	AP	170W	C	110	30	30	S	100	200	3.0A	0.1	3.0A	40	E	1.0K	E
2N3315	G	P		2N3311	AP	170W	C	110	45	45	S	100	200	3.0A	0.1	3.0A	40	E	1.0K	E
2N3316	G	P		2N3311	AP	170W	C	110	60	60	S	100	200	3.0A	0.1	3.0A	40	E	1.0K	E
2N3317	S	P			SC	0.15W	A	140	30	30	O								6.4M	T
2N3318	S	P			SC	0.15W	A	140	15	15	O								7.6M	T
2N3319	S	P			SC	0.15W	A	140	10	6.0	O								12M	T
2N3320	G	P			SH	60M	A	100	15	10	O	50		20M	0.19	40M			600M	T
2N3321	G	P			SH	60M	A	100	12	7.0	O	100		10M	0.12	10M			600M	T
2N3322	G	P			SH	60M	A	100	12	7.0	O	30		40M	0.25	20M			600M	T
2N3323	G	P		2N3323	AH	0.15W	A	100	35	35	S	30	200	3.0M			30	E	200M	T
2N3324	G	P		2N3323	AH	0.15W	A	100	35	35	S	30	200	3.0M			30	E	200M	T
2N3325	G	P		2N3323	AH	0.15W	A	100	35	35	S	30	200	3.0M			30	E	200M	T
2N3326	S	N	2N2218A	2N2218A	SH	0.8W	A	175	60	45	O	40	120	0.15A	0.4	0.15A			250M	T
2N3327	S	N			AHP	20W	C	200	65	65	O	10		0.5A					100M	T
2N3328 thru 2N3336	Field-Effect Transistors, see Table on Page 176																			
2N3337	S	N	2N3287	2N3287	AH	0.3W	A	200	40	40	O	30	300	4.0M			30	E	400M	T
2N3338	S	N	2N3289	2N3287	AH	0.3W	A	200	40	40	O	30	300	4.0M			30	E	400M	T
2N3339	S	N	2N3288	2N3287	AH	0.3W	A	200	40	40	O	30	300	4.0M			30	E	400M	T
2N3340	S	N			S	0.4W	A	175	30	20	O	40		10*	0.2	10*			70M	T
2N3341	S	P			S	0.4W	A	175	30	20	O	40		10*	0.25	10*			50M	T
2N3342	S	P			S	0.25W	A	175	20	8.0	O	30		5.0M	0.1	5.0M				
2N3343	S	P			SC	0.25W	A	175	25	8.0	O	20		0.25M					2.0M	T
2N3344	S	P			SC	0.25W	A	175	30	30	O	25		1.0M					2.0M	T
2N3345	S	P			SC	0.25W	A	175	50	50	O	15		1.0M					2.0M	T
2N3346	S	P			SC	0.25W	A	175	50	50	O	25		1.0M					2.0M	T
2N3347	S	P			AM	300M	A	175	60	45	O	40	300	10*	0.5	10M	60	E	60M	T
2N3348	S	P			AM	300M	A	175	60	45	O	40	300	10*	0.5	10M	60	E	60M	T
2N3349	S	P			AM	300M	A	175	60	45	O	40	300	10*	0.5	10M	60	E	60M	T
2N3350	S	P			AM	300M	A	175	60	45	O	100	300	10*	0.5	10M	150	E	60M	T
2N3351	S	P			AM	300M	A	175	60	45	O	100	300	10*	0.5	10M	150	E	60M	T
2N3352	S	P			AM	300M	A	175	60	45	O	100	300	10*	0.5	10M	150	E	60M	T
2N3353 thru 2N3364	Thyristors, see Table on Page 164																			
2N3365 thru 2N3370	Field-Effect Transistors, see Table on Page 176																			
2N3371	G	P			AH	150M	A	100	25	10	O	20	300	12M			25	E	320M	T

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N3374	S	N			AHP	5.0W	C	200	80	80	O	10		0.17A	0.3	0.15A			230M	T
2N3375	S	N		2N3375	AHP	11.6W	C	200	65	40	O	10	100	0.25A	1.0	0.25A			400M	T
2N3376 thru 2N3387	Field-Effect Transistors, see Table on Page 176																			
2N3388	S	N			S	0.6W	A	175	125	100	O	60		2.5M	1.0	2.5M			36M	T
2N3389	S	N			S	0.6W	A	175	195	160	O	60		7.0M	1.0	7.0M			36M	T
2N3390	S	N	MPS6521	MPS6512	A	0.2W	A	125	25	25	O	400	800	2.0M			400	E		
2N3391	S	N	MPS6515	MPS6512	A	0.2W	A	125	25	25	O	250	500	2.0M			250	E		
2N3391A	S	N	MPS6520	MPS6512	A	0.2W	A	125	25	25	O	250	500	2.0M			250	E		
2N3392	S	N	MPS3392	MPS3392	A	0.2W	A	125	25	25	O	150	300	2.0M			150	E		
2N3393	S	N	MPS3393	MPS3392	A	0.2W	A	125	25	25	O	90	180	2.0M			90	E		
2N3394	S	N	MPS3394	MPS3392	A	0.2W	A	125	25	25	O	55	110	2.0M			55	E		
2N3395	S	N	MPS3395	MPS3392	A	0.2W	A	125	25	25	O	150	500	2.0M			150	E		
2N3396	S	N	MPS3396		A	0.2W	A	125	25	25	O	90	500	2.0M			90	E		
2N3397	S	N	MPS3397		A	0.2W	A	125	25	25	O	55	500	2.0M			55	E		
2N3398	S	N	MPS3398		A	0.2W	A	125	25	25	O	55	800	2.0M			55	E		
2N3399	G	P			AH	80M	A	100	20			10		1.5M					400M	T
2N3400	G	P			SH	0.15W	A	100	20	20	O	50	300	10M	0.15	10M			150M	T
2N3401	S	P			SC	0.25W	A	150	25	25	O				0.25	5.0M	4.0	E	0.1M	B
2N3402	S	N	MPS6513	MPS6512	A	0.56W	A	150	25	25	O	75	225	2.0M	0.3	50M	75	E		
2N3403	S	N	MPS6515	MPS6512	A	0.56W	A	150	25	25	O	180	540	2.0M	0.3	50M	180	E		
2N3404	S	N			A	0.56W	A	150	50	50	O	75	225	2.0M	0.3	50M	75	E		
2N3405	S	N			A	0.56W	A	150	50	50	O	180	540	2.0M	0.3	50M	100	E		
2N3406	Unijunction Transistors, see Table on Page 184																			
2N3407	S	N			AH	0.2W	A	200	35	18	O	10	100	10M			10	E	300M	T
2N3408	S	P			AH	4.0W	A	200	40	25	O	10	100	40M			10	E	200M	T
2N3409	S	N		2N3409	AM	0.5W	A	200	60	30	O	30	120	0.1M	0.15	10M			250M	T
2N3410	S	N		2N3409	AM	0.5W	A	200	60	30	O	20	100	10*	0.15	10M			250M	T
2N3411	S	N		2N3409	AM	0.5W	A	200	60	30	O	20	100	10*	0.15	10M			250M	T
2N3412	G	P			A	60M	A	100	20	20	S	30	200	10M	0.2	10M	25	E	100M	T
2N3413	S	P			A	0.4W	A	200	150	150	O	10	45	50M	1.2	0.1A			0.25M	T
2N3414	S	N	MPS6513	MPS6512	A	0.36W	A	160	25	25	O	75	225	2.0M	0.3	50M	75	E		
2N3415	S	N	MPS6515	MPS6512	A	0.36W	A	160	25	25	O	180	540	2.0M	0.3	50M	180	E		
2N3416	S	N	MPS6515	MPS6512	A	0.36W	A	160	50	50	O	75	225	2.0M	0.3	50M	75	E		
2N3417	S	N	MPS6515	MPS6512	A	0.36W	A	160	50	50	O	180	540	2.0M	0.3	50M	100	E		
2N3418	S	N			SP	0.8W	A	175	85	60	O	20	60	1.0A	0.25	1.0A			40M	T
2N3419	S	N			SP	0.8W	A	175	125	80	O	20	60	1.0A	0.25	1.0A			40M	T
2N3420	S	N			SP	0.8W	A	175	85	60	O	40	120	1.0A	0.25	1.0A			40M	T
2N3421	S	N			SP	0.8W	A	175	125	80	O	40	120	1.0A	0.25	1.0A			40M	T
2N3422	Thyristors, see Table on Page 164																			
2N3423	S	N		2N3423	AM	0.3W	A	200	30	15	O	20	200	3.0M	0.4	10M			600M	T
2N3424	S	N		2N3423	AM	0.3W	A	200	30	15	O	20	200	3.0M	0.4	10M			600M	T
2N3425	S	N		2N3425	AHP	0.3W	A	200	40	15	O	30	120	10M	0.4	10M	20	E	300M	T
2N3426	S	N			SH	0.6W	A	200	25	12	O	30	120	0.3A	0.33	0.3A			450M	T
2N3427	G	P		2N3427	A	0.2W	A	100	45	30	R	100	350	0.1A	0.2	0.1A	200	E	4.0M	T
2N3428	G	P		2N3427	A	0.2W	A	100	45	30	R	150	400	0.1A	0.19	0.1A	350	E	5.0M	T
2N3429	S	N	2N3713	2N3713	SP	150W	C	175	50	50	O	10	35	5.0A	1.0	5.0A			20K	E
2N3430	S	N	2N3714	2N3713	SP	150W	C	175	100	100	O	10	35	5.0A	1.0	5.0A			20K	E
2N3431	S	N			SP	150W	C	175	150	150	O	10	35	5.0A	1.0	5.0A			20K	E
2N3432	S	N			SP	150W	C	175	200	200	O	10	35	5.0A	1.0	5.0A			20K	E
2N3433	S	N			SP	150W	C	175	250	250	O	10	35	5.0A	1.0	5.0A			20K	E
2N3434	S	N			SP	150W	C	175	300	300	O	10	35	5.0A	1.0	5.0A				
2N3435	S	N			AHP	1.0W	A	200	80	60	O	50	200	10M					140M	T
2N3436 thru 2N3438	Field-Effect Transistors, see Table on Page 176																			
2N3439	S	N		MJ3201	AH	1.0W	A	200	450	350	O	40	160	20M			25	E	15M	T
2N3440	S	N		MJ3201	AH	1.0W	A	200	300	250	O	40	160	20M			25	E	15M	T
2N3441	S	N		2N3738	AP	25W	C	200	160	140	O	20	80	0.5A	6.0	2.7A	15	E	0.2M	T
2N3442	S	N			AP	100W	C	200	160	140	O	20	70	3.0A	5.0	10A	12	E	80K	T
2N3443	G	P			AH	0.3W	A	100	20	15	O	20	150	10M			20	E	750M	T
2N3444	S	N		2N3252	SH	1.0W	A	200	80	50	O	20	60	0.5A	0.35	0.15A			150M	T
2N3445	S	N		2N3445	AP	115W	C	200	80	60	O	20	60	3.0A	1.5	3.0A	20	E	10M	T
2N3446	S	N		2N3445	AP	115W	C	200	100	80	O	20	60	3.0A	1.5	3.0A	20	E	10M	T
2N3447	S	N		2N3445	AP	115W	C	200	80	60	O	40	120	5.0A	1.5	5.0A	40	E	10M	T
2N3448	S	N		2N3445	AP	115W	C	200	100	80	O	40	120	5.0A	1.5	5.0A	40	E	10M	T
2N3449	G	P			SH	150M	A	100	15	6.0	O	20		10M	0.2	2.0M			300M	T
2N3450	S	N			SH	0.6W	A	200	120	60	O	40	120	0.15A	0.5	0.15A			100M	T
2N3451	S	P			SH	0.3W	A	200	6.0	6.0	O	30	120	10M	0.16	10M			500M	T
2N3452 thru 2N3460	Field-Effect Transistors, see Table on Page 176																			
2N3461	G	P			AP	5.0W	C	110	60	30	O	90	150	0.5A	0.4	1.0A	40	E	10K	E
2N3462	S	N			A	0.3W	A	200	50	35	O	100	300	10*	0.35	5.0M	150	E	10M	T
2N3463	S	N			A	0.3W	A	200	60	45	O	120	360	10*	0.35	1.0M	150	E	45M	T
2N3464	S	N			AHP	5.0W	C	200	60	40	O	35	100	0.2A	1.0	0.2A	30	E	50M	T
2N3465																				
2N3466	Field-Effect Transistors, see Table on Page 176																			
2N3467	S	P		2N3467	SH	1.0W	A	200	40	40	O	40	120	0.5A	0.3	0.15A			175M	T
2N3468	S	P		2N3467	SH	1.0W	A	200	50	50	O	25	75	0.5A	0.35	0.15A			150M	T
2N3469	S	N			AHP	1.25W	A	200	35	25	O	100	350	0.5A	0.5	1.0A	100	E	20M	T
2N3470	S	N			AP	150W	C	150	50	50	O	100	500	9.0A	3.5	9.0A	50	E	7.0K	E
2N3471	S	N			AP	150W	C	150	100	100	O	100	500	9.0A	3.5	9.0A	50	E	7.0K	E
2N3472	S	N			AP	150W	C	150	150	150	O	100	500	9.0A	3.5	9.0A	50	E	7.0K	E
2N3473	S	N			AP	150W	C	150	200	200	O	100	500	9.0A	3.5	9.0A	50	E	7.0K	E
2N3474	S	N			AP	150W	C	150	50	50	O	700	10K	4.0A	3.5	9.0A	100	E	4.0K	E
2N3475	S	N			AP	150W	C	150	100	100	O	700	10K	4.0A	3.5	9.0A	100	E	4.0K	E

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N3476	S	N			AP	150W	C	150	150	150	O	700	10K	4.0A	3.5	9.0A	100	E	4.0K	E
2N3477	S	N			AP	150W	C	150	200	200	O	700	10K	4.0A	3.5	9.0A	100	E	4.0K	E
2N3478	S	N			AH	0.2W	A	200	30	15	O	25	150	2.0M			25	E	750M	T
2N3479 thru 2N3484	Unijunction Transistors, see Table on Page 184																			
2N3485	S	P		2N2904	SH	2.0W	C	200	60	40	O	40	120	0.15A	0.4	0.15A			200M	T
2N3485A	S	P		2N2904	SH	2.0W	C	200	60	60	O	40	120	0.15A	0.4	0.15A			200M	T
2N3486	S	P		2N2904	SH	2.0W	C	200	60	40	O	100	300	0.15A	0.4	0.15A			200M	T
2N3486A	S	P		2N2904	SH	2.0W	C	200	60	60	O	100	300	0.15A	0.4	0.15A			200M	T
2N3487	S	N		2N3485	AP	115W	C	200	80	60	O	20	60	3.0A	0.3	1.0A	20	E	10M	T
2N3488	S	N		2N3485	AP	115W	C	200	100	80	O	20	60	3.0A	0.3	1.0A	20	E	10M	T
2N3489	S	N		2N3485	AP	115W	C	200	120	100	O	15	45	3.0A	0.3	1.0A	20	E	10M	T
2N3490	S	N		2N3485	AP	115W	C	200	80	60	O	40	120	5.0A	0.3	1.0A	40	E	10M	T
2N3491	S	N		2N3485	AP	115W	C	200	100	80	O	40	120	5.0A	0.3	1.0A	40	E	10M	T
2N3492	S	N		2N3485	AP	115W	C	200	120	100	O	30	90	5.0A	0.3	1.0A	40	E	10M	T
2N3493	S	N			SH	0.15W	A	200	12	8.0	O	40	120	0.5M	0.15	10*			400M	T
2N3494	S	P		2N3494	AH	0.6W	A	200	80	80	O	35		0.1A	0.3	10M	40	E	200M	T
2N3495	S	P		2N3494	AH	0.6W	A	200	120	120	O	35		0.1M	0.35	10M	40	E	150M	T
2N3496	S	P		2N3494	AH	0.4W	A	200	80	80	O	35		0.1A	0.3	10M	40	E	200M	T
2N3497	S	P		2N3494	AH	0.4W	A	200	120	120	O	35		0.1M	0.35	10M	40	E	150M	T
2N3498	S	N		2N3498	AH	1.0W	A	200	100	100	O	40	120	0.15A	0.2	10M	50	E	150M	T
2N3499	S	N		2N3498	AH	1.0W	A	200	100	100	O	100	300	0.15A	0.2	10M	75	E	150M	T
2N3500	S	N		2N3498	AH	1.0W	A	200	150	150	O	40	120	0.15A	0.2	10M	50	E	150M	T
2N3501	S	N		2N3498	AH	1.0W	A	200	150	150	O	100	300	0.15A	0.2	10M	75	E	150M	T
2N3502	S	P	2N2905	2N2904	SH	0.7W	A	200	45	45	O	115	300	50M	0.25	50M	135	E	200M	T
2N3503	S	P	2N2905A	2N2904	SH	0.7W	A	200	60	60	O	115	300	50M	0.25	50M	135	E	200M	T
2N3504	S	P	2N2907	2N2904	SH	0.4W	A	200	45	45	O	115	300	50M	0.25	50M	135	E	200M	T
2N3505	S	P	2N2907A	2N2904	SH	0.4W	A	200	60	60	O	115	300	50M	0.25	50M	135	E	200M	T
2N3506	S	N		2N3506	SH	1.0W	A	200	60	40	O	40	200	1.5A	1.0	1.5A			60M	T
2N3507	S	N		2N3506	SH	1.0W	A	200	80	50	O	30	150	1.5A	1.0	1.5A			60M	T
2N3508	S	N		2N3506	SH	0.4W	A	200	40	20	O	40	120	10M	0.25	10M			500M	T
2N3509	S	N		2N3506	SH	0.4W	A	200	40	20	O	100	300	10M	0.25	10M			500M	T
2N3510	S	N		2N3510	SH	0.36W	A	200	40	10	O	25	150	0.15A	0.25	10M	20	E	350M	T
2N3511	S	N		2N3510	SH	0.36W	A	200	40	15	O	30	120	0.15A	0.25	10M	20	E	450M	T
2N3512	S	N	2N2537	2N2537	SH	0.8W	A	200	60	35	O	10		0.5A	1.0	0.5A			250M	T
2N3513	S	N	2N2480A	2N2060	AM	0.25W	A	200	80	40	O	50	200	1.0M	1.2	50M	50	E	50M	T
2N3514	S	N			AM	0.25W	A	175	80	40	O	50	200	1.0M	1.2	50M	50	E	50M	T
2N3515	S	N		2N3515	AM	0.25W	A	175	80	40	O	50	200	1.0M	1.2	50M	50	E	50M	T
2N3516	S	N			AM	0.25W	A	200	100	60	O	50	200	1.0M	1.2	50M	50	E	60M	T
2N3517	S	N			AM	0.25W	A	175	100	60	O	50	200	1.0M	1.2	50M	50	E	60M	T
2N3518	S	N		2N3515	AM	0.25W	A	175	100	60	O	50	200	1.0M	1.2	50M	50	E	60M	T
2N3519	S	N			AM	0.25W	A	175	60	30	O	150	600	1.0M	1.0	5.0M	150	E	60M	T
2N3520	S	N			AM	0.25W	A	175	60	30	O	150	600	1.0M	1.0	5.0M	150	E	60M	T
2N3521	S	N			AM	0.3W	A	200	70	55	O	100	300	10*	1.0	10M			30M	T
2N3522	S	N			AM	0.25W	A	200	70	55	O	100	300	10*	1.0	10M			30M	T
2N3523	S	N			AM	0.25W	A	175	70	55	O	100	300	10*	1.0	10M			30M	T
2N3524	S	N			AM	0.25W	A	175	70	55	O	100	300	10*	1.0	10M			30M	T
2N3525	Thyristors, see Table on Page 164																			
2N3526	S	N			AH	0.8W	A	200	130	120	O	30	120	30M	1.0	50M	25	E	40M	T
2N3527	S	P			A	0.4W	A	200	30	30	O	25	75	0.1N		0.1N	100	E	5.0M	T
2N3528 thru 2N3541	Thyristors, see Table on Page 164																			
2N3543	S	N			AHP	60W	C	200	65	60	O	10	80	4.5A	1.0	4.5A			150M	T
2N3544	S	N		2N3544	AH	0.3W	A	175	25	25	S	25		10M					600M	T
2N3545	S	P			SH	0.36W	A	200	20	20	O	40	120	10M	0.2	10M			250M	T
2N3546	S	P		2N3546	SH	0.36W	A	200	15	12	O	30	120	10M	0.15	10M			700M	T
2N3547	S	P			A	0.36W	A	200	60	60	O	100	500	1.0M	1.0	10M	120	E	45M	T
2N3548	S	P			A	0.4W	A	200	60	45	O	100	300	10*	1.0	10M	150	E	60M	T
2N3549	S	P			A	0.4W	A	200	60	60	O	100	500	10*	1.0	10M	150	E	60M	T
2N3550	S	P			A	0.4W	A	200	60	45	O	200	600	10*	0.9	5.0M	300	E	60M	T
2N3551	S	N			SHP	40W	C	175	115	60	O	20	90	10A	1.0	10A			40M	T
2N3552	S	N			SHP	40W	C	175	140	80	O	20	90	10A	1.0	10A			40M	T
2N3553	S	N		2N3375	AHP	7.0W	C	200	65	40	O	10	100	0.25A	1.0	0.25A			400M	T
2N3554	S	N			SH	0.8W	A	200	60	30	O	25	100	0.75A	0.7	0.75A			150M	T
2N3555 thru 2N3562	Thyristors, see Table on Page 164																			
2N3563	S	N			AH	0.2W	A	125	30	12	O	20	200	8.0M			20	E	600M	T
2N3564	S	N			AH	0.2W	A	125	30	15	O	20	500	15M	0.3	20M	20	E	400M	T
2N3565	S	N	MPS6514	MPS6512	A	0.2W	A	125	30	25	O	150	600	1.0M			120	E	40M	T
2N3566	S	N	MPS6514	MPS6512	A	0.3W	A	125	40	30	O	150	600	10M	1.0	0.1A			40M	T
2N3567	S	N	MPS6530	MPS6530	A	0.3W	A	125	80	40	O	40	120	0.15A	0.25	0.15A			60M	T
2N3568	S	N			A	0.3W	A	125	80	60	O	40	120	0.15A	0.25	0.15A			60M	T
2N3569	S	N	MPS6531	MPS6530	A	0.3W	A	125	80	40	O	100	300	0.15A	0.25	0.15A			60M	T
2N3570	S	N			AH	0.2W	A	200	30	15	O	20	150	5.0M			20	E	1.5G	T
2N3571	S	N			AH	0.2W	A	200	25	15	O	20	200	5.0M			20	E	1.5G	T
2N3572	S	N			AH	0.2W	A	200	25	13	O	20	300	5.0M			20	E	1.0G	T
2N3573 thru 2N3575	Field-Effect Transistors, see Table on Page 176																			
2N3576	S	P			SH	0.36W	A	200	20	15	O	40	120	10M	0.15	10M			400M	T
2N3577	S	N			AHP	85W	C	175	100	80	O	12	60	1.0A	5.25	1.0A	12	E	10M	T
2N3578	Field-Effect Transistors, see Table on Page 176																			
2N3579	S	P			AH	0.4W	A	200	60	60	O	30	120	1.0M	0.5	5.0M	30	E	80M	T
2N3580	S	P			AH	0.4W	A	200	60	60	O	60	240	1.0M	0.5	5.0M	60	E	80M	T
2N3581	S	P			AH	0.4W	A	200	50	40	O	50	150	0.1M	0.5	5.0M	50	E	30M	T

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N3582	S	P			AH	0.4W	A	200	50	40	O	100	300	0.1M	0.5	5.0M	100	E	30M	T
2N3583	S	N			AHP	35W	C	200	250	175	O	40	200	0.5A	5.0	1.0A	25	E	10M	T
2N3584	S	N			SP	35W	C	200	330	250	O	8.0	140	1.0A	0.75	1.0A			10M	T
2N3585	S	N	2N3767	2N3766	SP	35W	C	200	440	300	O	8.0	140	1.0A	0.75	1.0A			10M	T
2N3586	S	P			SC	125M	A	200	45	45	O								0.1M	T
2N3587	S	N			AM	0.3W	A	200	60	45	O	80	500	1.0M	1.0	10M			80M	T
2N3588	G	P			AM	0.1W	A	85	25			20		1.0M					200M	T
2N3589	S	N			AHP	2.0W	A	175	200	200	R	30	90	0.2A	2.0	0.2A	30	E	15M	T
2N3590	S	N			AHP	2.0W	A	175	200	200	R	75	150	0.2A	2.0	0.2A	75	E	15M	T
2N3591	S	N			AHP	1.0W	A	175	200	200	R	30	90	0.2A	2.0	0.2A	30	E	15M	T
2N3592	S	N			AHP	1.0W	A	175	200	200	R	75	150	0.2A	2.0	0.2A	75	E	15M	T
2N3593	S	N			AHP	1.0W	A	175	200	200	R	30	90	0.2A	2.0	0.2A	30	E	15M	T
2N3594	S	N			AHP	1.0W	A	175	200	200	R	75	150	0.2A	2.0	0.2A	75	E	15M	T
2N3595	S	N			AHP	1.5W	A	175	200	200	R	30	90	0.2A	2.0	0.2A	30	E	15M	T
2N3596	S	N			AHP	1.5W	A	175	200	200	R	75	150	0.2A	2.0	0.2A	75	E	15M	T
2N3597	S	N	2N3767	2N3766	SHP	100W	C	200	60	40	O	40	120	10A	0.5	10A	75	E	30M	T
2N3598	S	N	2N3446	2N3445	SHP	100W	C	200	80	60	O	40	120	10A	0.5	10A	75	E	30M	T
2N3599	S	N	2N3447	2N3445	SHP	100W	C	200	100	80	O	40	120	10A	0.5	10A	75	E	30M	T
2N3600	S	N			AH	0.2W	A	200	30	15	O	20	150	3.0M			40	E	850M	T
2N3601	G	P			SP	0.286W	C	100	100	40	O	60	180	1.0A	0.2	0.1A	50	E	20M	T
2N3602	G	P			SP	0.286W	C	100	100	40	O	60	180	1.0A	0.2	0.1A	50	E	20M	T
2N3603	G	P			SP	0.286W	C	100	130	55	O	60	180	1.0A	0.2	0.1A	50	E	20M	T
2N3604	G	P			SP	0.286W	C	100	130	55	O	60	180	1.0A	0.2	0.1A	50	E	20M	T
2N3605	S	N	MPS3646	MPS3646	S	0.2W	A	150	18	14	O	30		10M	0.25	10M			300M	T
2N3605A	S	N			S	320M	A	120	40	15	O	30	120	10M	0.25	10M			300M	T
2N3606	S	N	MPS3646	MPS3646	S	0.2W	A	150	18	14	O	30		10M	0.25	10M			300M	T
2N3606A	S	N			S	320M	A	120	40	15	O	30	120	10M	0.25	10M			300M	T
2N3607	S	N	MPS3646	MPS3646	S	0.2W	A	150	18	14	O	30		10M	0.25	10M			300M	T
2N3608 thru 2N3610	Field-Effect Transistors, see Table on Page 176																			
2N3611	G	P		2N3611	AP	85W	C	110	40	30	S	35	70	3.0A	0.25	3.0A	40	E	0.3M	T
2N3612	G	P		2N3611	AP	85W	C	110	60	45	S	35	70	3.0A	0.25	3.0A	40	E	0.3M	T
2N3613	G	P		2N3611	AP	85W	C	110	40	30	S	60	120	3.0A	0.25	3.0A	60	E	0.3M	T
2N3614	G	P		2N3611	AP	85W	C	110	60	45	S	60	120	3.0A	0.25	3.0A	60	E	0.3M	T
2N3615	G	P		2N3615	AP	85W	C	110	80	60	S	30	60	3.0A	0.25	3.0A	40	E	0.3M	T
2N3616	G	P		2N3615	AP	85W	C	110	100	75	S	30	60	3.0A	0.25	3.0A	40	E	0.3M	T
2N3617	G	P		2N3615	AP	85W	C	110	80	60	S	45	90	3.0A	0.25	3.0A	60	E	0.3M	T
2N3618	G	P		2N3615	AP	85W	C	110	100	75	S	45	90	3.0A	0.25	3.0A	60	E	0.3M	T
2N3619	S	N			AHP	7.5W	C	175	75	40	O	40		1.0A	0.75	1.0A			200M	T
2N3620	S	N			AHP	7.5W	C	175	75	40	O	40		1.0A	1.0	3.0A			200M	T
2N3621	S	N			AHP	30W	C	175	75	40	O	40		1.0A	1.25	5.0A			200M	T
2N3622	S	N			AHP	30W	C	175	75	40	O	40		1.0A	1.25	5.0A			200M	T
2N3623	S	N			AHP	7.5W	C	175	75	40	O	40		1.0A	0.75	1.0A			200M	T
2N3624	S	N			AHP	7.5W	C	175	75	40	O	40		1.0A	1.0	3.0A			200M	T
2N3625	S	N			AHP	30W	C	175	75	40	O	40		1.0A	1.25	5.0A			200M	T
2N3626	S	N			AHP	30W	C	175	75	40	O	40		1.0A	1.25	5.0A			200M	T
2N3627	S	N			AHP	7.5W	C	175	100	50	O	40		1.0A	0.75	1.0A			200M	T
2N3628	S	N			AHP	7.5W	C	175	100	50	O	40		1.0A	1.0	3.0A			200M	T
2N3629	S	N			AHP	30W	C	175	100	50	O	40		1.0A	1.25	5.0A			200M	T
2N3630	S	N			AHP	30W	C	175	100	50	O	40		1.0A	1.25	5.0A			200M	T
2N3631	Field-Effect Transistors, see Table on Page 176																			
2N3632	S	N		2N3375	AHP	23W	C	200	65	40	O	10	150	0.25A	1.0	1.0A			250M	T
2N3633	S	N			SH	0.3W	A	200	15	6.0	O	50	150	10M	0.21	3.0M			1.3G	T
2N3634	S	P		2N3634	AH	1.0W	A	200	140	140	O	50	150	50M			40	E	150M	T
2N3635	S	P		2N3634	AH	1.0W	A	200	140	140	O	100	300	50M			80	E	200M	T
2N3636	S	P		2N3634	AH	1.0W	A	200	175	175	O	50	150	50M			40	E	150M	T
2N3637	S	P		2N3634	AH	1.0W	A	200	175	175	O	100	300	50M			80	E	200M	T
2N3638	S	P			SH	0.3W	A	125	25	25	O	30		50M	0.25	50M	25	E	100M	T
2N3638A	S	P			SH	0.3W	A	125	25	25	O	100		50M	0.25	50M	100	E	150M	T
2N3639	S	P	MPS3639	MPS3639	SH	0.2W	A	125	6.0	6.0	O	30	120	10M	0.16	10M			500M	T
2N3640	S	P	MPS3640	MPS3640	SH	0.2W	A	125	12	12	O	30	120	10M	0.2	10M			500M	T
2N3641	S	N	MPS6530	MPS6530	AHP	0.35W	A	125	60	30	O	40	120	0.15A	0.22	0.15A			250M	T
2N3642	S	N	MPS6530	MPS6530	AHP	0.35W	A	125	60	45	O	40	120	0.15A	0.22	0.15A			250M	T
2N3643	S	N	MPS6531	MPS6530	AHP	0.35W	A	125	60	30	O	100	300	0.15A	0.22	0.15A			250M	T
2N3644	S	P			SH	0.3W	A	125	45	45	O	115	300	50M	0.25	50M			200M	T
2N3645	S	P			SH	0.3W	A	125	60	60	O	115	300	50M	0.25	50M			200M	T
2N3646	S	N	MPS3646	MPS3646	SH	0.2W	A	125	40	15	O	30	120	30M	0.2	30M			350M	T
2N3647	S	N		2N3510	SH	0.4W	A	200	40	10	O	25	150	0.15A	0.25	10M	20	E	350M	T
2N3548	S	N		2N3510	SH	0.4W	A	200	40	15	O	30	120	0.15A	0.25	10M	20	E	450M	T
2N3649 thru 2N3658	Thyristors, see Table on Page 164																			
2N3659	S	N			AH	4.0W	C	200	220	170	O	20		10M			20	E	50M	T
2N3660	S	P	2N3719		AHP	5.0W	C	200	40	30	O	25	100	0.5A	1.2	0.5A			25M	T
2N3661	S	P	2N3720		AHP	5.0W	C	200	60	50	O	25	100	0.5A	1.2	0.5A			25M	T
2N3662	S	N			AH	0.2W	A	125	18	12	O	20		8.0M					700M	T
2N3663	S	N			AH	0.2W	A	125	30	12	O	20		8.0M					700M	T
2N3664	S	N		2N3664	AHP	5.0W	C	200	60	60	S	8.0	80	50M	0.75	0.25A			300M	T
2N3665	S	N			S	5.0W	C	200	120	80	O	40	120	0.15A	0.5	0.15A			60M	T
2N3666	S	N			S	5.0W	C	200	120	80	O	100	300	0.15A	0.5	0.15A			60M	T
2N3667	S	N	2N3715	2N3713	SP	117W	C	200	50	50	O	15	60	8.0A	1.5	8.0A			0.5M	T
2N3668 thru 2N3670	Thyristors, see Table on Page 164																			
2N3671	S	P			S	0.6W	A	200	60	50	O	75	225	0.15A	0.4	0.15A			200M	T
2N3672	S	P			S	0.4W	A	200	60	50	O	75	225	0.15A	0.4	0.15A			200M	T
2N3673	S	P			S	0.35W	A	200	60	50	O	75	225	0.15A	0.4	0.15A			200M	T

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N3675	S	N	2N4238	2N4237	SP	8.8W	C	200	90	55	O	12	60	1.0A	0.8	1.0A			1.0M	T
2N3676	S	N	2N4239	2N4237	SP	8.8W	C	200	90	90	O	12	60	1.0A	0.8	1.0A			1.0M	T
2N3677	S	P			SC	0.4W	A	200	30	20	O								5.0M	T
2N3678	S	N			SH	0.8W	A	200	75	55	O	40	120	0.15A	0.4	0.15A			250M	T
2N3679	Unijunction Transistors, see Table on Page 184																			
2N3680	S	N			AM	0.3W	A	200	60	50	O	150	600	10*	0.7	10M	300	E	60M	T
2N3681	S	N			AH	0.2W	A	200	10	7.0	O	20	220	2.0M	0.37	4.0M	20	E	1.0G	T
2N3682	S	N			AH	0.36W	A	200	40	15	O	40	120	10M			45	E	600M	T
2N3683	S	N			AH	0.2W	A	200	30	12	O	20	150	8.0M			30	E	1.0G	T
2N3684 thru 2N3687	Field-Effect Transistors, see Table on Page 176																			
2N3688	S	N			AH	0.2W	A	125	40	40	O	30		4.0M					400M	T
2N3689	S	N			AH	0.2W	A	125	40	40	O	30		4.0M					400M	T
2N3690	S	N			AH	0.2W	A	125	40	40	O	30		4.0M					400M	T
2N3691	S	N	MPS6512	MPS6512	A	0.2W	A	125	35	20	O	40	160	10M	0.7	10M	40	E	200M	T
2N3692	S	N	MPS6513	MPS6512	A	0.2W	A	125	35	20	O	100	400	10M	0.7	10M	100	E	200M	T
2N3693	S	N			AH	0.2W	A	125	45	45	O	40	160	10M					200M	T
2N3694	S	N			AH	0.2W	A	125	45	45	O	100	400	10M					200M	T
2N3695 thru 2N3698	Field-Effect Transistors, see Table on Page 176																			
2N3700	S	N			AH	0.5W	A	200	140	80	O	100	300	0.15A	0.2	0.15A	80	E	100M	T
2N3701	S	N			AH	0.5W	A	200	140	80	O	40	120	0.15A	0.2	0.15A	30	E	80M	T
2N3702	S	P			A	0.3W	A	150	40	25	O	60	300	50M	0.25	50M			100M	T
2N3703	S	P			A	0.3W	A	150	50	30	O	30	150	50M	0.25	50M			100M	T
2N3704	S	N			A	0.36W	A	150	50	30	O	100	300	50M	0.6	0.1A			100M	T
2N3705	S	N			A	0.36W	A	150	50	30	O	50	150	50M	0.8	0.1A			100M	T
2N3706	S	N			A	0.36W	A	150	40	20	O	30	600	50M	1.0	0.1A			100M	T
2N3707	S	N			A	0.25W	A	150	30	30	O	100	400	0.1M	1.0	10M	100	E		
2N3708	S	N			A	0.25W	A	150	30	30	O	45	660	1.0M	1.0	10M	45	E		
2N3709	S	N			A	0.25W	A	150	30	30	O	45	165	1.0M	1.0	10M	45	E		
2N3710	S	N			A	0.25W	A	150	30	30	O	90	330	1.0M	1.0	10M	90	E		
2N3711	S	N			A	0.25W	A	150	30	30	O	180	660	1.0M	1.0	10M	180	E		
2N3712	S	N		2N3712	AH	0.8W	A	200	150	150	O	30	150	30M	2.0	50M	25	E	40M	T
2N3713	S	N		2N3713	AHP	150W	C	200	80	60	O	25	75	1.0A	1.0	5.0A	25	E	30K	E
2N3714	S	N		2N3713	AHP	150W	C	200	100	80	O	25	75	1.0A	1.0	5.0A	25	E	30K	E
2N3715	S	N		2N3713	AHP	150W	C	200	80	60	O	50	150	1.0A	0.8	5.0A	25	E	30K	E
2N3716	S	N		2N3713	AHP	150W	C	200	100	80	O	50	150	1.0A	0.8	5.0A	25	E	30K	E
2N3717	S	N			AHP	7.5W	C	200	60	60	S	2.0	100	0.5A	1.0	0.5A			250M	T
2N3718	S	N			AHP	10W	C	200	60	60	S	2.0	100	0.5A	1.0	0.5A			250M	T
2N3719	S	P		2N3719	SHP	6.0W	C	200	40	40	O	25	180	1.0A	1.5	0.3A			60M	T
2N3720	S	P		2N3719	SHP	6.0W	C	200	60	60	O	25	180	1.0A	1.5	3.0A			60M	T
2N3721	S	N	MP3731		A	0.2W	A	125	18	18	O						60	E		
2N3722	S	N		2N3722	S	0.8W	A	200	80	60	O	40	150	0.1A	0.22	0.1A			300M	T
2N3723	S	N		2N3722	SH	0.8W	A	200	100	80	O	40	150	0.1A	0.25	10M			300M	T
2N3724	S	N			SH	0.8W	A	200	50	30	O	60	150	0.1A	0.2	0.1A			300M	T
2N3724A	S	N			SH	1W	A		50	30	O	60	150	100M	0.2	100M				
2N3725	S	N			SH	0.8W	A	200	80	50	O	60	150	0.1A	0.26	0.1A			300M	T
2N3725A	S	N			SH	1W	A		80	50	O	60	150	100M	0.26	100M	3	E		
2N3726	S	P			AM	0.4W	A	200	45	45	O	135	350	1.0M	0.25	50M	135	E	200M	T
2N3727	S	P			AM	0.4W	A	200	45	45	O	135	350	1.0M	0.25	50M	135	E	200M	T
2N3728	S	N			AM	0.45W	A	200	60	30	O	80	280	0.15A	0.22	0.15A	50	E	250M	T
2N3729	S	N			AM	0.45W	A	200	60	30	O	80	280	0.15A	0.22	0.15A	50	E	250M	T
2N3730	G	P			AP	10W	A	100	200	200	S									
2N3731	G	P			AP	5.0W	A	100	320	320	S	15		6.0A						
2N3732	G	P			AP	3.0W	A	100	100	100	S	35	500	0.7A					1.0M	T
2N3733	S	N		2N3733	AHP	23W	C	200	65	40	O	10	150	0.25A	1.0	1.0A			250M	T
2N3734	S	N		2N3734	SH	1.0W	A	200	50	30	O	30	120	1.0A	0.2	10M			300M	T
2N3734A	S	N			SH	1.0W	A		50	30	O	30	120	1.0A	0.9	1.0A	2.5	E		
2N3735	S	N		2N3734	SH	1.0W	A	200	75	50	O	20	80	1.0A	0.2	10M			250M	T
2N3735A	S	N			SH	1.0W	A		75	50	O	20	80	1.0A	0.9	1.0A	2.5	E		
2N3736	S	N		2N3734	SH	0.5W	A	200	50	30	O	30	120	1.0A	0.2	10M			300M	T
2N3736A	S	N			SH	0.5W	A		50	30	O	30	120	1.0A	0.9	1.0A	2.5	E		
2N3737	S	N		2N3734	SH	0.5W	A	200	75	50	O	20	80	1.0A	0.2	10M			250M	T
2N3737A	S	N			SH	0.5W	A		75	50	O	20	80	1.0A	0.9	1.0A	2.5	E		
2N3738	S	N		2N3738	AP	20W	C	175	250	225	O	40	200	0.1A	2.5	0.25A	35	E	15M	T
2N3739	S	N		2N3738	AP	20W	C	175	325	300	O	40	200	0.1A	2.5	0.25A	35	E	15M	T
2N3740	S	P		2N3740	AP	25W	C	200	60	60	O	30	100	0.25A	0.6	1.0A	25	E	4.0M	T
2N3741	S	P		2N3740	AP	25W	C	200	80	80	O	30	100	0.25A	0.6	1.0A	25	E	4.0M	T
2N3742	S	N		2N3742	AH	1.0W	A	200	300	300	O	20	200	30M	1.0	10M	20	E	30M	T
2N3743	S	P		2N3743	AH	1.0W	A	200	300	300	O	25	250	30M	5.0	10M	30	E	30M	T
2N3744	S	N			AHP	30W	C	200	60	40	O	20	60	1.0A	0.25	1.0A	20	E	30M	T
2N3745	S	N			AHP	30W	C	200	80	60	O	20	60	1.0A	0.25	1.0A	20	E	30M	T
2N3746	S	N			AHP	30W	C	200	100	80	O	20	60	1.0A	0.25	1.0A	20	E	30M	T
2N3747	S	N			AHP	30W	C	200	60	40	O	40	120	1.0A	0.25	1.0A	40	E	40M	T
2N3748	S	N			AHP	30W	C	200	80	60	O	40	120	1.0A	0.25	1.0A	40	E	40M	T
2N3749	S	N			AHP	30W	C	200	100	80	O	40	120	1.0A	0.25	1.0A	40	E	40M	T
2N3750	S	N			AHP	30W	C	200	60	40	O	100	300	1.0A	0.25	1.0A	100	E	50M	T
2N3751	S	N			AHP	30W	C	200	80	60	O	100	300	1.0A	0.25	1.0A	100	E	50M	T
2N3752	S	N			AHP	30W	C	200	100	80	O	100	300	1.0A	0.25	1.0A	100	E	50M	T
2N3753 thru 2N3761	Thyristors, see Table on Page 164																			
2N3762	S	P		2N3762	SH	1.0W	A	200	40	40	O	30	120	1.0A	0.1	10M			180M	T
2N3763	S	P		2N3762	SH	1.0W	A	200	60	60	O	20	80	1.0A	0.1	10M			150M	T
2N3764	S	P		2N3762	SH	0.5W	A	200	40	40	O	30	120	1.0A	0.1	10M			180M	T
2N3765	S	P		2N3762	SH	0.5W	A	200	60	60	O	20	80	1.0A	0.1	10M			150M	T

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N3766	S	N		2N3766	AP	20W	C	175	80	60	O	40	160	0.5A	2.5	1.0A	40	E	15M	T
2N3767	S	N		2N3766	AP	20W	C	175	100	80	O	40	160	0.5A	2.5	1.0A	40	E	15M	T
2N3770	G	P			AH	50M	A	100	10	6.0	O	10	200	1.0M			10	E	100M	T
2N3771	S	N			AP	150W	C	200	50	40	O	15	60	15A	2.0	15A	40	E	0.2M	T
2N3772	S	N		2N3713	AP	150W	C	200	100	60	O	15	60	10A	1.4	10A	40	E	0.2M	T
2N3773	S	N			AP	150W	C	200	160	140	O	15	60	8.0A	1.4	8.0A	40	E	0.2M	T
2N3774	S	P	2N4234	2N4234	SP	5.0W	C	200	40	40	O	20	60	0.2A	0.2	0.2A			1.0M	T
2N3775	S	P	2N4235	2N4234	SP	5.0W	C	200	60	60	O	20	60	0.2A	0.2	0.2A			1.0M	T
2N3776	S	P	2N4236	2N4234	SP	5.0W	C	200	80	80	O	20	60	0.2A	0.2	0.2A			1.0M	T
2N3777	S	P	2N4236	2N4234	SP	5.0W	C	200	100	100	O	20	60	0.2A	0.2	0.2A			1.0M	T
2N3778	S	P	2N4234	2N4234	SP	5.0W	C	200	40	40	O	10	40	0.2A	0.2	0.2A			1.0M	T
2N3779	S	P	2N4235	2N4234	SP	5.0W	C	200	60	60	O	10	40	0.2A	0.2	0.2A			1.0M	T
2N3780	S	P	2N4236	2N4234	SP	5.0W	C	200	80	80	O	10	40	0.2A	0.2	0.2A			1.0M	T
2N3781	S	P	2N4236	2N4234	SP	5.0W	C	200	100	100	O	10	40	0.2A	0.2	0.2A			1.0M	T
2N3782	S	P	2N4234	2N4234	SP	5.0W	C	200	40	40	O	10	60	1.0A	0.75	1.0A			1.0M	T
2N3783	G	P		2N3783	AH	0.15W	A	100	30	20	O	20	200	3.0M	0.25	5.0M	20	E	0.8G	T
2N3784	G	P		2N3783	AH	0.15W	A	100	30	20	O	20	200	3.0M	0.25	5.0M	20	E	0.7G	T
2N3785	G	P		2N3783	AH	0.15W	A	100	15	12	O	15	200	3.0M	0.35	5.0M	15	E	0.7G	T
2N3788	S	N			AP	100W	C	200	400	325	O	20	180	0.50A					50K	E
2N3789	S	P		2N3789	AP	150W	C	200	60	60	O	25	90	1.0A	1.0	5.0A	25	E	30K	E
2N3790	S	P		2N3789	AP	150W	C	200	60	80	O	25	90	1.0A	1.0	5.0A	25	E	30K	E
2N3791	S	P		2N3789	AP	150W	C	200	60	60	O	50	180	1.0A	1.0	5.0A	25	E	30K	E
2N3792	S	P		2N3789	AP	150W	C	200	80	80	O	50	180	1.0A	1.0	5.0A	25	E	30K	E
2N3793	S	N	MPS6530	MPS6530	A	0.25W	A	125	40	20	O	20	120	10M	0.4	10M			100M	T
2N3794	S	N	MPS6531	MPS6530	A	0.25W	A	125	40	20	O	100	600	10M	0.4	10M			100M	T
2N3795	S	P			SP	5.0W	C	200	120	120	O	12	36	10M	0.2	10M			0.5M	T
2N3796 2N3797	Field-Effect Transistors, see Table on Page 176																			
2N3798	S	P		2N3798	A	0.36W	A	200	60	60	O	150	450	0.5M	0.2	0.1M	150	E	30M	T
2N3799	S	P		2N3798	A	0.36W	A	200	60	60	O	300	900	0.5M	0.2		300	E	30M	T
2N3800	S	P		2N3800	A	0.25W	A	200	60	60	O	150	450	0.1M	0.2	0.1M	150	E	100M	T
2N3801	S	P		2N3800	A	0.25W	A	200	60	60	O	300	900	0.1M	0.2	0.1M	300	E	100M	T
2N3802	S	P		2N3800	AM	0.25W	A	200	60	60	O	150	450	0.1M	0.2	0.1M	150	E	100M	T
2N3803	S	P		2N3800	AM	0.25W	A	200	60	60	O	300	900	0.1M	0.2	0.1M	300	E	100M	T
2N3804	S	P		2N3800	AM	0.25W	A	200	60	60	O	150	450	0.1M	0.2	0.1M	150	E	100M	T
2N3804A	S	P		2N3804A	AM	0.25W	C		60	60	0	150	450	100*	0.2	100*	150	E	30M	T
2N3805	S	P		2N3800	AM	0.25W	A	200	60	60	O	300	900	0.1M	0.2	0.1M	300	E	100M	T
2N3805A	S	P		2N3804A	AM	0.25W	C		60	60	0	300	900	100*	0.2	100*	300	E	30M	T
2N3806	S	P		2N3800	A	0.5W	A	200	60	60	O	150	450	0.1M	0.2	0.1M	150	E	100M	T
2N3807	S	P		2N3800	A	0.5W	A	200	60	60	O	300	900	0.1M	0.2	0.1M	300	E	100M	T
2N3808	S	P		2N3800	AM	0.5W	A	200	60	60	O	150	450	0.1M	0.2	0.1M	150	E	100M	T
2N3809	S	P		2N3800	AM	0.5W	A	200	60	60	O	300	900	0.1M	0.2	0.1M	300	E	100M	T
2N3810	S	P		2N3800	AM	0.5W	A	200	60	60	O	150	450	0.1M	0.2	0.1M	150	E	100M	T
2N3810A	S	P		2N3804A	AM	0.50W	A		60	60	0	150	450	100*	0.2	100*	150	E	30M	T
2N3811	S	P		2N3800	AM	0.5W	A	200	60	60	O	300	900	0.1M	0.2	0.1M	300	E	100M	T
2N3811A	S	P		2N3804A	AM	0.50W	A		•60	60	0	300	900	100*	0.2	100*	300	E	30M	T
2N3812	S	P		2N3800	AM	350M	A	200	60	60	O	150	450	0.1M	0.2	0.1M	150	E	100M	T
2N3813	S	P		2N3800	AM	350M	A	200	60	60	O	300	900	0.1M	0.2	0.1M	300	E	100M	T
2N3814	S	P		2N3800	AM	350M	A	200	60	60	O	150	450	0.1M	0.2	0.1M	150	E	100M	T
2N3815	S	P		2N3800	AM	350M	A	200	60	60	O	300	900	0.1M	0.2	0.1M	300	E	100M	T
2N3816	S	P		2N3800	AM	350M	A	200	60	60	O	150	450	0.1M	0.2	0.1M	150	E	100M	T
2N3816A	S	P		2N3804A	AM	0.25W	C		60	60	0	150	450	100*	0.2	100*	150	E	30M	T
2N3817	S	P		2N3800	AM	350M	A	200	60	60	O	300	900	0.1M	0.2	0.1M	300	E	100M	T
2N3817A	S	P		2N3804A	AM	0.25W	C		60	60	0	300	900	100*	0.2	100*	300	E	30M	T
2N3818	S	N		2N3818	AHP	25W	C	175	60	60	S	5.0	50	400M	0.5	1.0A	3.0	E		
2N3819 thru 2N3824	Field-Effect Transistors, see Table on Page 176																			
2N3825	S	N	MPS3398		AH	0.25W	A	150	30	15	O	20		2.0M	0.25	2.0M			200M	T
2N3826	S	N	MPS3826		AH	0.2W	A	150	60	45	O	40	160	10M					200M	T
2N3827	S	N	MPS3827		AH	0.2W	A	150	60	45	O	100	400	10M					200M	T
2N3828	S	N	MPS6565	MPS6565	AH	0.3W	A	150	40	40	O	30	200	12M					360M	T
2N3829	S	P			SH	0.36W	A	200	35	20	O	30	120	30M	0.18	10M			350M	T
2N3830	S	N			SH	1.0W	A	200	80	50	O	30		0.15A	0.3	0.15A			200M	T
2N3831	S	N			SH	1.0W	A	200	70	40	O	35		0.15A	0.3	0.15A			200M	T
2N3832	S	N			SH	0.2W	A	200	15	6.0	O	25	125	2.0M	0.4	10M			800M	T
2N3833	S	N			AHP				25	15	O	20		30M			2.5	E		
2N3834	S	N			AHP				25	15	O	20		30M			2.5	E		
2N3835	S	N			AHP				25	15	O	20		30M			2.5	E		
2N3836	S	N			SHP	1.0W	A	200	80	60	O	2K	20K	2.0A	1.8	5.0A			40M	T
2N3837	S	N			SHP	1.0W	A	200	100	80	O	2K	20K	2.0A	1.8	5.0A			40M	T
2N3838	S	N,P		2N3838	SH	0.25W	A	200	60	40	O	100	300	0.15A	0.4	0.15A	60	E	200M	T
2N3839	S	N		2N2857	AH	200M	A	200	30	15	O	30		3.0M					2.0G	T
2N3840	S	P			SC	0.4W	A	200	50	50	O	30		0.2M	0.1	5.0M			6.0M	T
2N3841	S	P			SC	0.3W	A	200	100	100	O	15		0.2M	0.12	5.0M			1.5M	T
2N3842	S	P			SC	0.3W	A	200	120	120	O	10		1.0M		5.0M			1.0M	T
2N3843	S	N	MPS6512	MPS6512	AH	0.2W	A	125	30	30	O	20	40	2.0M					60M	T
2N3843A	S	N	MPS6512	MPS6512	AH	0.2W	A	125	30	30	O	20	40	2.0M					60M	T
2N3844	S	N	MPS6512	MPS6512	AH	0.2W	A	125	30	30	O	35	70	2.0M					90M	T
2N3844A	S	N	MPS6512	MPS6512	AH	0.2W	A	125	30	30	O	35	70	2.0M					90M	T
2N3845	S	N	MPS6512	MPS6512	AH	0.2W	A	125	30	40	O	60	120	2.0M					126M	T
2N3845A	S	N	MPS6513	MPS6512	AH	0.2W	A	125	30	30	O	60	120	2.0M					126M	T
2N3846	S	N			AP	4.0W	A	175	300	200	O	10	60	10A	0.75	10A	50	E	10M	T
2N3847	S	N			AP	4.0W	A	175	400	300	O	10	60	10A	0.75	10A	50	E	10M	T
2N3848	S	N			AP	4.0W	A	175	300	300	O	10	60	15A	1.0	15A	50	E	10M	T
2N3849	S	N			AP	4.0W	A	175	400	300	O	10	60	15A	1.0	15A	50	E	10M	T
2N3850	S	N			SHP	30W	C	200	100	80	O	50	150	1.0A	0.25	1.0A			20M	T
2N3851	S	N			SHP	30W	C	200	100	80	O	30	90	1.0A	0.25	1.0A			20M	T
2N3852	S	N			SHP	30W	C	200	60	40	O	50	150	1.0A	0.25	1.0A			20M	T
2N3853	S	N			SHP	30W	C	200	60	40	O	30	90	1.0A	0.25	1.0A			20M	T
2N3854	S	N	MPS6512	MPS6512	AH	0.2W	A	150	18	18	O	35	70	2.0M					100M	T
2N3854A	S	N	MPS6512	MPS6512	AH	0.2W	A	150	30	30	O	35	70	2.0M					100M	T
2N3855	S	N	MPS6512	MPS6512	AH	0.2W	A	150	18	18	O	60	120	2.0M					130M	T
2N3855A	S	N	MPS6512	MPS6512	AH	0.2W	A	150	30	30	O	60	120	2.0M					130M	T

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} @ I_C (min)	(max)	Units	$V_{CE(SAT)}$ @ I_C (volts)	Units	h_{f-}	Subscript	f_- Units	Subscript
2N3856	S	N	MPS6513	MPS6512	AH	0.2W	A	150	18	18	O	100	200	2.0M					140M	T
2N3856A	S	N	MPS6513	MPS6512	AH	0.2W	A	150	30	30	O	100	200	2.0M					140M	T
2N3857	S	P			A	0.6W	A	200	45	45	O	50	200	1.0M	0.1	10M	45	E	4.0M	T
2N3858	S	N	MPS6512	MPS6512	AH	0.2W	A	125	30	30	O	60	120	2.0M					90M	T
2N3858A	S	N	MPS6566	MPS6565	AH	200M	A	100	60	60	O	45		1.0M					90M	T
2N3859	S	N	MPS6513	MPS6512	AH	0.2W	A	125	30	30	O	100	200	2.0M					90M	T
2N3859A	S	N	MPS6566	MPS6565	A	200M	A	100	60	60	O	75		1.0M					90M	T
2N3860	S	N	MPS6514	MPS6512	AH	0.2W	A	125	30	30	O	150	300	2.0M					90M	T
2N3861	S	N			AP	2.0W	A	175	530	530	V	30	200	25M	1.5	25M	20	E	50M	T
2N3862	S	N			S	0.36W	A	200	50	20	O	50	150	10M	0.25	10M			600M	T
2N3863	S	N	2N3715	2N3713	SP	117W	C	200	70	50	O	30	90	3.0A	1.0	3.0A			0.5M	T
2N3864	S	N	2N3716	2N3713	SP	117W	C	200	110	90	O	30	90	3.0A	1.0	3.0A			0.5M	T
2N3865	S	N			SP	117W	C	200	160	150	O	30	90	3.0A	1.0	3.0A			0.5M	T
2N3866	S	N		2N3866	AHP	5.0W	C	200	55	30	O	10	200	50M	1.0	0.1A			250M	T
2N3867	S	P			SH	1.0W	A	200	40	40	O	40	200	1.5A	0.75	1.5A			60M	T
2N3868	S	P			SH	1.0W	A	200	60	60	O	30	150	1.5A	0.75	1.5A			60M	T
2N3869	S	N			AHP	2.5W	C	175	40	20	O	20	150	30M	0.7	0.45A			0.4G	T
2N3870 thru 2N3873	Thyristors, see Table on Page 164																			
2N3876	S	N			AP	150W	C	175	140	50	O	25	150	10A	1.0	10A	80	E	50M	T
2N3877	S	N	2N4410	2N4409	A	0.2W	A	150	70	70	O	20	250	2.0M						
2N3877A	S	N	2N4410	2N4409	A	0.2W	A	150	85	85	O	20	250	2.0M						
2N3878	S	N			AHP	35W	C	200	120	50	O	40	200	0.5A	2.0	4.0A	40	E	40M	T
2N3879	S	N			SP	35W	C	200	120	75	O	12	100	4.0A	1.2	4.0A			40M	T
2N3880	S	N			AH	0.2W	A	200	30	15	O	30	200	3.0M			50	E	1.2G	T
2N3881	S	N			AH	0.6W	A	200	60	35	O				1.5	0.15A	50	E	70M	T
2N3882	Field-Effect Transistors, see Table on Page 176																			
2N3883	G	P		2N3883	SH	0.3W	A	100	25	15	O	30		0.2A	0.5	0.2A			100M	T
2N3884 thru 2N3899	Thyristors, see Table on Page 164																			
2N3900	S	N	2N5088	2N5088	A	0.2W	A	125	18	18	O	250	500	2.0M			170	E		
2N3900A	S	N	2N5088	2N5088	A	0.2W	A	125	18	18	O	250	500	2.0M			170	E		
2N3901	S	N	2N5088	2N5088	A	0.2W	A	125	18	18	O	350	700	2.0M			350	E		
2N3902	S	N			SP	100W	C	150	400	400	O	20	100	1.0A	2.5	2.5A			40K	E
2N3903	S	N		2N3903	SH	0.31W	A	135	60	40	O	50	150	10M	0.2	10M	50	E	250M	T
2N3904	S	N		2N3903	SH	0.31W	A	135	60	40	O	100	300	10M	0.2	10M	100	E	300M	T
2N3905	S	P		2N3905	SH	0.31W	A	135	40	40	O	50	150	10M	0.25	10M	50	E	200M	T
2N3906	S	P		2N3905	SH	0.31W	A	135	40	40	O	100	300	10M	0.25	10M	100	E	250M	T
2N3907	S	N	2N2915	2N2913	AM	0.3W	A	200	60	45	O	60	300	10*	0.35	1.0M			60M	T
2N3908	S	N	2N2916	2N2913	AM	0.3W	A	200	60	60	O	100	500	10*	0.35	1.0M			60M	T
2N3909,A	Field-Effect Transistors, see Table on Page 176																			
2N3910	S	P			SC	0.5W	A	200	60	50	O	40	160	1.0M	0.3	10M			4.0M	T
2N3911	S	P			SC	0.5W	A	200	60	40	O	60	240	1.0M	0.3	10M			8.0M	T
2N3912	S	P			SC	0.5W	A	200	60	30	O	90		1.0M	0.3	10M			10M	T
2N3913	S	P			SC	0.4W	A	200	60	50	O	40	160	1.0M	0.3	10M			4.0M	T
2N3914	S	P			SC	0.4W	A	200	60	40	O	60	240	1.0M	0.3	10M			8.0M	T
2N3915	S	P			SC	0.4W	A	200	60	30	O	90		1.0M	0.3	10M			10M	T
2N3916	S	N			AP	5.0W	C	150	150	150	O	40	200	0.15A	5.0	0.15A	30	E	50M	T
2N3917	S	N			AP	20W	C	150	80	40	O	30	120	1.0A	1.2	1.0A	15	E	50M	T
2N3918	S	N			AP	20W	C	150	80	40	O	100	300	1.0A	1.2	1.0A	30	E	50M	T
2N3919	S	N			SP	15W	C	150	120	60	O	40	120	2.0A	1.2	10A			80M	T
2N3920	S	N			SP	15W	C	150	120	60	O	100	300	2.0A	1.2	10A			80M	T
2N3921 2N3922	Field-Effect Transistors, see Table on Page 176																			
2N3923	S	N			AH	0.8W	A	200	150	150	O	30	120	25M	1.0	25M	20	E	40M	T
2N3924	S	N		2N3924	AHP	7.0W	C	200	36	18	O								250M	T
2N3925	S	N		2N3924	AHP	10W	C	200	36	18	O								250M	T
2N3926	S	N		2N3924	AHP	11.6W	C	200	36	18	O								250M	T
2N3927	S	N		2N3924	AHP	23.2W	C	200	36	18	O								200M	T
2N3928	S	N			SHP	7.5W	C	175	80	40	O	20	300	1.5A	5.0	1.5A			200M	T
2N3929	S	N			SHP	30W	C	175	80	40	O	20	300	1.5A	5.0	1.5A			200M	T
2N3930	S	P			A	0.4W	A	200	180	180	O	80	300	10M	0.25	10M	100	E	40M	T
2N3931	S	P			A	0.7W	A	200	180	180	O	80	300	10M	0.25	10M	100	E	40M	T
2N3932	S	N			AH	0.2W	A	200	30	20	O	40	150	2.0M			50	E	750M	T
2N3933	S	N			AH	0.2W	A	200	40	30	O	60	200	2.0M			60	E	750M	T
2N3934 2N3935	Field-Effect Transistors, see Table on Page 176																			
2N3936 thru 2N3940	Thyristors, see Table on Page 164																			
2N3941	S	N			AM	0.75W	C	200	60	45	O	400		10*			300	E	200M	T
2N3942	S	N			AM	0.75W	C	200	60	45	O	400		10*			300	E	200M	T
2N3943	S	N			AM	0.5W	C	200	60	45	O	400		10*			300	E	200M	T
2N3944	S	N			AM	0.5W	C	200	60	45	O	400		10*			300	E	200M	T
2N3945	S	N			S	5.0W	C	200	70	50	O	40	250	0.15A	0.5	0.15A			60M	T
2N3946	S	N		2N3946	SH	360M	A	200	60	40	O	50	150	10M	0.3	50M	50	E	250M	T
2N3947	S	N		2N3946	SH	360M	A	200	60	40	O	100	300	10M	0.3	50M	100	E	300M	T
2N3948	S	N		2N3948	AHP	1.0W	A	200	36	20	O	15		50M					700M	T
2N3950	S	N		2N3950	AHP	70W	C	200	65	35	O								150M	T
2N3953	S	N			AH	0.2W	A	200	15	12	O	30	360	2.0M			40	E	1.3G	T
2N3954																				
2N3954,A 2N3955,A 2N3956 thru 2N3958	Field-Effect Transistors, see Table on Page 176																			
2N3959	S	N		2N3959	SH	400M	A	200	20	12	O	40	200	10M	0.3	30M	13	E	1.3G	T
2N3960	S	N		2N3959	SH	400M	A	200	20	12	O	40	200	10M	0.3	30M	16	E	1.6G	T
2N3961	S	N		2N3375	AHP	10W	C	200	65	40	O								400M	T

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N3962	S	P			A	0.36W	A	200	60	60	O	100	300	10*	0.25	10M	100	E	40M	T
2N3963	S	P			A	0.36W	A	200	80	80	O	100	300	10*	0.25	10M	100	E	40M	T
2N3964	S	P			A	0.36W	A	200	45	45	O	250	500	10*	0.25	10M	250	E	50M	T
2N3965	S	P			A	0.36W	A	200	60	60	O	250	500	10*	0.25	10M	250	E	50M	T
2N3966 thru 2N3972	Field-Effect Transistors, see Table on Page 176																			
2N3973	S	N	2N4400	2N4400	S	0.36W	A	150	60	30	O	35	100	10M	0.3	0.15A			200M	T
2N3974	S	N	2N4401	2N4400	S	0.36W	A	150	60	30	O	55	200	10M	0.3	0.15A			200M	T
2N3975	S	N	2N4400	2N4400	S	0.36W	A	150	60	30	O	35	100	10M	0.3	0.15A			200M	T
2N3976	S	N	2N4401	2N4400	S	0.36W	A	150	60	30	O	55	200	10M	0.3	0.15A			200M	T
2N3977	S	P			SC	0.4W	A	200	15	10	O	40		5.0M	0.1	5.0M			1.0M	T
2N3978	S	P			SC	0.4W	A	200	25	20	O	30		5.0M	0.15	5.0M			1.0M	T
2N3979	S	P			SC	0.4W	A	200	40	35	O	20		5.0M	0.15	5.0M			1.0M	T
2N3980	Unijunction Transistors, see Table on Page 184																			
2N3981	S	N			SH	0.8W	A	200	60	30	O	30	120	0.15A	0.4	0.15A			250M	T
2N3982	S	N			SH	0.8W	A	200	50	20	O	40	140	0.15A	0.4	0.15A			250M	T
2N3983	S	N			AH	0.2W	A	150	30	12	O	30		4.0M					500M	T
2N3984	S	N			AH	0.2W	A	150	30	12	O	20		4.0M					400M	T
2N3985	S	N			AH	0.2W	A	150	30	12	O	20		4.0M					300M	T
2N3986 thru 2N3992	Thyristors, see Table on Page 164																			
2N3993	Field-Effect Transistors, see Table on Page 176																			
2N3994	Field-Effect Transistors, see Table on Page 176																			
2N3995	G	P	2N2929	2N2929	AH	0.3W	A	100	20	12	O	40	200	2.0M			150	E	0.6G	T
2N3996	S	N			SHP	2.0W	A	200	100	80	O	40	120	1.0A	0.25	1.0A			40M	T
2N3997	S	N			SHP	2.0W	A	200	100	80	O	80	240	1.0A	0.25	1.0A			40M	T
2N3998	S	N			SHP	2.0W	A	200	100	80	O	40	120	1.0A	0.25	1.0A			40M	T
2N3999	S	N			SHP	2.0W	A	200	100	80	O	80	240	1.0A	0.25	1.0A			40M	T
2N4000	S	N			SHP	1.0W	A	200	100	80	O	30	120	0.5A	0.3	0.5A			40M	T
2N4001	S	N			SHP	1.0W	A	200	120	100	O	40	120	0.5A	0.3	0.5A			40M	T
2N4002	S	N			AP	4.0W	A		100	80	O	20	80	15A			30	E	30M	B
2N4003	S	N			AP	4.0W	A		120	100	O	20	80	15A			30	E	30M	B
2N4004	S	N			AP	1.2W	A		100	80	O	30	150	10A					30M	B
2N4005	S	N			AP	1.2W	A		120	100	O	30	150	10A					30M	B
2N4006	S	P			A	400M	A	200	10	6.0	O						40	E	20M	T
2N4007	S	P			S	400M	A	200	20	15	O						30	E	15M	T
2N4008	S	P			S	400M	A	200	35	30	O						20	E	15M	T
2N4009	Matched Pair 2N4006																			
2N4010	Matched Pair 2N4007																			
2N4011	Matched Pair 2N4008																			
2N4012	S	N		2N4012	AP	11.6W	C	200	65	40	O	4.0	40	1.0A	1.0	0.25A			400M	T
2N4013	S	N			SH	360M	A	200	60	40	O		150	100M					300M	T
2N4014	S	N			SH	360M	A	200	80	50	O		150	100M					300M	T
2N4015	S	P			AM	0.4W	A	200	60	60	O	135	350	1.0M	0.25	50M	135	E	200M	T
2N4016	S	P			AM	0.4W	A	200	60	60	O	135	350	1.0M	0.25	50M	135	E	200M	T
2N4017	S	P			A	600M	A	200	80	80	O	100	500	1.0M					40M	T
2N4018	S	P			A	400M	A	200	60	60	O						100	E	7.0M	E
2N4019	S	P			A	400M	A	200	45	45	O						250	E	50M	T
2N4020	S	P			AM	0.4W	A	200	45	45	O	250	500	10*	0.25	10M	250	E	50M	T
2N4021	S	P			AM	0.4W	A	200	60	60	O	100	350	10*	0.25	10M	100	E	40M	T
2N4022	S	P			AM	0.4W	A	200	60	60	O	250	500	10*	0.25	10M	250	E	50M	T
2N4023	S	P			AM	0.4W	A	200	45	45	O	250	500	10*	0.25	10M	250	E	50M	T
2N4024	S	P			AM	0.4W	A	200	60	60	O	100	350	10*	0.25	10M	100	E	40M	T
2N4025	S	P			AM	0.4W	A	200	60	60	O	250	500	10*	0.25	10M	250	E	50M	T
2N4026	S	P			A	0.5W	A	200	60	60	O	40	120	0.1A	1.0	1.0A			100M	T
2N4027	S	P			A	0.5W	A	200	80	80	O	40	120	0.1A	0.5	0.5A			100M	T
2N4028	S	P			A	0.5W	A	200	60	60	O	100	300	0.1A	1.0	1.0A			150M	T
2N4029	S	P			A	0.5W	A	200	80	80	O	100	300	0.1A	0.5	0.5A			150M	T
2N4030	S	P			A	0.8W	A	200	60	60	O	40	120	0.1A	1.0	1.0A			100M	T
2N4031	S	P			A	0.8W	A	200	80	80	O	40	120	0.1A	0.5	0.5A			100M	T
2N4032	S	P			A	0.8W	A	200	60	60	O	100	300	0.1A	1.0	1.0A			150M	T
2N4033	S	P			A	0.8W	A	200	80	80	O	100	300	0.1A	0.5	0.5A			150M	T
2N4034	S	P			SH	0.36W	A	200	40	40	O	70	200	10M	0.13	1.0M	50	E	400M	T
2N4035	S	P			SH	0.36W	A	200	40	40	O	150	300	10M	0.13	1.0M	150	E	450M	T
2N4036	S	P			S	5.0W	A	200	90	65	O	40	140	0.15A					60M	T
2N4037	S	P			S	1.0W	A	200	60	40	O	50	250	0.15A					60M	T
2N4038 2N4039	Field-Effect Transistors, see Table on Page 176																			
2N4040	S	N			AHP	17.5W	C	200	60	40	O	10	80	0.1A	2.0	1.0A			400M	T
2N4041	S	N			AHP	10W	C	200	60	40	O	10	80	75M	2.0	0.5A			400M	T
2N4042	S	N			AM	0.3W	C	200	60	60	O	200	600	10*	0.35	1.0M			200M	T
2N4043	S	N			AM	0.3W	C	200	45	45	O	80	800	10*	0.35	1.0M			150M	T
2N4044	S	N			AM	0.4W	C	200	60	60	O	200	600	10*	0.35	1.0M			200M	T
2N4045	S	N			AM	0.4W	C	200	45	45	O	80	800	10*	0.35	1.0M			150M	T
2N4046	S	N			SH	800M	A	200	50	30	O		150	100M					250M	T
2N4047	S	N			SH	800M	A	200	80	50	O		150	100M					250M	T
2N4048	G	P		2N4048	AP	170W	C	110	45	30	O	60	120	15A	0.30	60A			2.0K	E
2N4049	G	P		2N4048	AP	170W	C	110	60	45	O	60	120	15A	0.30	60A			2.0K	E
2N4050	G	P		2N4048	AP	170W	C	110	75	60	O	60	120	15A	0.30	60A			2.0K	E
2N4051	G	P		2N4048	AP	170W	C	110	45	30	O	60	180	15A	0.30	60A			2.0K	E
2N4052	G	P		2N4048	AP	170W	C	110	60	45	O	60	180	15A	0.30	60A			2.0K	E
2N4053	G	P		2N4048	AP	170W	C	110	75	60	O	60	180	15A	0.30	60A			2.0K	E
2N4054	S	N			AP	6.25W	C	150	300	300	O	30	90	50M	5.0	75M			15M	T
2N4055	S	N			AP	6.25W	C	150	250	250	O	30	90	50M	5.0	75M			15M	T
2N4056	S	N			AP	6.25W	C	150	200	200	O	30	90	50M	5.0	75M			15M	T
2N4057	S	N			AP	6.25W	C	150	150	150	O	30	90	50M	5.0	75M			15M	T
2N4058	S	P	MPS6522	MPS6516	A	0.25W	A	150	30	30	O	100	400	0.1M	0.7	10M	100	E		
2N4059	S	P	MPS6516	MPS6516	A	0.25W	A	150	30	30	O	45	660	1.0M	0.7	10M	45	E		

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N4060	S	P	MPS6516	MPS6516	A	0.25W	A	150	30	30	O	45	165	1.0M	0.7	10M	45	E		
2N4061	S	P	MPS6517	MPS6516	A	0.25W	A	150	30	30	O	90	330	1.0M	0.7	10M	90	E		
2N4062	S	P	MPS6518	MPS6516	A	0.25W	A	150	30	30	O	180	660	1.0M	0.7	10M	180	E		
2N4063	S	N			AP	10W	C	200	450	350	O	40	160	0.02A					15M	E
2N4064	S	N			AP	10W	C	200	300	250	O	40	160	0.02A					15M	E
2N4065 thru 2N4067	Field-Effect Transistors, see Table on Page 176																			
2N4068	S	N			AH	500M	A	175	150	150	O	30		30M					50M	T
2N4069	S	N			AP	1.0W	C	175	150	150	O	30		0.03A	0.68				50M	T
2N4070	S	N	2N3448	2N3445	AP	115W	C	200	100	80	O	40	120	5.0A	1.5	5.0A	40	E	10M	T
2N4072	S	N		2N4072	AHP	1.5W	C	200	40	20	O	10		25A					550M	T
2N4073	S	N		2N4072	AHP	1.5W	C	200	40	20	O	10		25A					550M	T
2N4074	S	N			AH	400M	A	175	40	40	O						400	E		
2N4075	S	N	2N3764	2N3762	AP	30W	C	200		80	O	30	90						30M	T
2N4076	S	N			AP	30W	C	200		80	O	50	150						30M	T
2N4080	S	P			AHP	300M	A	200	20	15	O	20		3.0M					1.0G	T
2N4081	S	N			AH	200M	A		40	40	O	40	180	2.0M			40	E	600M	T
2N4082 thru 2N4085	Field-Effect Transistors, see Table on Page 176																			
2N4086	S	N	MPS6514	MPS6512	A	200M	A		12	12	O	150	300	2.0M			150	E		
2N4087	S	N	MPS6515	MPS6512	A	200M	A		12	12	O	250	500	2.0M			250	E		
2N4087A	S	N	MPS6515	MPS6512	A	200M	A		12	12	O	250	500	2.0M			250	E		
2N4088 thru 2N4095	Field-Effect Transistors, see Table on Page 176																			
2N4096 thru 2N4098	Thyristors, see Table on Page 164																			
2N4099	S	N			AM	300M	A	200	55	55	O	175		1.0M					150M	T
2N4100	S	N			AM	400M	A	200	55	55	O	175		1.0M					150M	T
2N4101 thru 2N4103	Thyristors, see Table on Page 164																			
2N4104	S	N			AH	300M	A	175	60	60	O						1400	E	540M	T
2N4106	G	P	MP2060	MPS2060	A	1.6W	A		25			70	350	5.0M						
2N4108 thru 2N4110	Thyristors, see Table on Page 164																			
2N4111	S	N			AP	30W	C		100	60	O	40	120	2.0A					70M	T
2N4112	S	N			AP	30W	C		100	60	O	100	300	2.0A					80M	T
2N4113	S	N			AP	30W	C		120	80	O	40	120	2.0A					70M	T
2N4114	S	N			AP	3.0W	A		120	80	O	100	300	2.0A					80M	E
2N4115	S	N			AP	37W	C		120	80	O	40	120	2.0A					70M	E
2N4116	S	N			AP	37W	C		120	80	O	100	300	2.0A					80M	E
2N4117,A thru 2N4120,A	Field-Effect Transistors, see Table on Page 176																			
2N4121	S	P	2N3905	2N3905	AH	200M	A	125	40	40	O	70		10M			50	E	400M	T
2N4122	S	P	2N3906	2N3905	AH	200M	A	125	40	40	O	150		10M			150	E	450M	T
2N4123	S	N		2N4123	SH	310M	A	135	40	30	O	50	150	2.0M	0.3	50M	50	E	250M	T
2N4124	S	N		2N4123	SH	310M	A	135	30	25	O	120	360	2.0M	0.3	50M	120	E	300M	T
2N4125	S	P		2N4125	SH	310M	A	135	30	30	O	50	150	2.0M	0.4	50M	50	E	200M	T
2N4126	S	P		2N4125	SH	310M	A	135	25	25	O	120	360	2.0M	0.4	50M	120	E	250M	T
2N4127	S	N			AP	25W	C		60	40	O	10	80	0.2A					300M	T
2N4128	S	N			AP	40W	C		60	40	O	10	80	0.2A					200M	T
2N4130	S	N			AP	120W	C		80	65	O	10	60	2.0A					1.25M	E
2N4131	S	N			AP	60W	C		90	80	O	10	80	1.0A					150M	E
2N4132	S	N			AHP	7.5W	C	175	90	80	O	10	80	0.2A	0.5	0.6A			200M	T
2N4133	S	N			AHP	3.0W	C	175	90	80	O	10	80	0.2A	0.5	0.6A			200M	T
2N4134	S	N			AH	200M	A	200	30	30	O						200	E	350M	T
2N4135	S	N			AH	200M	A	200	30	30	O						200	E	425M	T
2N4136	Pair of 2N2430 and 2N2431																			
2N4137	S	N			SP	360M	A	200	40	40	O	40	120	10M					500M	T
2N4138	S	N			SC	300M	A	200	30	30	O	50		1.0M					20M	T
2N4139	Field-Effect Transistors, see Table on Page 176																			
2N4140	S	N	2N4400	2N4400	AH	300M	A	125	60	30	O		120	150M					250M	T
2N4141	S	N	2N4401	2N4400	AH	300M	A	125	60	30	O		300	150M					250M	T
2N4142	S	P	2N4402	2N4402	AH	300M	A	125	60	40	O		120	150M					200M	T
2N4143	S	P	2N4403	2N4402	AH	300M	A	125	60	40	O		300	150M					200M	T
2N4144 thru 2N4149	Thyristors, see Table on Page 164																			
2N4150	S	N			AP	5W	C		100	80	O	40	120	5.0A					15M	T
2N4151 thru 2N4204	Thyristors, see Table on Page 164																			
2N4207	S	P			SH	300M	A	200	6.0	6.0	O	50	120	10M					650M	T
2N4208	S	P			SH	300M	A	200	12	12	O	30	120	10M					700M	T
2N4209	S	P			SH	300M	A	200	15	15	O	50	120	10M					850M	T
2N4210	S	N			AP	100W	C		80	60	O	20	100	10A					10M	T
2N4211	S	N			AP	100W	C		100	80	O	20	100	10A					10M	T
2N4212 thru 2N4219	Thyristors, see Table on Page 164																			
2N4220,A thru 2N4224	Field-Effect Transistors, see Table on Page 176																			
2N4225	S	N			AP	5.0W	C		100	40	O	40	150	1.0A					150M	T
2N4226	S	N			AP	5.0W	C		200	60	O	40	150	1.0A					150M	T
2N4227	S	N	2N4400	2N4400	S	300M	A	125	60	30	O		150	150M					250M	T

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N4228	S	P	2N4402	2N4402	AH	300M	A	125	60	40	O		150	150M					200M	T
2N4231	S	N		2N4231	AP	35W	C	200		40	O	25	100	1.5A	0.7	1.5A			1.0M	T
2N4232	S	N		2N4231	AP	35W	C	200		60	O	25	100	1.5A	0.7	1.5A			1.0M	T
2N4233	S	N		2N4231	AP	35W	C	200		80	O	25	100	1.5A	0.7	1.5A			1.0M	T
2N4234	S	P		2N4234	SP	1.0W	A	200	40	40	O	30	150	250M	0.6	1.0A			3.0M	T
2N4235	S	P		2N4234	SP	1.0W	A	200	60	60	O	30	150	250M	0.6	1.0A			3.0M	T
2N4236	S	P		2N4234	SP	1.0W	A	200	80	80	O	30	150	250M	0.6	1.0A			3.0M	T
2N4237	S	P		2N4237	AP	5.0W	C	175	50	40	O	40	160	500M	2.5	1.0A	40	E	10M	T
2N4238	S	P		2N4237	AP	5.0W	C	175	80	60	O	40	160	500M	2.5	1.0A	40	E	10M	T
2N4239	S	P		2N4237	AP	5.0W	C	175	100	60	O	40	160	500M	2.5	1.0A	40	E	10M	T
2N4240	S	N			AP	35W	C		440	300	O	30	240	0.75A					15M	T
2N4241	G	P			A	37.5W	C		32	20	O	60	300	300M	0.35	5.0A				
2N4242	G	P			AP	105W	A		80	60	O	40	80	5.0A					500K	T
2N4243	G	P			AP	105W	A		60	45	O	40	80	5.0A					500K	T
2N4244	G	P			AP	105W	A		40	30	O	40	80	5.0A					500K	T
2N4245	G	P			AP	105W	A		80	60	O	60	120	5.0A					500K	T
2N4246	G	P			AP	105W	A		60	45	O	60	120	5.0A					500K	T
2N4247	G	P			AP	105W	A		40	30	O	60	120	5.0A					500K	T
2N4248	S	P	2N5086	2N5086	A	200M	A	125	40	40	O						50	E	40M	T
2N4249	S	P	2N5086	2N5086	A	200M	A	125	60	60	O						100	E	40M	T
2N4250	S	P	2N5087	2N5086	A	200M	A	125	40	40	O						250	E	40M	T
2N4251	S	N			S	250M	A	200	15	10	O	100		10M					1300M	T
2N4252	S	N			AH	200M	A	175	30	18	O	50		2.0M					600M	T
2N4253	S	N			AH	200M	A	175	30	18	O	30		2.0M					600M	T
2N4254	S	N	MPS6547	MPS6546	A	200M	A	175	30	18	O	50		2.0M						
2N4255	S	N	MPS6547	MPS6546	A	200M	A	175	30	18	O	30		2.0M						
2N4256	S	N	2N3904	2N3903	A	200M	A		30	30	S		500	2.0M						
2N4257	S	P			SH	200M	A	125	6.0	6.0	O	30	120	10M					500M	T
2N4258	S	P			SH	200M	A	125	12	12	O	30	120	10M					700M	T
2N4259	S	N			A H	175M	A	175	40	30	O						70	E		
2N4260	S	P		2N4260	SH	200M	A	200	15	15	O	30	150	10M	15	10M	16	E	1500M	T
2N4261	S	P		2N4260	SH	200M	A	200	5.0	15	O	30	150	15A	15	10M	20	E	2000M	T
2N4262	S	N			AP	1.5W	C		25	10	O	75		0.3A					600M	T
2N4263	S	N			AP	1.5W	C		25	10	O	75		0.3A					800M	T
2N4264	S	N		2N4264	S	310M	A	135	30	15	O	40	160	10M					300M	T
2N4265	S	P		2N4264	SH	310M	A	135	30	12	O	100	400	15A	0.22	10M			300M	T
2N4267 thru 2N4268	Field-Effect Transistors, see Table on Page 176																			
2N4269	S	N			A	360M	A	200	200	140	O		200	10M						
2N4270	S	N			A	580M	A	200	200	140	O		200	10M						
2N4271	S	N			AP	5.0W	C		175	140	O	20	140	0.2A					20M	T
2N4272	S	N			AP	5.0W	C		175	140	O	20	140	1.0A					10M	T
2N4273	S	N			AP	25W	C		175	140	O	20	140	1.0A					10M	T
2N4274	S	N			SH	280M	A	125	30	12	O	18		100M					400M	T
2N4275	S	N			S H	280M	A	125	40	15	O	18		100M					400M	T
2N4276	G	P		2N4276	AP	170W	C	110	30	20	O	60	120	15A	0.15	15A			2.0K	E
2N4277	G	P		2N4276	AP	170W	C	110	30	20	O	80	180	15A	0.15	15A			2.0K	E
2N4278	G	P		2N4276	AP	170W	C	110	45	30	O	60	120	15A	0.15	15A			2.0K	E
2N4279	G	P		2N4276	AP	170W	C	110	45	30	O	80	180	15A	0.15	15A			2.0K	E
2N4280	G	P		2N4276	AP	170W	C	110	60	45	O	60	120	15A	0.15	15A			2.0K	E
2N4281	G	P		2N4276	AP	170W	C	110	60	45	O	80	180	15A	0.15	15A			2.0K	E
2N4282	G	P		2N4276	AP	170W	C	110	75	60	O	60	120	15A	0.15	15A			2.0K	E
2N4283	G	P		2N4276	AP	170W	C	110	75	60	O	80	180	15A	0.15	15A			2.0K	E
2N4284	S	P			A	250M	A	165	25	25	O		600	1.0M						
2N4285	S	P			A	250M	A	165	35	35	O		600	1.0M						
2N4286	S	N	MPS6515		A	250M	A	150	30	25	O						600	E	40M	T
2N4287	S	N	MPS6566		A	250M	A	150	45	45	O						600	E	40M	T
2N4288	S	P	MPS6518	MPS6516	A	250M	A	150	30	25	O						600	E	40M	T
2N4289	S	P	2N5086		A	250M	A	150	60	45	O						600	E	40M	T
2N4290	S	P	MPS6533	MPS6530	A	250M	A	150	30	20	O						600	E	40M	T
2N4291	S	P	MPS6534	MPS6530	A	250M	A	150	40	30	O						600	E	40M	T
2N4292	S	N	MPS918	MPS918	A	200M	A	150	30	15	O	20		3.0M					600M	T
2N4293	S	N	MPS918	MPS918	A	200M	A	150	30	15	O						60	E	600M	T
2N4294	S	N	2N4264	2N4264	SH	200M	A	150	30	12	O	30	120	10M					400M	T
2N4295	S	N	2N4264	2N4264	SH	200M	A	150	40	15	O	40	120	10M					500M	T
2N4296	S	N			SP	20W	C		350	250	O	50	150	0.05A					20M	T
2N4297	S	N			AP	20W	C		350	250	O	75	300	0.05A					20M	T
2N4298	S	N			AP	20W	C		500	350	O	25	75	0.05A					20M	T
2N4299	S	N			AP	20W	C		500	350	O	50	150	0.05A					20M	T
2N4300	S	N			AP	15W	C		100	80	O	30	120	1.0A					30M	T
2N4301	S	N			AP	50W	C		100	80	O	30	120	5.0A					40M	T
2N4302 thru 2N4304	Field-Effect Transistors, see Table on Page 176																			
2N4305	S	N			AP	1.5W	A		120	80	O	50	150	1.0A						
2N4306	S	N			AP	4.0W	A		120	80	O	50	150	1.0A						
2N4307	S	N			AP	1.5W	A		100	60	O	50	150	1.0A						
2N4308	S	N			AP	4.0W	A		100	60	O	50	150	1.0A						
2N4309	S	N			AP	1.5W	A		120	80	O	50	150	1.0A						
2N4310	S	N			AP	4.0W	A		120	80	O	40	120	1.0A						
2N4311	S	N			AP	1.5W	A		100	60	O	40	120	1.0A						
2N4312	S	N			AP	4.0W	A		100	60	O	40	120	1.0A						
2N4313	S	P			SC	200M	A	125	12	12	O	30	120	30M					700M	T
2N4314	S	P			AP	1.0W	A		90	65	O	50	250	0.15A					200M	T
2N4316 thru 2N4319	Thyristors, see Table on Page 164																			

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N4338 thru 2N4343	Field-Effect Transistors, see Table on Page 176																			
2N4346					AP	5.0W	A			60	0									
2N4347	S	N			AP	100W	C		140	120	0	15	60	2.0A						
2N4348	S	N			AP	120W	C		140	120	0	15	60	5.0A						
2N4350	S	N			AP	7.0W	C		65	40	0	10	200	0.35A					300M	T
2N4351 2N4352 2N4353	Field-Effect Transistors, see Table on Page 176																			
2N4354	S	P			A	350M	A	125	60	60	0	25		0.1M					500M	T
2N4355	S	P			A	350M	A	125	60	60	0	60		0.1M					500M	T
2N4356	S	P			A	350M	A	125	80	80	0	25		0.1M					500M	T
2N4357	S	P			A	400M	A	200	240	240	0	80	300	10M	0.5	10M	100	E	40M	T
2N4358	S	P			A	400M	A	200	240	240	0	80	300	10M	0.5	10M	100	E	40M	T
2N4359	S	P			A	360M	A	200	45	45	0	50	600	1.0M	0.25	10M	50	E		
2N4360	Field-Effect Transistors, see Table on Page 176																			
2N4361 thru 2N4380	Thyristors, see Table on Page 164																			
2N4381 2N4382	Field-Effect Transistors, see Table on Page 176																			
2N4383	S	N			AH	800M	A	200	40	30	0						1000	E	120M	T
2N4384	S	N			AH	500M	A	200	40	30	0						1000	E	120M	T
2N4385	S	N			AH	800M	A	200	40	30	0						1000	E	120M	T
2N4386	S	N			AH	500M	A	200	40	30	0						1000	E	120M	T
2N4387	S	P				20W	A	200	40	40	0	25	100	500M						
2N4388	S	P				20W	A	200	60	60	0	25	100	500M						
2N4389	S	P			SH	200M	A	125	12	12	0	30	180	10M	0.15	10M	4.0	E		
2N4390	S	N			S	500M	A	175	120	120	0	20		2.0M					50M	T
2N4391 thru 2N4393	Field-Effect Transistors, see Table on Page 176																			
2N4395	S	N	2N3715	2N3713	AP	62.5W	C		60	40	0	50	170	2.0A					4M	T
2N4396	S	N	2N3715	2N3713	AP	62.5W	C		80	60	0	40	170	2.0A					4M	T
2N4397	S	N			AM	200M	A		40	40	0	40	180	2.0M			40	E	600M	T
2N4398	S	P		2N4398	AP	200W	C	200	40	40	0	15	60	15A	1.0	15A	40	E	4M	T
2N4399	S	P		2N4398	AP	200W	C	200	60	60	0	15	60	15A	1.0	15A	40	E	4M	T
2N4400	S	N		2N4400	SH	310M	A	135	60	40	0	50	150	150M	0.4	150M	20	E	200M	T
2N4401	S	N		2N4400	SH	310M	A	135	60	40	0	100	300	150M	0.4	150M	40	E	250M	T
2N4402	S	P		2N4402	SH	310M	A	135	40	40	0	50	150	150M	0.4	150M	30	E	150M	T
2N4403	S	P		2N4402	SH	310M	A	135	40	40	0	100	300	150M	0.4	150M	60	E	200M	T
2N4404	S	P		2N4404	A	5.0W	C		80	80	0	40	120	150M	0.15	10M			200M	T
2N4405	S	P		2N4404	A	5.0W	C		80	80	0	100	300	150M	0.15	10M			200M	T
2N4406	S	P		2N4406	A	5.0W	C		80	80	0	30	120	500M	0.2	150M			150M	T
2N4407	S	P		2N4406	A	5.0W	C		80	80	0	80	240	500M	0.2	150M			150M	T
2N4409	S	N		2N4409	S	310M	A	135	80	50	0	60	400	1.0M	0.2	1.0M				
2N4410	S	N		2N4409	S	310M	A	135	120	80	0	60	400	1.0M	0.2	1.0M				
2N4411	S	P			S	150M	A	200	15	12	0	40		0.5M					400M	T
2N4412	S	N			AH	600M	A	200	40	30	0						1000	E	100M	T
2N4412A	S	P			AH	600M	A	200	60	60	0						120	E	20M	T
2N4413	S	P			AH	400M	A	200	40	30	0						1000	E	100M	T
2N4413A	S	P			AH	400M	A	200	60	60	0						120	E	20M	T
2N4414	S	P			AH	600M	A	200	40	30	0						1000	E	100M	T
2N4414A	S	P			AH	600M	A	200	60	60	0						100	E	20M	T
2N4415	S	P			AH	400M	A	200	40	30	0						1000	E	100M	T
2N4415A	S	P			AH	400M	A	200	60	60	0						100	E	20M	T
2N4416 2N4416A 2N4417	Field-Effect Transistors, see Table on Page 176																			
2N4418	S	N	2N4264	2N4264	S	250M	A	125	40	40	S	40	120	10M					500M	T
2N4419	S	N	2N4264	2N4264	S	250M	A	125	30	30	S	30		10M					400M	T
2N4420	S	N	MPS3646	MPS3646	S	250M	A	125	40	40	S	30	120	30M					350M	T
2N4421	S	N	MPS3646	MPS3646	S	250M	A	125	30	30	S	25		30M					300M	T
2N4422	S	N	MPS3646	MPS3646	S	250M	A	125	40	40	S	30	120	30M					350M	T
2N4423	S	N	MPS3640	MPS3646	S	250M	A	125	12	12	S	40	150	30M					400M	T
2N4424	S	N	MPS3711	MPS3707	S	360M	A	150	40	40	0						180	E		
2N4425	S	N			S	560M	A	150	40	40	0	180		2M						
2N4427	S	N			AP	3.5W	C		40	20	0	10	200	0.1A					500M	T
2N4428	S	N			AP	3.5W	C		55	35	0	20	200	0.05A					700M	T
2N4429	S	N			AP	5.0W	C		55	35	0	20	200	0.05A					700M	T
2N4430	S	N			AP	10W	C		55	40	0	20	200	0.1A					600M	T
2N4431	S	N			AP	18W	C		55	40	0	20	200	0.1A					600M	T
2N4432	S	N			AH	600M	A		50	30	0	40	130	6.0M			45	E		
2N4432A	S	N			AH	600M	A		50	30	0	80	150	6.0M			90	E		
2N4436	S	N			AHP	200M	A	125	60	30	0	40	120	150M	0.22	150M			250M	T
2N4437	S	N			AHP	200M	A	125	60	30	0	100	300	150M	0.22	150M			250M	T
2N4438	S	N			A	1.0W	A	200	300	300	0	40	120	50M	1.0	100M			30M	T
2N4439	S	N			A	1.0W	A	200	300	300	0	100	240	50M	1.0	100M			30M	T
2N4440	S	N			AP	11.6W	C		65	40	0	10	200	0.125A					400M	T
2N4441 thru 2N4444	Thyristors, see Table on Page 164																			
2N4445 thru 2N4448	Field-Effect Transistors, see Table on Page 176																			
2N4449	S	N			SH	0.3W	A			40	0	40		10M	0.18	10M			500M	T
2N4450	S	N			SH	3.0W	C	200	60	30	0	75		10M	0.22	150M			250M	T

						MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N4451	S	P			S	0.3W	A			12	0	40		30M	0.25	30M			400M	T
2N4452	S	P			S	0.35W	A	200	45	45	0	115	300	50M	0.4	15M	135	E	200M	T
2N4453	S	P			S	0.3W	A			18	0	40		30M	0.25	30M			400M	T
2N4576	S	N	2N3716	2N3713	AHP	150W	C	200	100	80	0	50	150	1.0A	0.8	5.0A	25	E	30K	E
2N4851 thru 2N4853	Unijunction Transistors, see Table on Page 184																			
2N4854	Complementary Pair				SH	300M	A	200	60	40	0	50		1.0M					200M	T
2N4855					SH	300M	A	200	60	40	0	25		1.0M					200M	T
2N4856 thru 2N4861	Field-Effect Transistors, see Table on Page 176																			
2N4862	S	N			AP			200	140	120	0	50	150	0.5A	0.2	0.5A	50	E	50M	T
2N4863	S	N			AP			200	140	120	0	50	150	0.5A	0.2	0.5A	50	E	50M	T
2N4864	S	N			AP			200	140	120	0	50	150	0.5A	0.2	0.5A	50	E	50M	T
2N4865	S	N			SP	350W	C	200	100	80	0	10	40	70A	1.5	50A			10M	T
2N4866	S	N			SP	350W	C	200	140	120	0	10	40	70A	1.5	50A			10M	T
2N4867,A thru 2N4869,A	Field-Effect Transistors, see Table on Page 176																			
2N4870 2N4871	Unijunction Transistors, see Table on Page 184																			
2N4872	S	P			SH	700M	C	200	12	12	0	50	120	10M	0.13	1.0M	9.0	E		
2N4873	S	N			SH	360M	A	200	40	15	0	110	150	10M	0.2	10M	7.0	E		
2N4874	S	N			AH	720M	A	175	30	20	0						200	E	900M	T
2N4875	S	N			AH	720M	A	175	40	25	0						200	E	800M	T
2N4876	S	N			AH	720M	A	175	40	30	0						200	E	650M	T
2N4877	S	N			AP	10W	C	200		60	0	20	100	4.0A	1.0	4.0A			4.0M	T
2N4878	S	N			AM	300M	C		60	60	0	200	600	10*	0.35	1.0M			200M	T
2N4879	S	N			AM	300M	C		55	55	0	150	600	10*	0.35	1.0M			150M	T
2N4880	S	N			AM	300M	C		45	45	0	80	800	10*	0.35	1.0M			150M	T
2N4881 thru 2N4886	Field-Effect Transistors, see Table on Page 176																			
2N4888	S	P			A	300M	A	125	150	150	0	40	400	10M	0.5	10M			30M	T
2N4889	S	P			A	300M	A	125	150	150	0	80	300	10M	0.5	10M			40M	T
2N4890	S	P		2N4890	S	1.0W	A		60	40	0	50	250	150M	1.4	150M	5.0	E		
2N4891 thru 2N4894	Unijunction Transistors, see Table on Page 184																			
2N4895	S	N			SP	4.0W	C	200	120	60	0	100	300	2.0A	1.0	5.0A	4.0	E		
2N4896	S	N			SP	4.0W	C	200	120	60	0	40	120	2.0A	1.0	5.0A	2.5	E		
2N4897	S	N			SP	4.0W	C	200	150	80	0	40	120	2.0A	1.0	5.0A	2.5	E		
2N4898	S	P		2N4898	AP	25W	C	200	40	40	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4899	S	P		2N4898	AP	25W	C	200	60	60	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4900	S	P		2N4898	AP	25W	C	200	80	80	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4901	S	P		2N4901	AP	87.5W	C	200	40	40	0	20	80	1.0A	0.4	1.0A	20	E	4.0M	T
2N4902	S	P		2N4901	AP	87.5W	C	200	60	60	0	20	80	1.0A	0.4	1.0A	20	E	4.0M	T
2N4903	S	P		2N4901	AP	87.5W	C	200	80	80	0	20	80	1.0A	0.4	1.0A	20	E	4.0M	T
2N4904	S	P		2N4904	AP	87.5W	C	200	40	40	0	25	100	2.5A	1.0	2.5A	40	E	4.0M	T
2N4905	S	P		2N4904	AP	87.5W	C	200	60	60	0	25	100	2.5A	1.0	2.5A	40	E	4.0M	T
2N4906	S	P		2N4904	AP	87.5W	C	200	80	80	0	25	100	2.5A	1.0	2.5A	40	E	4.0M	T
2N4907	S	P			AP	150W	C	200		40	0	20	80	4.0A	0.75	4.0A			4.0M	T
2N4908	S	P			AP	150W	C	200		60	0	20	80	4.0A	0.75	4.0A			4.0M	T
2N4909	S	P			AP	150W	C	200		80	0	20	80	4.0A	0.75	4.0A			4.0M	T
2N4910	S	N		2N4910	AP	25W	C	200	40	40	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4911	S	N		2N4910	AP	25W	C	200	60	60	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4912	S	N		2N4910	AP	25W	C	200	80	80	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4913	S	N		2N4913	AP	87.5W	C	200	40	40	0	25	100	2.5A	1.0	2.5A	20	E	4.0M	T
2N4914	S	N		2N4913	AP	87.5W	C	200	60	60	0	25	100	2.5A	1.0	2.5A	20	E	4.0M	T
2N4915	S	N		2N4913	AP	87.5W	C	200	80	80	0	25	100	2.5A	1.0	2.5A	20	E	4.0M	T
2N4916	S	P			SH	500M	C	125	30	30	0	70	200	10M	0.14	10M			400M	T
2N4917	S	P			SH	500M	C	125	30	30	0	150	300	10M	0.14	10M			450M	T
2N4918	S	P		2N4918	AP	30W	C	150	40	40	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4919	S	P		2N4918	AP	30W	C	150	60	60	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4920	S	P		2N4918	AP	30W	C	150	80	80	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4921	S	N		2N4921	AP	30W	C	150	40	40	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4922	S	N		2N4921	AP	30W	C	150	60	60	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4923	S	N		2N4921	AP	30W	C	150	80	80	0	20	100	0.5A	0.6	1.0A	25	E	3.0M	T
2N4924	S	N		2N4924	AH	1.0W	A	175	100	100	0	40	200	150M	0.4	50M			100M	T
2N4925	S	N		2N4924	AH	1.0W	A	175	150	150	0	40	200	150M	0.4	50M			100M	T
2N4926	S	N		2N4926	AH	1.0W	A	175	200	200	0	20	200	30M	2.0	30M	25	E	300M	T
2N4927	S	N		2N4926	AH	1.0W	A	175	250	250	0	20	200	30M	2.0	30M	25	E	300M	T
2N4928	S	P		2N4928	A	3.0W	C		100	100	0	25	200	10M	0.5	10M			100M	T
2N4929	S	P		2N4928	A	5.0W	C		150	150	0	25	200	10M	0.5	10M			100M	T
2N4930	S	P		2N4928	A	5.0W	C		200	200	0	20	200	10M	5.0	10M			20M	T
2N4931	S	P		2N4928	A	5.0W	C		250	250	0	20	200	10M	5.0	10M			20M	T
2N4932	S	N			AP	70W	C		50	25	0	10	100	1.0A					100M	T
2N4933	S	N			AP	70W	C		70	35	0	10	100	1.0A					100M	T
2N4934	S	N			AH	200M	A		40	30	0	40	170	2.0M					700M	T
2N4935	S	N			AH	200M	A		50	40	0	60	200	2.0M					700M	T
2N4936	S	N			AH	200M	A		50	40	0	60	250	2.0M			70	E	700M	T
2N4937	S	P		2N4937	AM	600M	A	200	50	40	0	50	250	1.0M			50	E	300M	T
2N4938	S	P		2N4937	AM	600M	A	200	50	40	0	50	250	1.0M			50	E	300M	T
2N4939	S	P		2N4937	AM	600M	A	200	50	40	0	50	250	1.0M			50	E	300M	T
2N4940	S	P		2N4937	AM	600M	A	200	50	40	0	50	250	1.0M			50	E	300M	T
2N4941	S	P		2N4937	AM	600M	A	200	50	40	0	50	250	1.0M			50	E	300M	T
2N4942	S	P		2N4937	AM	600M	A	200	50	40	0	50	250	1.0M			50	E	300M	T

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N4943	S	N			AP	800M	A		120	80	0	100	300	150M	0.25	150M			45M	T
2N4944	S	N			A	600M	C	125	80	40	0	40	100	150M	0.25	150M			60M	T
2N4945	S	N			A	600M	C	125	80	60	0	40	100	150M	0.25	150M			60M	T
2N4946	S	N			A	600M	C	125	80	40	0	100	300	150M	0.25	150M			60M	T
2N4947																				
2N4948	Unijunction Transistors, see Table on Page 184																			
2N4949																				
2N4950	S	N			SP	300W	C		80	60	0	10		50A	1.5	50A			100K	T
2N4951	S	N			A	360M	A	150	60	30	0	60	200	150M	0.3	150M			250M	T
2N4952	S	N			A	360M	A	150	60	30	0	100	300	150M	0.3	150M			250M	T
2N4953	S	N			A	360M	A	150	60	30	0	200	600	150M	0.3	150M			250M	T
2N4954	S	N			A	360M	A	150	40	30	0	60	600	150M	0.3	150M			250M	T
2N4955	S	N			AL	750M	C	125	30	25	0	60	600	10*	0.35	1.0M	150	E	60M	T
2N4956	S	N			AM	750M	C	125	30	25	0	60	600	10*	0.35	1.0M	150	E	60M	T
2N4957	S	P		2N4957	A	200M	A	200	30	30	0	20	40	2.0M					1200M	T
2N4958	S	P		2N4957	A	200M	A	200	30	30	0	20	40	2.0M					1000M	T
2N4959	S	P		2N4957	A	200M	A	200	30	30	0	20	40	2.0M					1000M	T
2N4960	S	N			A	800M	A	200	60	60	0	100	300	150M	0.7	10M			250M	T
2N4961	S	N			A	500M	A	200	80	80	0	100	300	150M	0.7	10M			250M	T
2N4962	S	N			A	800M	A	200	60	60	0	100	300	150M	0.7	10M			250M	T
2N4963	S	N			A	500M	A	200	80	80	0	100	300	150M	0.7	10M			250M	T
2N4964	S	P			A	200M	A		50	40	0	30	120	10*	0.4	10M	40	E		
2N4965	S	P			A	200M	A		50	40	0	80	400	10*	0.4	10M	100	E		
2N4966	S	N			A	200M	A		50	40	0	40	200	10*	0.4	10M	40	E		
2N4967	S	N			A	200M	A		50	40	0	100	600	10*	0.4	10M	100	E		
2N4968	S	N			A	200M	A		30	25	0	40	200	10*	0.4	10M	40	E		
2N4969	S	N			SH	200M	A		50	30	0	40	120	150M	0.4	150M				
2N4970	S	N			SH	200M	A		50	30	0	100	350	150M	0.4	150M				
2N4971	S	P			SH	200M	A		50	40	0	40	120	150M	0.4	150M				
2N4972	S	P			SH	200M	A		50	40	0	100	300	150M	0.4	150M				
2N4973	S	P			AH	200M	A		20	15	0	20		3.0M	0.5	10M				
2N4974	S	P		2N4974	AL	800M	A	200	40	30	0	5000	9000	1.0*			25000	E	175M	T
2N4975	S	P		2N4974	AL	800M	A	200	40	30	0	1000	4000	1.0*			15000	E	175M	T
2N4976	S	N			AHP	5.0W	C		55	30	0	20	250	50M					1000M	T
2N4977																				
thru	Field-Effect Transistors, see Table on Page 176																			
2N4979																				
2N4980	S	P			SC	400M	A		30	30	0	60	300	1.0M					10M	T
2N4981	S	P			SC	400M	A		50	50	0	40	200	1.0M					5.0M	T
2N4982	S	P			SC	400M	A		70	70	0	30	150	1.0M					3.0M	T
2N4983																				
thru	Thyristors, see Table on Page 164																			
2N4993																				
2N4994	S	N				200M	A		60	45	0	40	160	10M						
2N4995	S	N			AH	200M	A		60	45	0	100	400	10M						
2N4996	S	N			AH	200M	A		30	18	0	50		2M						
2N4997	S	N			AH	200M	A		30	18	0	30	150	2M						
2N4998	S	N			AP	35W	C	200	100	80	0	30	90	1.0A	5.0	3.0A	20	E	50M	T
2N4999	S	P			AP	35W	C	200	100	80	0	30	90	1.0A	5.0	3.0A	20	E	50M	T
2N5000	S	N			AP	35W	C	200	100	80	0	70	200	1.0A	5.0	3.0A	50	E	60M	T
2N5001	S	P			AP	35W	C	200	100	80	0	70	200	1.0A	5.0	3.0A	50	E	60M	T
2N5002	S	N			AP	58W	C	200	100	80	0	30	90	2.5A	1.5	5.0A	20	E	60M	T
2N5003	S	P			AP	58W	C	200	100	80	0	30	90	2.5A	1.5	5.0A	20	E	60M	T
2N5004	S	N			AP	58W	C	200	100	80	0	70	200	2.5A	1.5	5.0A	50	E	70M	T
2N5005	S	P			AP	58W	C	200	100	80	0	70	200	2.5A	1.5	5.0A	50	E	70M	T
2N5006	S	N			AP	118W	C	200	100	80	0	30	90	5.0A	1.5	10A	20	E	30M	T
2N5007	S	P			AP	118W	C	200	100	80	0	30	90	5.0A	1.5	10A	20	E	30M	T
2N5008	S	N			AP	118W	C	200	100	80	0	70	200	5.0A	1.5	10A	50	E	40M	T
2N5009	S	P			AP	118W	C	200	100	80	0	70	200	5.0A	1.5	10A	50	E	40M	T
2N5010	S	N			A	2.0W	C		500	500	R	30	180	25M	1.4	25M				
2N5011	S	N			A	2.0W	C		600	600	R	30	180	25M	1.5	25M				
2N5012	S	N			A	2.0W	C		700	700	R	30	180	25M	1.6	25M				
2N5013	S	N			A	2.0W	C		800	800	R	30	180	20M	1.6	20M				
2N5014	S	N			A	2.0W	C		900	900	R	30	180	20M	1.6	20M				
2N5015	S	N			A	2.0W	C		1000	1000	R	30	180	20M	1.8	20M				
2N5016	S	N			AHP				65	30	0	10	200	0.5A					500M	T
2N5017	S	N			AHP				65	30	0	10	200	0.5A					500M	T
2N5018																				
thru	Field-Effect Transistors, see Table on Page 176																			
2N5021																				
2N5022	S	P			SH	1.0W	A		50	50	0	25	100	500M	0.2	100M				
2N5023	S	P			SH	1.0W	A		30	30	0	40	100	500M	0.17	100M				
2N5024	S	N			SH	200M	A		20	10	0	25		10M			13	E	1300M	T
2N5025	S	N			AHP	45W	C	300	75	75	0	20		2.0A	1.0	2.0A				
2N5026	S	N			AHP	45W	C	300	90	90	0	20		2.0A	1.0	2.0A				
2N5027	S	N			S	320M	A	120		30	0	50	150	150M	0.45	150M				
2N5028	S	N			S	320M	A	120		30	0	100	300	150M	0.45	150M				
2N5029	S	N				320M	A	120		15	0	40	120	10M	0.25	10M				
2N5030	S	N				320M	A	120		12	0	30		10M	0.25	10M				
2N5033	Field-Effect Transistors, see Table on Page 176																			
2N5034	S	N			AP	83W	C	150	55	45	R	20	70	2.5A	2.5	6.0A	15	E		
2N5035	S	N			AP	83W	C	150	55	45	R	20	70	3.0A	3.0	8.0A	15	E		
2N5036	S	N			AP	83W	C	150	70	60	R	20	70	2.5A	2.5	6.0A	15	E		
2N5037	S	N			AP	83W	C	150	70	60	R	20	70	3.0A	3.0	8.0A	15	E		
2N5038	S	N			SP	140W	C	200	150	150	V	20	100	12A	2.5	20A				
2N5039	S	N			SP	140W	C	200	120	120	V	20	100	10A	2.5	20A				
2N5040	S	P			A	300M	A	125	25	25	0	30	600	150M	1.0	0.5A			100M	T
2N5041	S	P			A	300M	A	125	40	40	0	40	150	150M	0.5	0.5A			80M	T

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N5042	S	P			A	800M	A	200	40	40	0	40	150	150M	1.1	0.5A			100M	T
2N5043	G	P				30M	A	125	15	7.0	0		150	3.0M						
2N5044	G	P				30M	A	125	15	7.0	0		150	3.0M						
2N5045																				
thru	Field-Effect Transistors, see Table on Page 176																			
2N5047																				
2N5048	S	N			SP	100W	C	175	120	100	0	15	60	10A	2.0	10A			10M	T
2N5049	S	N			SP	100W	C	175	60	50	0	15	60	10A	2.5	10A			10M	T
2N5050	S	N			AP	40W	C	200		120	0	35	105	0.5A	0.9	0.5A			20M	T
2N5051	S	N			AP	40W	C	200		150	0	35	105	0.5A	0.9	0.5A			20M	T
2N5052	S	N			AP	40W	C	200		200	0	35	105	0.5A	0.9	0.5A			20M	T
2N5053	S	N			AH	200M	A	200	30	15	0	25	150	2.0M					1300M	T
2N5054	S	N			AH	200M	A	200	30	15	0	25	150	2.0M					1300M	T
2N5055	S	P			SH	200M	A	125	12	12	0	30	100	30M	0.13	1.0M				
2N5056	S	P			SH	360M	A	200	15	15	0	30	100	30M	0.13	1.0M				
2N5057	S	P			SH	360M	A	200	15	15	0	40	100	30M	0.13	1.0M				
2N5058	S	N				1.0W	C	200	300	300	0	35	150	30M						
2N5059	S	N				1.0W	C	200	250	250	0	30	150	30M						
2N5060																				
thru	Thyristors, see Table on Page 164																			
2N5064																				
2N5065	S	N			SH	2.5W	C	200	25	15	0	50	120	300M	0.23	100M			550M	T
2N5066	S	N			SC	400M	A		30	20	0								5.0M	T
2N5067	S	N		2N5067	AP	87.5W	C	200	40	40	0	20	80	1.0A	0.4	1.0A	20	E	4.0M	T
2N5068	S	N		2N5067	AP	87.5W	C	200	60	60	0	20	80	1.0A	0.4	1.0A	20	E	4.0M	T
2N5069	S	N		2N5067	AP	87.5W	C	200	80	80	0	20	80	1.0A	0.4	1.0A	20	E	4.0M	T
2N5070	S	N			AHP	70W	C		65	30	0	10	100	3.0A					100M	T
2N5071	S	N			AHP	70W	C		65	30	0	10	100	3.0A					100M	T
2N5072	S	N			AHP	125W	C		100	100	R	15	60	3.0A	1.0	10A			40M	T
2N5073	S	N			AH	600M	A		180	120	0	30	120	200M					40M	T
2N5074	S	N			AP	70W	C	200	200	200	0	30	110	0.5A	2.0	3.0A	30	E	40M	T
2N5075	S	N			AP	70W	C	200	200	200	0	90	250	0.5A	2.0	3.0A	30	E	40M	T
2N5076	S	N			AP	70W	C	200	250	250	0	30	110	0.5A	2.0	3.0A	30	E	40M	T
2N5077	S	N			AP	70W	C	200	250	250	0	90	250	0.5A	2.0	3.0A	30	E	40M	T
2N5078	Field-Effect Transistors, see Table on Page 176																			
2N5079	S	N			A	1.8W	C		60	30	0	100	300	150M	0.2	150M			400M	T
2N5080	S	N			A	1.8W	C		60	30	0	200	500	150M	0.2	150M			500M	T
2N5081	S	N			AH	1.2W	C		70	50	0	100	400	1.0M	0.2	10M	100	E	600M	T
2N5082	S	N			AH	1.2W	C		60	30	0	100	400	1.0M	0.2	10M	100	E	600M	T
2N5083	S	N			SP	35W	C	200	120	60	0	40	120	2.0A	1.0	10A			50M	T
2N5084	S	N			SP	35W	C	200	120	60	0	100	300	2.0A	1.0	10A			80M	T
2N5085	S	N			SP	35W	C	200	150	80	0	40	120	2.0A	1.0	10A			50M	T
2N5086	S	P		2N3086	A	310M	A	135	50	50	0	150	500	0.1M	0.3	10M	150	E	40M	T
2N5087	S	P		2N3086	A	310M	A	135	50	50	0	250	800	0.1M	0.3	10M	250	E	40M	T
2N5088	S	N		2N5088	A	310M	A	135	35	30	0	300	900	0.1M	0.5	10M	350	E	50M	T
2N5089	S	N		2N5088	A	310M	A	135	30	25	0	400	1200	0.1M	0.5	10M	450	E	50M	T
2N5090	S	N			AHP			200	55	30	0	10	200	50M	1.0	100M			500M	T
2N5091	S	P			A			175	350	300	0	40	250	25M	3.0	25M			20M	T
2N5092	S	N			A			175	400	350	0	50	300	25M	0.5	25M			50M	T
2N5093	S	P			A			175	400	350	0	40	250	25M	3.0	25M			20M	T
2N5094	S	P			A			175	450	400	0	40	250	25M	3.0	25M			20M	T
2N5095	S	N			A			175	500	400	0	50	300	25M	0.5	25M			50M	T
2N5096	S	P			A			175	500	450	0	40	250	25M	3.0	25M			20M	T
2N5097	S	N			A			175	600	450	0	50	300	25M	0.5	25M			50M	T
2N5098	S	N			A			175	700	500	0	50	300	25M	0.5	25M			50M	T
2N5099	S	N			A			175	800	550	0	50	300	25M	0.5	25M			50M	T
2N5100	S	P			A			175	450	400	0	40	250	25M	3.0	25M			20M	T
2N5101	S	N			A			175	500	400	0	50	300	25M	0.5	25M			50M	T
2N5102	S	N			AHP	70W	C		90	50	R	10	100	500M					150M	T
2N5103																				
thru	Field-Effect Transistors, see Table on Page 176																			
2N5105																				
2N5106	S	N			A	800M	A	200	60	30	0	100	300	150M	0.22	150M			250M	T
2N5107	S	N			A	360M	A	200	60	30	0	100	300	150M	0.22	150M			250M	T
2N5108	S	N			AHP	3.5W	C		55	55	R								1.2G	T
2N5109	S	N			AHP	3.5W	C		40	20	0	70	210	50M					1.2G	T
2N5110	S	P			AP	5.0W	C	175	40	40	0	15	60	500M	0.9	500M	10	E	1.0M	T
2N5111	S	P			AP	5.0W	C	175	80	80	0	15	60	500M	0.9	500M	10	E	1.0M	T
2N5112	S	P			AP	34W	C	175	40	40	0	15	60	500M	0.9	500M	10	E	1.0M	T
2N5113	S	P			AP	34W	C	175	80	80	0	15	60	500M	0.9	500M	10	E	1.0M	T
2N5114																				
thru	Field-Effect Transistors, see Table on Page 176																			
2N5116																				
2N5126	S	N			A	200M	A	125	20	20	0	20	350	4M	2.0	10M	15	E		
2N5127	S	N			A	200M	A	125	20	12	0	15	300	2M	0.3	10M	12	E		
2N5128	S	N			A	200M	A	125	15	12	0	35	350	50M	0.25	150M				
2N5129	S	N			A	300M	A	125	15	12	0	35	350	50M	0.25	150M				
2N5130	S	N			A	200M	A	125	30	12	0	15	250	8M	0.6	10M	12	E		
2N5131	S	N			A	200M	A	125	20	15	0	30	500	10M	1.0	10M	25	E		
2N5132	S	N			A	200M	A	125	20	20	0	30	400	10M	2.0	10M	20	E		
2N5133	S	N			A	200M	A	125	20	18	0	60	1000	1.0M	0.4	1.0M	50	E		
2N5134	S	N			SH	200M	A	125	20	10	0	20	150	10M	0.2	10M				
2N5135	S	N			A	300M	A	125	30	25	0	50	600	10M	1.0	100M				
2N5136	S	N			A	220M	A	125	30	20	0	20	400	150M	0.25	150M				
2N5137	S	N			A	300M	A	125	30	20	0	20	400	150M	0.25	150M				
2N5138	S	P			A	200M	A	125	30	30	0	50	800	100*	0.3	10M	40	E		
2N5139	S	P			SH	200M	A	125	20	20	0	40		1.0M	0.15	1.0M				
2N5140	S	P			SH	200M	A	125	5.0	5.0	0	20	140	10M	0.2	10M				

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N5141	S	P			SH	200M	A	125	6.0	6.0	0	30		30M	0.2	10M				
2N5142	S	P			SH	300M	A	125	20	20	0	30		50M	0.5	50M				
2N5143	S	P			SH	200M	A	125	20	20	0	30		50M	0.5	50M				
2N5144	S	N			SH	360M	A	200	50	30	0	60	150	100M	0.2	100M			300M	T
2N5145	S	N			SH	800M	A	200	50	30	0	60	150	100M	0.2	100M			300M	T
2N5146	S	P		2N5146	AL	400M	A		40	40	0	20		1.0A	1.0	1.0A			150M	T
2N5147	S	P			AP	1.0W	A	200	100	80	0	30	90	1.0A	5.0	3.0A	20	E	50M	T
2N5148	S	N			AP	1.0W	A	200	100	80	0	30	90	1.0A	5.0	3.0A	20	E	50M	T
2N5149	S	P			AP	1.0W	A	200	100	80	0	70	200	1.0A	5.0	3.0A	50	E	60M	T
2N5150	S	N			AP	1.0W	A	200	100	80	0	70	200	1.0A	5.0	3.0A	50	E	60M	T
2N5151	S	P			AP	1.0W	A	200	100	80	0	30	90	2.5A	1.5	5.0A	20	E	60M	T
2N5152	S	N			AP	1.0W	A	200	100	80	0	30	90	2.5A	1.5	5.0A	20	E	60M	T
2N5153	S	P			AP	1.0W	A	200	100	80	0	70	200	2.5A	1.5	5.0A	50	E	70M	T
2N5154	S	N			AP	1.0W	A	200	100	80	0	70	200	2.5A	1.5	5.0A	50	E	70M	T
2N5155	G	P		2N5155	SP			110	140	120	0	25	100	8.0A	0.9	25A			100G	T
2N5156	G	P			SP	93W	C	100	100	60	0	25	60	5.0A	1.0	10A			150G	T
2N5157	G	P			SP			150	700	500	0	30	90	1.0A	2.5	3.5A			2.8M	T
2N5158 2N5159	Field-Effect Transistors, see Table on Page 176																			
2N5160	S	P		2N5160	AHP	5.0W	C		60	40	0	10		50M					500M	T
2N5161	S	P		2N5161	AHP	20W	C		60	40	0	10		250M						
2N5162	S	P		2N5161	AHP	50W	C		60	40	0	10		2.0A						
2N5163	Field-Effect Transistors, see Table on Page 176																			
2N5164,R thru 2N5171,R	Thyristors, see Table on Page 164																			
2N5172	S	N			A	200M	A		25	25	0	100	500	10M	0.25	10M	100	E		
2N5177	S	N			AHP	40W	C	200	60	35	0	10	150	100M					200M	T
2N5178	S	N			AHP	70W	C	200	60	35	0	10	150	200M					200M	T
2N5179	S	N			AH	200M	A		20	12	0	25	250	3.0M	0.4	10M	25	E	900M	T
2N5180	S	N			AH	180M	A		30	15	0	20	200	2.0M					650M	T
2N5181	S	N			AH	180M	A		45			27		1.0M					400M	T
2N5182	S	N			AH	180M	A		35			27		1.0M					400M	T
2N5183	S	N			AH	500M	A		18	18	0	75		10M			70	E	62.5M	T
2N5184	S	N			AH	500M	A			120	0	10		50M						
2N5185	S	N			AH	1.0W	A			120	0	10		50M					50M	T
2N5186	S	N			SH	300M	A		10	5.0	S	25		10M	0.3	10M				
2N5187	S	N			SH	1.0W	A		25	25	S	30		10M	0.25	10M				
2N5188	S	N			SH	800M	A		60	55	S	25		150M	0.5	150M				
2N5189	S	N			SH	1.0W	A		60	55	S	15		1.0M	1.0	1.0A				
2N5190	S	N		2N5190	AP	40W	C	150	40	40	0	25	100	1.5A	1.4	4.0A	20	E		
2N5191	S	N		2N5190	AP	40W	C	150	60	60	0	25	100	1.5A	1.4	4.0A	20	E		
2N5192	S	N		2N5190	AP	40W	C	150	80	80	0	20	80	1.5A	1.4	4.0A	20	E		
2N5193	S	P		2N5193	AP	40W	C	150	40	40	0	25	100	1.5A	1.4	4.0A	20	E		
2N5194	S	P		2N5193	AP	40W	C	150	60	60	0	25	100	1.5A	1.4	4.0A	20	E		
2N5195	S	P		2N5193	AP	40W	C	150	80	80	0	20	80	1.5A	1.4	4.0A	20	E		
2N5196 thru 2N5199	Field-Effect Transistors, see Table on Page 176																			
2N5200	S	N			A	1.2W	C	250	20	20	0	50	150	10M	0.5	50M			900M	T
2N5201	S	N			A	1.2W	C	250	20	20	0	75	150	10M	0.5	50M			1100M	T
2N5202	S	N			SP	35W	C	200	100	75	V	10	100	4.0A	1.2	4.0A			60M	T
2N5204 thru 2N5207	Thyristors, see Table on Page 164																			
2N5208	S	P		2N5208	AH	310M	A		30	25	0	20	120	2.0M						
2N5209	S	N		2N5209	A	310M	A		50	50	0	100	300	0.1M	0.7	10M	150	E		
2N5210	S	N		2N5209	A	310M	A		50	50	0	200	600	0.1M	0.7	10M	250	E		
2N5211	S	N			AHP	3.0W	C	200	80	80	0	10	60	0.2A	0.5	0.54A			200M	T
2N5212	S	N			AHP	7.5W	C	200	80	80	0	10	60	0.2A	0.5	0.54A			200M	T
2N5213	S	N			AHP	7.5W	C	200	70	40	0	10	80	0.2A	0.5	0.5A			350M	T
2N5214	S	N			AHP	60W	C	200	95	95	S	10	75	1.0A	1.5	4.5A			150M	T
2N5215	S	N			AHP	23W	C	200	70	70	0	10	80	0.5A	0.5	1.0A			400M	T
2N5216	S	N			AHP	25W	C	200	80	80	0	10	60	0.5A	1.2	1.5A			350M	T
2N5217	S	N			AHP	7.5W	C	200	80	80	0	10	80	0.2A	0.5	0.5A			350M	T
2N5218	S	N			AP			200	220	200	0	15	120	5.0A	0.6	5.0A	40	E	40M	T
2N5219	S	N		2N5219	A	310M	A		20	15	0	35	500	2.0M	0.4	10M	35	E		
2N5220	S	N		2N5219	A	310M	A		15	15	0	30	600	50M	0.5	150M	30	E		
2N5221	S	P		2N5219	A	310M	A		15	15	0	30	600	50M	0.5	150M	30	E		
2N5222	S	N		2N5219	A	310M	A		20	15	0	20	1500	4.0M	1.0	4.0M	20	E		
2N5223	S	N		2N5219	A	310M	A		25	20	0	50	800	2.0M	0.7	10M	50	E		
2N5224	S	N		2N5219	SH	310M	A		25	12	0	40	400	10M	0.35	10M				
2N5225	S	N		2N5219	A	310M	A		25	25	0	30	600	50M	0.8	100M	30	E		
2N5226	S	P		2N5219	A	310M	A		25	25	0	30	600	50M	1.0	100M	30	E		
2N5227	S	P		2N5219	A	310M	A		30	30	0	50	700	2.0M	0.4	10M	50	E		
2N5228	S	P		2N5228	SH	310M	A		5.0	5.0	0	30		10M	0.4	10M				
2N5229	S	P			SC	2.0W	C		15	10	0	50		100*						
2N5230	S	P			SC	2.0W	C		30	20	0	50		100*						
2N5231	S	P			SC	2.0W	C		50	30	0	50		100*						
2N5232	S	N			A	330M	A		70	50	0	250	500	2.0M	0.125	10M	250	E		
2N5233	S	N			A	330M	A		80	60	0	100	300	10M	0.125	10M	100	E		
2N5234	S	N			A	330M	A		80	60	0	250	500	10M	0.125	10M	250	E		
2N5235	S	N			A	330M	A		80	60	0	400	800	10M	0.125	10M	400	E		
2N5236	S	N			AH	1.0W	C	200	40	20	0	30	120	50M	0.2	50M			500M	T
2N5237	S	N			SP			200	150	120	0	40	120	5.0A	0.6	5.0A	2.5	E	25M	T
2N5238	S	N			SP			200	200	170	0	40	120	5.0A	0.6	5.0A	2.5	E	25M	T
2N5241	S	N			SP			150	400	400	0	15	35	2.5A	2.5	5.0A			2.5M	T
2N5242	S	P			SH	0.5W	A			20	0	25	100	500M	0.38	500M			170M	T

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N5243	S	P			SH	0.5W	A			30	0	25	100	500M	0.38	500M			170M	T
2N5245 thru 2N5248	Field-Effect Transistors, see Table on Page 176																			
2N5249	S	N			A	330M	A		70	50	0	400	800	2.0M	0.125	10M	400	E		
2N5249A	S	N			A	330M	A		70	50	0	400	800	2.0M	0.125	10M	400	E		
2N5252	S	N			A	7.0W	C		300	300	0	40	120	100M	1.0	200M			30M	T
2N5253	S	N			A	7.0W	C		300	300	0	80	250	100M	1.0	200M			30M	T
2N5254	S	P			AL	0.8W	C	125	40	40	0	50	750	0.1M	0.25	10M	70	E	40M	T
2N5255	S	P			AM	0.8W	C	125	40	40	0	150	750	0.10M	0.25	10M			40M	T
2N5256	S	P			AM	0.8W	C	125	40	40	0	150	750	0.10M	0.25	10M			40M	T
2N5257 thru 2N5261	Thyristors, see Table on Page 164																			
2N5262	S	N			SH	1.0W	A		75	50	0	35		100M	0.8	1.0A				
2N5264	S	N			SP	87W	C	200	400	180	0	30	300	1.0A	1.25	7.0A			50M	T
2N5265 thru 2N5270	Field-Effect Transistors, see Table on Page 176																			
2N5271	S	N			SH	600M	A													
2N5272	S	N			SH	360M	A		40	40	S	100	400	10M	0.25	10M			500M	T
2N5273 thru 2N5275	Thyristors, see Table on Page 164																			
2N5276	S	N			S	360M	A		25	15	0	30	90	1.0M	0.2	20M			600M	T
2N5277 2N5278	Field-Effect Transistors, see Table on Page 176																			
2N5279	S	N			AH	5.0W	C		400			40	160	20M	0.5	50M			15M	T
2N5280	S	N			AH	15W	C	175	400			40	160	20M	0.5	50M			15M	T
2N5281	S	P			A			175	175	150	0	20	200	1.0M	2.0	10M			20M	T
2N5282	S	P			A			175	325	300	0	20	200	1.0M	2.0	10M			20M	T
2N5284	S	N			AP			200	120	80	0	30	90	2.5A	0.75	2.5A	20	E	60M	T
2N5285	S	N			AP			200	120	80	0	70	200	2.5A	0.75	2.5A	50	E	70M	T
2N5286	S	P			AP			200	100	100	0	30	90	2.5A	0.75	2.5A	20	E	60M	T
2N5287	S	P			AP			200	100	100	0	70	200	2.5A	0.75	2.5A	50	E	70M	T
2N5288	S	N			AP			200	120	100	0	30	90	5.0A	0.9	5.0A	20	E	30M	T
2N5289	S	N			AP			200	120	100	0	70	200	5.0A	0.9	5.0A	50	E	40M	T
2N5290	S	P			AP			200	100	100	0	30	90	5.0A	0.9	5.0A	20	E	30M	T
2N5291	S	P			AP			200	100	100	0	70	200	5.0A	0.9	5.0A	50	E	40M	T
2N5292	S	P			SH	1.0W	C	200		12	S	40	100	30M	0.12	10M			800M	T
2N5293	S	N			AP	36W	C	150	80	75	R	30	120	0.5A	2.0	3.6A	15	E		
2N5294	S	N			AP	36W	C	150	80	75	R	30	120	0.5A	2.0	3.6A	15	E		
2N5295	S	N			AP	36W	C	150	60	50	R	30	120	1.0A	2.0	3.6A	20	E		
2N5296	S	N			AP	36W	C	150	60	50	R	30	120	1.0A	2.0	3.6A	20	E		
2N5297	S	N			AP	36W	C	150	80	70	R	20	80	1.5A	2.0	3.6A	25	E		
2N5298	S	N			AP	36W	C	150	80	70	R	20	80	1.5A	2.0	3.6A	25	E		
2N5301	S	N		2N5301	AP	200W	C	200	40	40	0	15	60	15A	0.75	10A	40	E		
2N5302	S	N		2N5301	AP	200W	C	200	60	60	0	15	60	15A	0.75	10A	40	E		
2N5303	S	N		2N5301	AP	200W	C	200	80	80	0	15	60	10A	1.0	10A	40	E		
2N5305	S	N			AL	450M	A		25	25	0	2K	20K	2.0M	1.4	200M	2000	E	60M	T
2N5306	S	N			AL	400M	A		25	25	0	7K	70K	2.0M	1.4	200M	7000	E	60M	T
2N5307	S	N			AL	400M	A		40	40	0	2K	20K	2.0M	1.4	200M	2000	E	60M	T
2N5308	S	N			AL	400M	A		40	40	0	7K	70K	2.0M	1.4	200M	7000	E	60M	T
2N5309	S	N			A	330M	A		70	50	0	60	120	10*	0.125	10M	66	E		
2N5310	S	N			A	330M	A		70	50	0	100	300	10*	0.125	10M	110	E		
2N5311	S	N			A	330M	A		70	50	0	250	500	10*	0.125	10M				
2N5312	S	P			AP	50W	C	200	80	80	0	30	90	10A	1.5	10A	30	E	30M	T
2N5313	S	N			AP	50W	C	200	80	80	0	30	90	10A	1.5	10A	30	E	30M	T
2N5314	S	P			AP	50W	C	200	100	100	0	30	90	10A	1.5	10A	30	E	30M	T
2N5315	S	N			AP	50W	C	200	100	100	0	30	90	10A	1.5	10A	30	E	30M	T
2N5316	S	P			AP	50W	C	200	80	80	0	30	90	5.0A	0.6	5.0A	30	E	30M	T
2N5317	S	N			AP	50W	C	200	80	80	0	30	90	5.0A	0.6	5.0A	30	E	30M	T
2N5318	S	P			AP	50W	C	200	100	100	0	30	90	5.0A	0.6	5.0A	30	E	30M	T
2N5319	S	N			AP	50W	C	200	100	100	0	30	90	5.0A	0.6	5.0A	30	E	30M	T
2N5320	S	N			SP	10W	C	200	100	75	0	30	130	500M	0.5	500M			50M	T
2N5321	S	N			SP	10W	C	200	75	50	0	40	250	500M	0.8	500M			50M	T
2N5322	S	P			SP	10W	C	200	100	75	0	30	130	500M	0.7	500M			50M	T
2N5323	S	P			SP	10W	C	200	75	50	0	40	250	500M	1.2	500M			50M	T
2N5324	G	P		2N5324	SP	56W	C	110	250	150	0	20	60	5.0A	0.5	10A			2.0M	T
2N5325	G	P		2N5324	SP	56W	C	110	325	200	0	20	60	5.0A	0.5	10A			2.0M	T
2N5326	S	N			SP	400W*	C	200	100	80	0	50	150	1.0A	1.0	5.0A				
2N5327	S	N			SP	450W*	C	200	100	80	0	100	300	1.0A	0.3	3.0A				
2N5328	S	N			SP	450W*	C	200	100	80	0	100	300	1.0A	0.6	5.0A				
2N5329	S	N			SP	1000W*	C	200	150	90	0	40	120	10A	1.8	20A				
2N5330	S	N			SP	1000W*	C	200	150	90	0	40	120	10A	0.6	10A				
2N5331	S	N			SP	1000W*	C	200	150	90	0	40	120	10A	0.6	10A				
2N5332	S	P			SH	360M	A		20	12	0	20	80	1.0M	0.2	20M			600M	T
2N5333	S	P			AP	1.0W	A	200	100	80	0	30	120	1.0A	1.0	2.0A	30	E	30M	T
2N5334	S	N		2N5334	SP	6.0W	C	200	60	60	0	30	150	1.0A	0.7	2.0A			40M	T
2N5335	S	N		2N5334	SP	6.0W	C	200	80	80	0	30	150	1.0A	0.7	2.0A			40M	T
2N5336	S	N		2N5336	SP	6.0W	C	200	80	80	0	30	120	2.0A	0.7	2.0A			30M	T
2N5337	S	N		2N5336	SP	6.0W	C	200	80	80	0	60	240	2.0A	0.7	2.0A			30M	T
2N5338	S	N		2N5336	SP	6.0W	C	200	100	100	0	30	120	2.0A	0.7	2.0A			30M	T
2N5339	S	N		2N5336	SP	6.0W	C	200	100	100	0	60	240	2.0A	0.7	2.0A			30M	T
2N5344	S	P		2N5344	SP	40W	C	200	250	250	0	25	100	500M	3.0	1.0A			60M	T
2N5345	S	P		2N5344	SP	40W	C	200	300	300	0	25	100	500M	3.0	1.0A			60M	T
2N5346	S	N		2N5346	SP	60W	C	200	80	80	0	30	120	2.0A	0.7	2.0A			30M	T

*Pulsed

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N5347	S	N		2N5346	SP	60W	C	200	80	80	0	30	120	2.0A	0.7	2.0A			30M	T
2N5348	S	N		2N5346	SP	60W	C	200	100	100	0	60	240	2.0A	0.7	2.0A			30M	T
2N5349	S	N		2N5346	SP	60W	C	200	100	100	0	60	240	2.0A	0.7	2.0A			30M	T
2N5350	S	N			SP	350W	C	200	125	100	0	10	40	70A	5.0	90A			10M	T
2N5351	S	N			SP	350W	C	200	180	150	0	10	40	70A	5.0	90A			10M	T
2N5354	S	P			A	360M	A		25	25	0	40	120	50M	0.25	50M	32	E		
2N5355	S	P			A	360M	A		25	25	0	100	300	50M	0.25	50M	80	E		
2N5356	S	P			A	360M	A		25	25	0	250	500	50M	0.25	50M	200	E		
2N5357	S	P		2N5357	SP	30W	C	200	300	300	0	25	100	500M	0.3	100M			50M	T
2N5358 thru 2N5364	Field-Effect Transistors, see Table on Page 176																			
2N5365	S	P			A	360M	A		40	40	0	40	120	50M	0.25	50M	32	E		
2N5366	S	P			A	360M	A		40	40	0	100	300	50M	0.25	50M	80	E		
2N5367	S	P			A	360M	A		40	40	0	250	500	50M	0.25	50M	200	E		
2N5384	S	P			A	2.0W	A	200	100	80	0	20	80	2.0A	1.4	5.0A	20	E	30M	T
2N5385	S	P			A	2.0W	A	200	100	80	0	20	80	2.0A	1.4	5.0A	20	E	30M	T
2N5386	S	P			A	3.5W	A	200	100	80	0	20	80	6.0A	1.4	12A	20	E	30M	T
2N5387	S	N			A	3.5W	A	200	200	200	0	25	100	2.0A	2.2	7.0A	20	E	15M	T
2N5388	S	N			A	3.5W	A	200	250	250	0	25	100	2.0A	2.2	7.0A	20	E	15M	T
2N5389	S	N			A	3.5W	A	200	300	300	0	25	100	2.0A	2.2	7.0A	20	E	15M	T
2N5390	S	N			AL	1.0W	C	200	120	80	0	2K	20K	2.0A	2.5	5.0A			40M	T
2N5391 thru	Field-Effect Transistors, see Table on Page 176																			
2N5398																				
2N5399	S	N			SH	360M	A		25	15	0	30	90	1.0M	0.2	20M			600M	T
2N5404	S	P			AP	1.0W	A	200	80	80	0	20	60	2.0A	0.6	2.0A	20	E	40M	T
2N5405	S	P			AP	1.0W	A	200	100	100	0	20	60	2.0A	0.6	2.0A	20	E	40M	T
2N5406	S	P			AP	1.0W	A	200	80	80	0	40	120	2.0A	0.6	2.0A	40	E	40M	T
2N5407	S	P			AP	1.0W	A	200	100	100	0	40	120	2.0A	0.6	2.0A	40	E	40M	T
2N5408	S	P			AP	30W	C	200	80	80	0	20	60	2.0A	0.6	2.0A	20	E	40M	T
2N5409	S	P			AP	30W	C	200	100	100	0	20	60	2.0A	0.6	2.0A	20	E	40M	T
2N5410	S	P			AP	30W	C	200	80	80	0	40	120	2.0A	0.6	2.0A	40	E	40M	T
2N5411	S	P			AP	30W	C	200	100	100	0	40	120	2.0A	0.6	2.0A	40	E	40M	T
2N5412	S	N			AP	100W	C	175	80	60	0	10	160	2.0A	1.0	10A	20	E		
2N5413	S	N			SH	1.0W	A		60	40	0	25	100	2.0A	0.25	150M				
2N5414	S	N			SH	1.0W	A		80	50	0	25	100	2.0A	0.25	150M				
2N5415	S	P			AH	10W	C		200			30	150	50M					15M	T
2N5416	S	P			AH	10W	C		350			30	120	50M					15M	T
2N5417	S	N			SH	500M	A		40	35	0	80	250	150M	0.55	150M			250M	T
2N5421	S	N			AHP	3.0W	C		36	18	0	10	60	0.1A	0.5	0.2A			300M	T
2N5422	S	N			AHP	5.0W	C		36	18	0	10	60	0.5A	0.5	0.5A			300M	T
2N5423	S	N			AHP	12W	C		36	18	0	20	70	1.0A	0.5	1.0A			300M	T
2N5424	S	N			AHP	20W	C		36	18	0	20	100	2.0A	0.5	2.0A			250M	T
2N5425	S	N			AH				60	60	0	500		5.0A	2.5	5.0A	500	E		
2N5426	S	N			AH				60	60	0	1000		5.0A	2.2	5.0A	1000	E		
2N5427	S	N		2N5427	SP	35W	C	200	80	80	0	30	120	2.0A	0.7	2.0A			30M	T
2N5428	S	N		2N5427	SP	35W	C	200	80	80	0	60	240	2.0A	0.7	2.0A			30M	T
2N5429	S	N		2N5427	SP	35W	C	200	100	100	0	30	120	2.0A	0.7	2.0A			30M	T
2N5430	S	N		2N5427	SP	35W	C	200	100	100	0	60	240	2.0A	0.7	2.0A			30M	T
2N5431	Unijunction Transistors, see Table on Page 184																			
2N5432																				
2N5433	Field-Effect Transistors, see Table on Page 176																			
2N5434																				
2N5435	G	P		2N5435	SP	120W	C	110	80	60	0	20	60	25A	0.75	60A				
2N5436	G	P		2N5435	SP	120W	C	110	110	90	0	20	60	25A	0.75	60A				
2N5437	G	P		2N5435	SP	120W	C	110	140	120	0	20	60	25A	0.75	60A				
2N5438	G	P		2N5435	SP	120W	C	110	80	60	0	40	120	25A	0.50	60A				
2N5439	G	P		2N5435	SP	120W	C	110	110	90	0	40	120	25A	0.50	60A				
2N5440	G	P		2N5435	SP	120W	C	110	140	120	0	40	120	25A	0.50	60A				
2N5447	S	N			A	360M	A		40	25	0	60	300	50M	0.25	50M				
2N5448	S	N			A	360M	A		50	30	0	30	150	50M	0.25	50M				
2N5449	S	N			A	360M	A		50	30	0	100	300	50M	0.6	100M				
2N5450	S	N			A	360M	A		50	30	0	50	150	50M	0.8	100M				
2N5451	S	N			A	360M	A		40	20	0	30	600	50M	1.0	100M				
2N5452 thru 2N5454	Field-Effect Transistors, see Table on Page 176																			
2N5455	S	P			SH	340M	A	200	15	15	0	30	120	30M	0.50	300M			450M	T
2N5456	S	P			SH	340M	A	200	25	25	0	30	120	30M	0.55	300M			450M	T
2N5457 thru	Field-Effect Transistors, see Table on Page 176																			
2N5465																				
2N5466	S	N			AP			200	500	400	0	15	60	3.0A	0.5	3.0A	25	E		
2N5467	S	N			AP			200	700	400	0	15	60	3.0A	0.5	3.0A	25	E		
2N5468	S	N			AP			200	500	400	0	15	60	3.0A	0.5	3.0A	25	E		
2N5469	S	N			AP			200	700	400	0	15	60	3.0A	0.5	3.0A	25	E		
2N5471 thru 2N5476	Field-Effect Transistors, see Table on Page 176																			
2N5477	S	N		2N5477	SP	60W	C	200	80	80	0	30	120	2.0A	0.7	2.0A			30M	T
2N5478	S	N		2N5477	SP	60W	C	200	80	80	0	60	240	2.0A	0.7	2.0A			30M	T
2N5479	S	N		2N5477	SP	60W	C	200	100	100	0	30	120	2.0A	0.7	2.0A			30M	T
2N5480	S	N		2N5477	SP	60W	C	200	100	100	0	60	240	2.0A	0.7	2.0A			30M	T
2N5481	S	N			AHP	5.0W	C		50	30	0	20		50M						
2N5482	S	N			AHP	10W	C		50	30	0	20		50M						
2N5483	S	N			AHP	20W	C		45	30	0	20		100M						

TYPE	MATERIAL	POLARITY	REPLACE-MENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS								
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	h_{FE} (max)	@ I_C Units	$V_{CE(SAT)}$ (volts)	@ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
2N5484 thru 2N5486	Field-Effect Transistors, see Table on Page 176																			
2N5487	S	N			SP	15W	C	200	120	80	0	100	300	1.0A	0.25	1.0A				
2N5488	S	N			SP	15W	C	200	150	100	0	40	120	1.0A	0.25	1.0A				
2N5489	S	N			AP			200	100	100	0	15	50	40A	1.5	40A	10	E		
2N5498	S	N			AP	200W	C	200	150	130	0	10	50	15A	1.5	15A	25	E		
2N5505 thru 2N5524	Field-Effect Transistors, see Table on Page 176																			
2N5525	S	N			AL	360M	A		40	30	0	5000		10M	1.0	50M	5000	E	200M	T
2N5526	S	N			AL	360M	A		40	30	0	1000		10M	1.0	50M	1000	E	200M	T
2N5527	S	N			AP	5.0W	C	200	60	40	0	40	200	3.0A	1.25	3.0A	20	E	200M	T
2N5528	S	N			AP	35W	C	200	60	40	0	40	200	3.0A	1.25	3.0A	20	E	200M	T
2N5529	S	N			AP	35W	C	200	60	40	0	40	200	3.0A	1.25	3.0A	20	E	200M	T
2N5530	S	N			AP	35W	C	200	60	40	0	40	200	3.0A	1.25	3.0A	20	E	200M	T
2N5531	S	N			AP	5.0W	C	200	90	75	0	30	150	3.0A	1.25	3.0A	20	E	200M	T
2N5532	S	N			AP	35W	C	200	90	75	0	30	150	3.0A	1.25	3.0A	15	E	200M	T
2N5533	S	N			AP	35W	C	200	90	75	0	30	150	3.0A	1.25	3.0A	15	E	200M	T
2N5534	S	N			AP	35W	C	200	90	75	0	30	150	3.0A	1.25	3.0A	15	E	200M	T
2N5535	S	N			AP	50W	C	200	60	50	0	30	150	10A	1.25	5.0A	25	E	150M	T
2N5536	S	N			AP	50W	C	200	60	50	0	30	150	10A	1.25	5.0A	25	E	150M	T
2N5537	S	N			AP	50W	C	200	90	75	0	20	150	10A	1.25	5.0A	20	E	150M	T
2N5538	S	N			AP	50W	C	200	90	75	0	20	150	10A	1.25	5.0A	20	E	150M	T
2N5543 thru 2N5549	Field-Effect Transistors, see Table on Page 176																			
2N5552	S	N			SP	15W	C	200	120	80	0	50	150	5.0A	0.5	5.0A				
2N5555 thru 2N5558	Field-Effect Transistors, see Table on Page 176																			
2N5559	S	N			SP			200	150	120	X	20	60	4.0A	0.75	4.0A				
2N5560	S	N						200	175	120	X	30	90	15A	0.8	15A				
3N22		N			AH			85	15								0.96	B		
3N34	S	N				125M			30											
3N35	S	N				125M			30	30	O						25	E		
3N35A	S	N				125M			30	30	O						10	E		
3N39 thru 3N44	Reference Amplifiers, see Table on Page 182																			
3N45	G	P			SP	75W	C	100	60	35		30	120	5.0A	0.4	5.0A	30	E	600K	
3N46	G	P			SP	75W	C	100	80	50		20	80	5.0A	0.4	5.0A			300K	
3N47	G	P			SP	75W	C	100	40	25		30	120	5.0A	0.4	5.0A	30	E	500K	
3N48	G	P			SP	75W	C	100	60	40		20	80	5.0A	0.4	5.0A			300K	
3N49	G	P			SP	94W	C	100	60	35		30	120	5.0A	0.4	5.0A	30	E	600K	
3N50	G	P			SP	94W	C	100	80	50		20	80	5.0A	0.4	5.0A			300K	
3N51	G	P			SP	94W	C	100	40	25		30	120	5.0A	0.4	5.0A	30	E	500K	
3N52	G	P			SP	94W	C	100	60	40		20	80	5.0A	0.4	5.0A			300K	
3N58 thru 3N60	Thyristors, see Table on Page 164																			
3N62	S	N			SC				10						V_{off} = 200 μV					
3N63	S	N			SC				10						V_{off}= 100 μV					
3N64	S	N			SC				10						V_{off}= 50 μV					
3N65	S	N			SC										V_{off}= 200 μV					
3N66	S	N			SC										V_{off}= 100 μV					
3N67	S	N			SC										V_{off}= 50 μV					
3N68	S	N			SC				10						V_{off}= 200 μV					
3N68A	S	N				100M	A	200	10											
3N69	S	N			SC				10						V_{off}= 100 μV					
3N70	S	N			SC				10						V_{off}= 50 μV					
3N71	S	N			SC	100M		200	15	8.0	O	40		2.0M	V_{off}= 50 μV				100M	T
3N72	S	N			SC	100M		200	15	8.0	O	40		2.0M	V_{off}= 100 μV				100M	T
3N73	S	N			SC	100M		200	15	8.0	O	40		2.0M	V_{off}= 100 μV				100M	T
3N74	S	N			SC	300M		175	50						V_{off}= 50 μV				30M	T
3N75	S	N			SC	300M		175	50						V_{off}= 100 μV				30M	T
3N76	S	N			SC	300M		175	50						V_{off}= 200 μV				30M	T
3N77	S	N			SC	300M		175	40						V_{off}= 50 μV				30M	T
3N78	S	N			SC	200M		175	40						V_{off}= 100 μV				30M	T
3N79	S	N			SC	300M		175	40						V_{off}= 200 μV				30M	T
3N80 thru 3N86	Thyristors, see Table on Page 164																			
3N87	S	N			SC	200M	A		20	10	O	5.0		0.5M	V_{off}= 50 μV				100M	T
3N88	S	N			SC	200M	A		20	10	O	5.0		0.5M	V_{off}= 100 μV				100M	T
3N89	Field-Effect Transistors, see Table on Page 176																			

TYPE	MATERIAL	POLARITY	REPLACEMENT	REF.	USE	MAXIMUM RATINGS						ELECTRICAL CHARACTERISTICS							
						P_D @ 25°C	Ref Point	T_J °C	V_{CB} (volts)	V_{CE-} (volts)	Subscript	h_{FE} (min)	(max)	@ I_C Units	$V_{CE(SAT)}$ (volts) @ I_C Units	h_{f-}	Subscript	f_- Units	Subscript
3N90	S	P			SC	300M	A	200	50						V_{off}= 50 μV			6.0M	T
3N91	S	P			SC	300M	A	200	50						V_{off}= 100 μV			6.0M	T
3N92	S	P			SC	300M	A	200	50						V_{off}= 200 μV			6.0M	T
3N93	S	P			SC	300M	A	200	50						V_{off}= 50 μV			6.0M	T
3N94	S	P			SC	300M	A	200	50						V_{off}= 100 μV			6.0M	T
3N95	S	P			SC	300M	A	200	50						V_{off}= 200 μV			6.0M	T
3N96 thru 3N99	Field-Effect Transistors, see Table on Page 176																		
3N100	S	P			SC	300M	A	200	20						V_{off}= 50 μV				
3N101	S	P			SC	300M	A	200	30						V_{off}= 50 μV				
3N102	S	P			SC	300M	A	200	40						V_{off}= 50 μV				
3N103	S	P			SC	300M	A	200	50						V_{off}= 50 μV				
3N104	S	P			SC	300M	A	200	60						V_{off}= 50 μV				
3N105	S	P			SC	300M	A	200	20						V_{off}= 250 μV				
3N106	S	P			SC	300M	A	200	40						V_{off}= 250 μV				
3N107	S	P			SC	300M	A	200	60						V_{off}= 250 μV				
3N108	S	P			SC	300M	A	200	50									12M	T
3N109	S	P			SC	300M	A	200	50									12M	T
3N110	S	P			SC	300M	A	200	50									12M	T
3N111	S	P			SC	300M	A	200	50									12M	T
3N112	S	P			SC	200M	A	200	50										
3N113	S	P			SC	200M	A	200	50										
3N114	S	P			SC	300M	A	200	30									12M	T
3N115	S	P			SC	300M	A	200	30									12M	T
3N116	S	P			SC	300M	A	200	30									12M	T
3N117	S	P			SC	300M	A	200	50									12M	T
3N118	S	P			SC	300M	A	200	50									12M	T
3N119	S	P			SC	300M	A	200	50									12M	T
3N120	S	N			SC	200M	A	200	30										
3N121	S	N			SC	200M	A	125	30									40M	T
3N123	S	P			SC	100M	A	200	30									6.0M	E
3N124 thru 3N126	Field-Effect Transistors, see Table on Page 176																		
3N127	S	N			SC	200M	A	200	30	20	O								
3N128	Field-Effect Transistors, see Table on Page 176																		
3N129	S	P			SC	300M	A		20									2.0M	E
3N130	S	P			SC	300M	A		30									2.0M	E
3N131	S	P			SC	300M	A		40									2.0M	E
3N132	S	P			SC	300M	A		50									2.0M	E
3N133	S	P			SC	300M	A		60									2.0M	E
3N134	S	P			SC	300M	A		20									2.0M	E
3N135	S	P			SC	300M	A		40									2.0M	E
3N136	S	P			SC	300M	A		60									2.0M	E
3N138 thru 3N143	Field-Effect Transistors, see Table on Page 176																		
3N145 thru 3N150	Field-Effect Transistors, see Table on Page 176																		
3N152 thru 3N161	Field-Effect Transistors, see Table on Page 176																		

THYRISTORS

INDEX AND SHORT FORM SPECIFICATIONS

This table contains a numerical listing and short-form specifications for thyristors with EIA-registered 2N and 3N numbers. Specific types of thyristors listed include silicon controlled rectifiers, gate-controlled switches, and silicon controlled switches.

KEY

TYPE	REPLACE-MENT	REFERENCE	I_f A	V_{FOM}/V_{ROM} V	T_J °C	I_{GT} mA	V_{GT} V
Numerical Listing of Registered Type Numbers. *Device with gate turn-off characteristics	Type number of recommended replacement or of nearest electrical equivalent fully characterized in this book	Reference device number indicates specific Data Sheet on which device is characterized	Forward Current *Pulse current rating	Maximum Forward Voltage Maximum Reverse Voltage For most thyristors, $V_{FOM} = V_{ROM}$ and only one voltage value is tabulated	Maximum Junction Temperature	Maximum DC Gate Current required to cause switching from the "OFF" state to the "ON" state (at 25°C)	The DC Voltage between gate and cathode required to produce the DC Gate Trigger Current (I_{GT})

TYPE	REPLACEMENT	REF.	I_f A	V_{FOM}/V_{ROM} V	T_J °C	I_{GT} mA	V_{GT} V
2N681		2N681	25	25	125	40	2.0
2N681A			28	25	125	40	2.0
2N682		2N681	25	50	125	40	2.0
2N682A			28	50	125	40	2.0
2N683		2N681	25	100	125	40	2.0
2N683A			28	100	125	40	2.0
2N684		2N681	25	150	125	40	2.0
2N684A			28	150	125	40	2.0
2N685		2N681	25	200	125	40	2.0
2N685A			28	200	125	40	2.0
2N686		2N681	25	250	125	40	2.0
2N686A			28	250	125	40	2.0
2N687		2N681	25	300	125	40	2.0
2N687A			28	300	125	40	2.0
2N688		2N681	25	400	125	40	2.0
2N688A			28	400	125	40	2.0
2N689		2N681	25	500	125	40	2.0
2N689A			28	500	125	40	2.0
2N690			25	600	125	40	2.0
2N690A			25	600	125	40	2.0
2N691			25	700	125	40	2.0
2N692			25	800	125	40	2.0
2N764*			0.39	30	125	1.0	1.0
2N765*			0.20	60	125	1.0	1.0
2N766*			0.20	100	125	1.0	1.0
2N767*			0.20	200	125	1.0	1.0
2N876	2N4212	2N4212	0.35	15	150	0.2	0.8
2N877	2N4212	2N4212	0.35	30	150	0.2	0.8
2N878	2N4213	2N4212	0.35	60	150	0.2	0.8
2N879	2N4214	2N4212	0.35	100	150	0.2	0.8
2N880	2N4215	2N4212	0.35	150	150	0.2	0.8
2N881	2N4216	2N4212	0.35	200	150	0.2	0.8
2N882			0.35	300	150	0.2	0.8
2N883			0.35	400	150	0.2	0.8
2N884	2N4212	2N4212	0.35	15	150	0.02	0.6
2N885	2N4213	2N4212	0.35	30	150	0.02	0.6
2N886	2N4214	2N4212	0.35	60	150	0.02	0.6
2N887	2N4214	2N4212	0.35	100	150	0.02	0.6
2N888	2N4215	2N4212	0.35	150	150	0.02	0.6
2N889	2N4216	2N4212	0.35	200	150	0.02	0.6
2N890			0.35	300	150	0.02	0.6
2N891			0.35	400	150	0.02	0.6
2N892*			0.250	15	125	0.05	0.70
2N893*			0.250	15	125	0.05	0.70
2N894*			0.250	30/15	125	0.05	0.70
2N895*			0.250	30/15	125	0.05	0.70
2N896*			0.250	60/15	125	0.05	0.70
2N897*			0.250	60/15	125	0.05	0.70
2N898*			0.250	100/15	125	0.05	0.70
2N899*			0.250	100/15	125	0.05	0.70
2N900*			0.250	200/15	125	0.05	0.70
2N901*			0.250	200/15	125	0.05	0.70
2N948	2N4212	2N4212	0.26	30	150	0.02	1.0
2N949	2N4213	2N4212	0.26	60	150	0.02	1.0
2N950	2N4214	2N4212	0.26	100	150	0.02	1.0
2N951	2N4215	2N4212	0.26	200	150	0.02	1.0
2N1595		2N1595	1.6	50	125	10	3.0
2N1595A	2N1595	2N1595	1.6	50	150	2.0	2.0
2N1596		2N1595	1.6	100	125	10	3.0
2N1596A	2N1596	2N1595	1.6	100	150	2.0	2.0
2N1597		2N1595	1.6	200	125	10	3.0
2N1597A	2N1597	2N1595	1.6	200	150	2.0	2.0
2N1598		2N1595	1.6	300	125	10	3.0
2N1598A	2N1598	2N1595	1.6	300	150	2.0	2.0
2N1599		2N1595	1.6	400	125	10	3.0
2N1599A	2N1599	2N1595	1.6	400	150	2.0	2.0
2N1600	2N4168	2N4151	4.0	50	125	10	3.0
2N1600A	2N4168	2N4151	4.0	50	125	4.5	3.0
2N1601	2N4169	2N4151	4.0	100	125	10	3.0

THYRISTOR INDEX (continued)

TYPE	REPLACEMENT	REF.	I_f A	V_{FOM}/V_{ROM} V	T_J °C	I_{GT} mA	V_{GT} V
2N1602	2N4170	2N4151	4.0	200	125	10	3.0
2N1603	2N4171	2N4151	4.0	300	125	10	3.0
2N1604	2N4172	2N4151	4.0	400	125	10	3.0
2N1686*			0.5	30	125	1.0	1.0
2N1687*			0.5	60	125	1.0	1.0
2N1688*			0.5	100	125	1.0	1.0
2N1689*			0.5	200	125	1.0	1.0
2N1765	2N1765		0.5	400	85	10	1.5
2N1770	2N4167	2N4151	4.7	25	125	15	2.0
2N1770A			4.7	25	150	15	2.0
2N1771	2N4168	2N4151	4.7	50	125	15	2.0
2N1771A			4.7	50	150	15	2.0
2N1772	2N4169	2N4151	4.7	100	125	15	2.0
2N1772A			4.7	100	150	15	2.0
2N1773	2N4170	2N4151	4.7	150	125	15	2.0
2N1773A			4.7	150	150	15	2.0
2N1774	2N4170	2N4151	4.7	200	125	15	2.0
2N1774A			4.7	200	150	15	2.0
2N1775	2N4171	2N4151	4.7	250	125	15	2.0
2N1775A			4.7	250	150	15	2.0
2N1776	2N4171	2N4151	4.7	300	125	15	2.0
2N1776A			4.7	300	150	15	2.0
2N1776B			4.7	300	150	15	2.0
2N1777	2N4172	2N4151	4.7	400	125	15	2.0
2N1777A			7.0	400	150	15	2.0
2N1778	2N4173	2N4151	7.4	500	125	15	2.0
2N1778A			7.0	500	150	15	2.0
2N1792			110	60	125	75	3.0
2N1793			110	120	125	75	3.0
2N1794			110	180	125	75	3.0
2N1795			110	240	125	75	3.0
2N1796			110	300	125	75	3.0
2N1797			110	360	125	75	3.0
2N1798			110	480	125	75	3.0
2N1799			110	600	125	75	3.0
2N1800			110	720	125	75	3.0
2N1801			110	840	125	75	3.0
2N1802			110	960	125	75	3.0
2N1803			110	1080	125	90	3.0
2N1804			110	1200	125	90	3.0
2N1805			110	500	125	75	3.0
2N1806			110	600	125	75	3.0
2N1807			110	700	125	75	3.0
2N1842		2N1842	16	25	100	80	2.0
2N1842A		2N1842A	16	25	125	80	2.0
2N1842B	2N1842A	2N1842A	20	25	125	75	3.0
2N1843		2N1842	16	50	100	80	2.0
2N1843A		2N1842A	16	50	125	80	2.0
2N1843B	2N1843A	2N1842A	20	50	125	75	3.0
2N1844		2N1842	16	100	100	80	2.0
2N1844A		2N1842A	16	100	125	80	2.0
2N1844B	2N1844A	2N1842A	20	100	125	75	3.0
2N1845		2N1842	16	150	100	80	2.0
2N1845A		2N1842A	16	150	125	80	2.0
2N1845B	2N1845A	2N1842A	20	150	125	75	3.0
2N1846		2N1842	16	200	100	80	2.0
2N1846A		2N1842A	16	200	125	80	2.0
2N1846B	2N1846A	2N1842A	20	200	125	75	3.0
2N1847		2N1842	16	250	100	80	2.0
2N1847A		2N1842A	16	250	125	80	2.0
2N1847B	2N1847A	2N1842A	20	250	125	75	3.0
2N1848		2N1842	16	300	100	80	2.0
2N1848A		2N1842A	16	300	125	80	2.0
2N1848B	2N1848A	2N1842A	20	300	125	75	3.0
2N1849		2N1842	16	400	100	80	2.0
2N1849A		2N1842A	16	400	125	80	2.0
2N1849B	2N1849A	2N1842A	20	400	125	75	3.0
2N1850		2N1842	16	500	100	80	2.0
2N1850A		2N1842A	16	500	125	80	2.0

TYPE	REPLACEMENT	REF.	I_f A	V_{FOM}/V_{ROM} V	T_J °C	I_{GT} mA	V_{GT} V
2N1850B	2N1850A	2N1842A	20	500	125	75	3.0
2N1869	2N4212	2N4212	1.25	15	150	0.2	0.8
2N1869A			1.25	15	150	0.2	0.8
2N1870	2N4213	2N4212	1.25	30	150	0.2	0.8
2N1870A			1.25	30	150	0.2	0.8
2N1871	2N4214	2N4212	1.25	60	150	0.2	0.8
2N1871A			1.25	60	150	0.2	0.8
2N1872	2N4214	2N4212	1.25	100	150	0.2	0.8
2N1872A			1.25	100	150	0.2	0.8
2N1873	2N4215	2N4212	1.25	150	150	0.2	0.8
2N1873A			1.25	150		0.2	0.8
2N1874	2N4216	2N4212	1.25	200	150	0.2	0.8
2N1874A			1.25	200	150	0.2	0.8
2N1875	2N4212	2N4212	1.25	15	150	0.020	0.6
2N1875A			1.25	15	150	0.020	0.6
2N1876	2N4213	2N4212	1.25	30	150	0.020	0.6
2N1876A			1.25	30	150	0.020	0.6
2N1877	2N4214	2N4212	1.25	60	150	0.020	0.6
2N1877A			1.25	60	150	0.020	0.6
2N1878	2N4214	2N4212	1.25	100	150	0.020	0.6
2N1878A			1.25	100	150	0.020	0.6
2N1879	2N4215	2N4212	1.25	150	150	0.020	0.6
2N1879A			1.25	150	150	0.020	0.6
2N1880	2N4216	2N4212	1.25	200	150	0.020	0.6
2N1880A			1.25	200	150	0.020	0.6
2N1881	2N4212	2N4212	1.0	30	150	2.0	2.0
2N1882	2N4213	2N4212	1.0	60	150	2.0	2.0
2N1883	2N4214	2N4212	1.0	100	150	2.0	2.0
2N1884	2N4215	2N4212	1.0	150	150	2.0	2.0
2N1885	2N4216	2N4212	1.0	200	150	2.0	2.0
2N1909			70	25	125	75	3.0
2N1910			70	50	125	75	3.0
2N1911			70	100	125	75	3.0
2N1912			70	150	125	75	3.0
2N1913			70	200	125	75	3.0
2N1914			70	250	125	75	3.0
2N1914A			70	250	125	75	3.0
2N1914B			70	250	125	75	3.0
2N1915			70	300	125	75	3.0
2N1916			70	400	125	75	3.0
2N1929	2N4191	2N4151	0.75	25	125	15	2.0
2N1930	2N4192	2N4151	0.75	50	125	15	2.0
2N1931	2N4193	2N4151	0.75	100	125	15	2.0
2N1932	2N4194	2N4151	0.75	150	125	15	2.0
2N1933	2N4194	2N4151	0.75	200	125	15	2.0
2N1934	2N4195	2N4151	0.75	250	125	15	2.0
2N1935	2N4195	2N4151	0.75	300	125	15	2.0
2N2009	2N4212	2N4212	1.3	25	150	0.2	1.0
2N2010	2N4213	2N4212	1.3	50	150	0.2	1.0
2N2011	2N4214	2N4212	1.3	100	150	0.2	1.0
2N2012	2N4216	2N4212	1.3	200	150	0.2	1.0
2N2013			1.3	300	150	0.2	1.0
2N2014			1.3	400	150	0.2	1.0
2N2023			70	25	150	75	3.0
2N2024			70	50	150	75	3.0
2N2025			70	100	150	75	3.0
2N2026			70	150	150	75	3.0
2N2027			70	200	150	75	3.0
2N2028			70	250	150	75	3.0
2N2029			70	300	150	75	3.0
2N2030			70	400	150	75	3.0
2N2031			110	50	125	75	3.0
2N2044			150	200	125	80	3.0
2N2045			150	300	125	80	3.0
2N2046			150	400	125	80	3.0
2N2047			150	500	125	80	3.0
2N2074	2N4213	2N4212	1.0	50	150	0.2	0.65
2N2260*			200	30	100	0.25	
2N2261*			200	30	100	0.5	

TYPE	REPLACEMENT	REF.	I_f A	V_{FOM}/V_{ROM} V	T_J °C	I_{GT} mA	V_{GT} V
2N2262*			200	30	100	5.0	
2N2322		2N2322	1.6	25	125	0.2	0.8
2N2322A			1.6	25	125	0.02	0.6
2N2323		2N2322	1.6	50	125	0.2	0.8
2N2323A			1.6	50	125	0.02	0.6
2N2324		2N2322	1.6	100	125	0.2	0.8
2N2324A			1.6	100	125	0.02	0.6
2N2325		2N2322	1.6	150	125	0.2	0.8
2N2325A			1.6	150	125	0.02	0.6
2N2326		2N2322	1.6	200	125	0.2	0.8
2N2326A			1.6	200	125	0.02	0.6
2N2327			1.6	250	125	0.2	0.8
2N2327A			1.6	250	125	0.02	0.6
2N2328			1.6	300	125	0.2	0.8
2N2328A			1.6	300	125	0.02	0.6
2N2329			1.6	400	125	0.2	0.8
2N2329A			1.6	400	125	0.02	0.6
2N2344			1.6	25	100	0.02	0.8
2N2345			1.6	50	100	0.02	0.8
2N2346			1.6	100	100	0.02	0.8
2N2347			1.6	150	100	0.02	0.8
2N2348			1.6	200	100	0.02	0.8
2N2454			3.0	400	105	15	3.0
2N2502	2N1850A	2N1842A	7.0	500	125	75	3.0
2N2503			225	50	125	100	2.5
2N2504			225	100	125	100	2.5
2N2505			225	200	125	100	2.5
2N2506			225	300	125	100	2.5
2N2507			225	400	125	100	2.5
2N2508			225	500	125	100	2.5
2N2542			230	50	125	125	3.0
2N2543			230	100	125	125	3.0
2N2544			230	200	125	125	3.0
2N2545			230	300	125	125	3.0
2N2546			230	400	125	125	3.0
2N2547			230	500	125	125	3.0
2N2548			230	600	125	125	3.0
2N2549			150	800	125	125	3.0
2N2550			150	1000	125	125	3.0
2N2573		2N2573	25	25	125	40	3.5
2N2574		2N2573	25	50	125	40	3.5
2N2575		2N2573	25	100	125	40	3.5
2N2576		2N2573	25	200	125	40	3.5
2N2577		2N2573	25	300	125	40	3.5
2N2578		2N2573	25	400	125	40	3.5
2N2579		2N2573	25	500	125	40	3.5
2N2619	2N4174	2N4151	7.4	600	125	45	2.0
2N2653	2N4172	2N4151	3.0	400	105	35	3.0
2N2679			0.35	30	150	0.02	0.7
2N2679A			0.35	30	150	0.02	0.7
2N2680			0.35	60	150	0.02	0.7
2N2680A			0.35	60	150	0.02	0.7
2N2681			0.35	100	150	0.02	0.7
2N2681A			0.35	100	150	0.02	0.70
2N2682			0.35	200	150	0.02	0.7
2N2682A			0.35	200	150	0.02	0.70
2N2683			0.28	30	125	0.02	0.8
2N2683A			0.28	30	125	0.02	0.80
2N2684			0.28	60	125	0.02	0.8
2N2684A			0.28	60	125	0.02	0.80
2N2685			0.28	100	125	0.02	0.8
2N2685A			0.28	100	125	0.02	0.80
2N2686			0.28	200	125	0.02	0.8
2N2686A			0.28	200	125	0.02	0.80
2N2687	2N4213	2N4212	0.28	30	125	0.2	1.0
2N2688	2N4214	2N4212	0.28	60	125	0.2	1.0
2N2689	2N4214	2N4212	0.28	100	125	0.2	1.0
2N2690	2N4216	2N4212	0.28	200	125	0.2	1.0
2N2888			25	200	125	40	1.5

TYPE	REPLACEMENT	REF.	I_f A	V_{FOM}/V_{ROM} V	T_J °C	I_{GT} mA	V_{GT} V
2N2889			25	250	125	40	1.5
2N3001			0.35	30	150	0.02	0.7
2N3002			0.35	60	150	0.02	0.7
2N3003			0.35	100	150	0.02	0.7
2N3004			0.35	200	150	0.02	0.7
2N3005			0.35	30	150	0.2	0.8
2N3006			0.35	60	150	0.2	0.8
2N3007			0.35	100	150	0.2	0.8
2N3008			0.35	200	150	0.2	0.8
2N3027			0.5	30	150	0.2	0.8
2N3028			0.5	60	150	0.2	0.8
2N3029			0.5	100	150	0.2	0.8
2N3030			0.5	30	150	0.02	0.6
2N3031			0.5	60	150	0.02	0.6
2N3032			0.5	100	150	0.02	0.6
2N3091			110	600	125	70	2.0
2N3092			110	700	125	70	2.0
2N3093			110	800	125	70	2.0
2N3094			110	900	125	70	2.0
2N3095			110	1000	125	70	2.0
2N3096			110	1100	125	70	2.0
2N3097			110	1200	125	70	2.0
2N3098			110	1300	125	70	2.0
2N3099			110	600	125	70	2.0
2N3100			110	700	125	70	2.0
2N3101			110	800	125	70	2.0
2N3102			110	900	125	70	2.0
2N3103			110	1000	125	70	2.0
2N3104			110	1100	125	70	2.0
2N3105			110	1200	125	70	2.0
2N3106			110	1300	125	70	2.0
2N3228	2N4154	2N4151	3.2	200	100	15	2.0
2N3254			0.25	15	150	0.02	0.75
2N3255			0.25	30	150	0.02	0.75
2N3256			0.25	60	150	0.02	0.75
2N3257			0.25	15	150	0.2	0.75
2N3258			0.25	30	150	0.2	0.75
2N3259			0.25	60	150	0.2	0.75
2N3269			8.0	100	150	0.2	0.8
2N3270			8.0	200	150	0.2	0.8
2N3271			8.0	300	150	0.2	0.8
2N3272			8.0	400	150	0.2	0.8
2N3273			2.2	100	150	0.2	0.8
2N3274			2.2	200	150	0.2	0.8
2N3275			2.2	300	150	0.2	0.8
2N3276			2.2	400	150	0.2	0.8
2N3353			400	50	125	200	4.0
2N3354			400	100	125	200	4.0
2N3355			400	200	125	200	4.0
2N3356			400	300	125	200	4.0
2N3357			400	400	125	200	4.0
2N3358			400	500	125	200	4.0
2N3359			400	600	125	200	4.0
2N3360			400	700	125	200	4.0
2N3361			400	800	125	200	4.0
2N3362			400	900	125	200	4.0
2N3363			400	1000	125	200	4.0
2N3364			400	1200	125	200	4.0
2N3422			196	600	125	150	3.0
2N3525	2N4156	2N4151	3.2	400	100	15	2.0
2N3528	2N4186	2N4151	1.3	200	100	15	2.0
2N3529	2N4188	2N4151	1.3	400	100	15	2.0
2N3530			400	50	125	300	4.0
2N3531			400	100	125	300	4.0
2N3532			400	200	125	300	4.0
2N3533			400	300	125	300	4.0
2N3534			400	400	125	300	4.0
2N3535			400	500	125	300	4.0
2N3536			400	600	125	300	4.0

TYPE	REPLACEMENT	REF.	I_F A	V_{FOM}/V_{ROM} V	T_J °C	I_{GT} mA	V_{GT} V
2N3537			400	700	125	300	4.0
2N3538			400	800	125	300	4.0
2N3539			400	900	125	300	4.0
2N3540			400	1000	125	300	4.0
2N3541			400	1200	125	300	4.0
2N3555			1.6	30	150	0.020	0.7
2N3556			1.6	60	150	0.020	0.7
2N3557			1.6	100	150	0.020	0.7
2N3558			1.6	200	150	0.020	0.7
2N3559			1.6	30	150	0.20	0.8
2N3560			1.6	60	150	0.20	0.8
2N3561			1.6	100	150	0.20	0.8
2N3562			1.6	200	150	0.20	0.8
2N3649			16	50	120	180	3.0
2N3650			16	100	120	180	3.0
2N3651			16	200	120	180	3.0
2N3652			16	300	120	180	3.0
2N3653			16	400	120	180	3.0
2N3654			16	50	120	180	3.0
2N3655			16	100	120	180	3.0
2N3656			16	200	120	180	3.0
2N3657			16	300	120	180	3.0
2N3658			16	400	120	180	3.0
2N3668	MCR649P-3	MCR649-1	13	100	100	40	2.0
2N3669	MCR649P-4	MCR649-1	13	200	100	40	2.0
2N3670	MCR649P-6	MCR649-1	13	400	100	40	2.0
2N3753			7.5	50	120	100	3.0
2N3754			7.5	100	120	100	3.0
2N3755			7.5	200	120	100	3.0
2N3756			7.5	300	120	100	3.0
2N3757			7.5	400	120	100	3.0
2N3758			7.5	500	120	100	3.0
2N3759			7.5	600	120	100	3.0
2N3760			7.5	700	120	100	3.0
2N3761			7.5	800	120	100	3.0
2N3870	MCR2835-3	MCR2835	22	100	100	40	2.0
2N3871	MCR2835-4	MCR2835	22	200	100	40	2.0
2N3872	MCR2835-6	MCR2835	22	400	100	40	2.0
2N3873	MCR2835-8	MCR2835	22	600	100	40	2.0
2N3884			175	50	125	300	4.0
2N3885			175	100	125	300	4.0
2N3886			175	200	125	300	4.0
2N3887			175	300	125	300	4.0
2N3888			175	400	125	300	4.0
2N3889			175	500	125	300	4.0
2N3890			175	600	125	300	4.0
2N3891			175	700	125	300	4.0
2N3892			175	800	125	300	4.0
2N3893			175	900	125	300	4.0
2N3894			175	1000	125	300	4.0
2N3895			175	1200	125	300	4.0
2N3896	MCR2935-3	MCR2835	22	100	100	40	2.0
2N3897	MCR2935-4	MCR2835	22	200	100	40	2.0
2N3898	MCR2935-6	MCR2835	22	400	100	40	2.0
2N3899	MCR2935-8	MCR2835	22	600	100	40	2.0
2N3936			7.0	100	125	60	3.2
2N3937			7.0	200	125	60	3.2
2N3938			7.0	300	125	60	3.2
2N3939			7.0	400	125	60	3.2
2N3940			7.0	500	125	60	3.2
2N3986			70	500	125	150	3.0
2N3987			70	600	125	150	3.0
2N3988			70	700	125	150	3.0
2N3989			70	800	125	150	3.0
2N3990			70	900	125	150	3.0
2N3991			70	1000	125	150	3.0
2N3992			70	1100	125	150	3.0
2N4096	2N4213	2N4212	0.2	50	125	0.2	0.8
2N4097	2N4214	2N4212	0.2	100	125	0.2	0.8

TYPE	REPLACEMENT	REF.	I_f A	V_{FOM}/V_{ROM} V	T_J °C	I_{GT} mA	V_{GT} V
2N4098	2N4216	2N4212	0.2	50	125	0.2	0.8
2N4101	2N4166	2N4151	3.2	600	100	15	2.0
2N4102	2N4166	2N4151	1.3	600	100	15	2.0
2N4103	MCR649P-8	MCR649-1	8.0	600	100	40	2.0
2N4108	2N4213	2N4212		50	125		
2N4109	2N4214	2N4212		100	125		
2N4110	2N4216	2N4212		200	125		
2N4144	MCR1906-1	MCR1906-1	0.250	15	150	1.0	0.8
2N4145	MCR1906-1	MCR1906-1	0.250	30	150	1.0	0.8
2N4146	MCR1906-2	MCR1906-1	0.250	60	150	1.0	0.8
2N4147	MCR1906-3	MCR1906-1	0.250	100	150	1.0	0.8
2N4148	MCR1906-4	MCR1906-1	0.250	150	150	1.0	0.8
2N4149	MCR1906-4	MCR1906-1	0.250	200	150	1.0	0.8
2N4151		2N4151	8.0	25	100	20	1.5
2N4152		2N4151	8.0	50	100	20	1.5
2N4153		2N4151	8.0	100	100	20	1.5
2N4154		2N4151	8.0	200	100	20	1.5
2N4155		2N4151	8.0	300	100	20	1.5
2N4156		2N4151	8.0	400	100	20	1.5
2N4157		2N4151	8.0	500	100	20	1.5
2N4158		2N4151	8.0	600	100	20	1.5
2N4159		2N4151	8.0	25	100	20	1.5
2N4160		2N4151	8.0	50	100	20	1.5
2N4161		2N4151	8.0	100	100	20	1.5
2N4162		2N4151	8.0	200	100	20	1.5
2N4163		2N4151	8.0	300	100	20	1.5
2N4164		2N4151	8.0	400	100	20	1.5
2N4165		2N4151	8.0	500	100	20	1.5
2N4166		2N4151	8.0	600	100	20	1.5
2N4167		2N4151	8.0	25	100	20	1.5
2N4168		2N4151	8.0	50	100	20	1.5
2N4169		2N4151	8.0	100	100	20	1.5
2N4170		2N4151	8.0	200	100	20	1.5
2N4171		2N4151	8.0	300	100	20	1.5
2N4172		2N4151	8.0	400	100	20	1.5
2N4173		2N4151	8.0	500	100	20	1.5
2N4174		2N4151	8.0	600	100	20	1.5
2N4175		2N4151	8.0	25	100	20	1.5
2N4176		2N4151	8.0	50	100	20	1.5
2N4177		2N4151	8.0	100	100	20	1.5
2N4178		2N4151	8.0	200	100	20	1.5
2N4179		2N4151	8.0	300	100	20	1.5
2N4180		2N4151	8.0	400	100	20	1.5
2N4181		2N4151	8.0	500	100	20	1.5
2N4182		2N4151	8.0	600	100	20	1.5
2N4183		2N4151	8.0	25	100	20	1.5
2N4184		2N4151	8.0	50	100	20	1.5
2N4185		2N4151	8.0	100	100	20	1.5
2N4186		2N4151	8.0	200	100	20	1.5
2N4187		2N4151	8.0	300	100	20	1.5
2N4188		2N4151	8.0	400	100	20	1.5
2N4189		2N4151	8.0	500	100	20	1.5
2N4190		2N4151	8.0	600	100	20	1.5
2N4191		2N4151	8.0	25	100	20	1.5
2N4192		2N4151	8.0	50	100	20	1.5
2N4193		2N4151	8.0	100	100	20	1.5
2N4194		2N4151	8.0	200	100	20	1.5
2N4195		2N4151	8.0	300	100	20	1.5
2N4196		2N4151	8.0	400	100	20	1.5
2N4197		2N4151	8.0	500	100	20	1.5
2N4198		2N4151	8.0	600	100	20	1.5
2N4199		2N4199	100*	300	105	50	1.5
2N4200		2N4199	100*	400	105	50	1.5
2N4201		2N4199	100*	500	105	50	1.5
2N4202		2N4199	100*	600	105	50	1.5
2N4203		2N4199	100*	700	105	50	1.5
2N4204		2N4199	100*	800	105	50	1.5
2N4212		2N4212	1.6	25	125	0.1	1.5
2N4213		2N4212	1.6	50	125	0.1	1.5

THYRISTOR INDEX (continued)

TYPE	REPLACEMENT	REF.	I_f A	V_{FOM}/V_{ROM} V	T_J °C	I_{GT} mA	V_{GT} V
2N4214		2N4212	1.6	100	125	0.1	1.5
2N4215		2N4212	1.6	150	125	0.1	1.5
2N4216		2N4212	1.6	200	125	0.1	1.5
2N4217			1.0	250	125		
2N4218			1.0	300	125		
2N4219			1.0	400	125		
2N4316			9.2	100	150	15	1.2
2N4317			9.2	200	150	15	1.2
2N4318			9.2	300	150	15	1.2
2N4319			9.2	400	150	15	1.2
2N4361			70	100		250	5.0
2N4362			70	200		250	5.0
2N4363			70	400		250	5.0
2N4364			70	600		250	5.0
2N4365			70	800		250	5.0
2N4366			70	1000		250	5.0
2N4367			70	1200		250	5.0
2N4368			70	1400		250	5.0
2N4369			70	1600		250	5.0
2N4370			70	1800		250	5.0
2N4371			70	100		250	5.0
2N4372			70	200		250	5.0
2N4373			70	400		250	5.0
2N4374			70	600		250	5.0
2N4375			70	800		250	5.0
2N4376			70	1000		250	5.0
2N4377			70	1200		250	5.0
2N4378			70	1400		250	5.0
2N4379			70	1600		250	5.0
2N4380			70	1800		250	5.0
2N4441		2N4441	8.0	50	100	30	1.5
2N4442		2N4441	8.0	200	100	30	1.5
2N4443		2N4441	8.0	400	100	30	1.5
2N4444		2N4441	8.0	600	100	30	1.5
2N4983			0.175	30	125	0.50	6.0
2N4984			0.200	30	150	0.15	7.5
2N4985			0.200	30	150	0.30	7.5
2N4986			0.175	30	125	0.20	7.0
2N4987			0.175	30	125	0.50	6.0
2N4988			0.200	30	150	0.15	7.5
2N4989			0.200	30	150	0.30	7.5
2N4990			0.175	30	125	0.20	7.0
2N4991			0.175		125	0.50	6.0
2N4992			0.200		150	0.12	7.5
2N4993			0.200		150	0.50	6.0
2N5060		2N5060	0.8	30	125	0.2	0.8
2N5061		2N5060	0.8	60	125	0.2	0.8
2N5062		2N5060	0.8	100	125	0.2	0.8
2N5063		2N5060	0.8	150	125	0.2	0.8
2N5064		2N5060	0.510	200	125	350	1.2
2N5164		2N5164	13	50	100	75	0.2
2N5165		2N5164	13	200	100	75	0.2
2N5166		2N5164	13	400	100	75	0.2
2N5167		2N5164	13	600	100	75	0.2
2N5168		2N5164	13	50	100	75	0.2
2N5169		2N5164	13	200	100	75	0.2
2N5170		2N5164	13	400	100	75	0.2
2N5171		2N5164	13	600	100	75	0.2
2N5204			200	600		80	3.0
2N5205			200	600		80	3.0
2N5206			200	600		80	3.0
2N5207			200	600		80	3.0
2N5257			200	400	105	800	3.0
2N5258			200	600	105	800	3.0
2N5259			200	800	105	800	3.0
2N5260			200	1000	105	800	3.0
2N5261			200	1200	105	800	3.0
2N5273			25	200	125	150	3.5
2N5274			25	400	125	150	3.5
2N5275			25	600	125	150	3.5

TYPE	REPLACEMENT	REF.	I_F A	V_{FOM}/V_{ROM} V	T_J °C	I_{GT} mA	V_{GT} V
3N58			0.064	40	150	0.001	0.65
3N59			0.064	40	150	0.001	0.65
3N60			0.064	40	150	0.001	0.65
3N80			0.127	40	150	0.001	0.65
3N81			0.127	65	150	0.001	0.65
3N82			0.127	100	150	0.001	0.65
3N83			0.032	70	125	0.15	0.80
3N84			0.111	40	125	0.01	0.65
3N85			0.111	100	125	0.01	0.65
3N86			0.127	65	150	0.001	0.65

FIELD-EFFECT TRANSISTORS

INDEX AND SHORT-FORM SPECIFICATIONS

This table contains a numerical listing and short-form specifications for field-effect transistors with EIA-registered 2N and 3N numbers.

KEY

TYPE	POLARITY	CONST.	NEAREST EQUIV.	REF.	I_{DSS} Min mA	I_{DSS} Max mA	I_{GSS} I_{DGO}* nA	Breakdown Voltage $V_{(BR)}$ Volts	Breakdown Voltage Sub-script	y_{fs} Min µmhos	y_{fs} Max µmhos	C_{iss} pF	NF dB µV*/$\sqrt{Hz}$	@ f	Units	NOTE

TYPE: Numerical Listing of Registered Type Numbers

POLARITY: N = n-channel
P = p-channel

CONST.: J = Junction FET
M = MOS FET

NEAREST EQUIV.: Type number of nearest electrical equivalent fully characterized in this book

REF.: Reference device number indicates specific Data Sheet on which device is characterized

I_{DSS}: Minimum and Maximum Drain Current with gate connected to source

I_{GSS}: Maximum Gate Current (leakage) with drain connected to source

I_{DGO}: *Maximum leakage from drain to gate with source open

Breakdown Voltage: Minimum Breakdown Voltage (Subscript defines conditions)

GS = Gate to source, drain connection not specified
GSS = Gate to source, drain connected to source
GD = Gate to drain, source connection not specified
GDS = Gate to drain, source connected to drain
DGO = Drain to gate, source open
DGS = Drain to gate, source connected to drain
DS = Drain to source, gate connection not specified
DSX = Drain to source, gate biased to cutoff or beyond

y_{fs}: Minimum and Maximum Forward Transadmittance

C_{iss}: Maximum Input Capacitance

NF: Noise Figure in dB or *, µV / $\sqrt{Hz}$ at a specified frequency

frequency units:
H = Hz
K = kHz
M = MHz

TYPE	POLARITY	CONST.	Nearest Equivalent	Reference	I_{DSS}		I_{GSS} I_{DGO}*	Breakdown Voltage		y_{fs}		C_{ISS}	NF	@ f		NOTE
					Min mA	Max mA(nA*)	nA	$V_{(BR)}$ Volts	Sub-script	Min µmhos	Max µmhos	pF	dB µV*/$\sqrt{Hz}$		Units	
2N2386	P	J	2N5266-9	2N5265			10	20	GS	1000		50				
2N2386A	P	J	2N5267-70	2N5265	1.0	15	10	20	DGO	2200	5000	10				
2N2497	P	J	2N5267	2N5265	1.0	5.0	10	20	GD	1000	2000	32	3.0	1.0	K	
2N2498	P	J	2N5268	2N5265	2.0	6.0	10	20	GD	1500	3000	32	3.0	1.0	K	
2N2499	P	J	2N5269-70	2N5265	5.0	15	10	20	GD	2000	4000	32	4.0	1.0	K	
2N2500	P	J	2N5267-8	2N5265	1.0	6.0	10	20	GS	1000	2000	32	1.0	1.0	K	
2N2606	P	J	2N5473-4	2N5471	0.1	0.5	1.0	30	GDS	110		6.0	3.0	1.0	K	
2N2607	P	J	2N5475-6	2N5471	0.3	1.5	3.0	30	GDS	330		10	3.0	1.0	K	
2N2608	P	J	2N5266-8	2N5265	0.9	4.5	10	30	GDS	1000		17	3.0	1.0	K	
2N2609	P	J	2N5268-70	2N5265	2.0	10	30	30	GDS	2500		30	3.0	1.0	K	
2N2620	N	J					100	50	DGO							
2N2794	P	J			1.5	5.0	10	20	DGO							
2N2841	P	J	2N5471-2	2N5471	0.025	0.125	1.0			60		6.0	3.0	1.0	K	
2N2842	P	J	2N5472-3	2N5471	0.065	0.325	3.0			180		10	3.0	1.0	K	
2N2843	P	J	2N5265	2N5265	0.2	1.0	10			540		17	3.0	1.0	K	
2N2844	P	J	2N5265-7	2N5265	1.0	2.2	30			1400		30	3.0	1.0	K	
2N3066	N	J	MFE2095	MFE2093	0.8	4.0	1.0	50	DGO	400	1000	10	3.0	1.0	K	
2N3066A	N	J			0.8	4.0	1.0	50	DGO	400	1000	10	0.25	1.0	K	
2N3067	N	J	MFE2093-4	MFE2093	0.2	1.0	1.0	50	DGO	400		18	3.0	1.0	K	
2N3067A	N	J			0.2	1.0	1.0	50	DGO	300	1000	10	0.25	1.0	K	
2N3068	N	J	MFE2093	MFE2093	0.05	0.25	1.0	50	DGO	200		18	3.0	1.0	K	
2N3068A	N	J	MFE2093	MFE2093	0.05	0.25	1.0	50	DGO	200	1000	10	0.25	1.0	K	
2N3069	N	J	2N4220A-2A	2N4220	2.0	10	1.0	50	DGO	1000		15	3.0	1.0	K	
2N3069A	N	J			2.0	10	1.0	50	DGO	1000	2500	15	0.25	1.0	K	
2N3070	N	J	2N4220A	2N4220	0.5	2.5	1.0	50	DGO	750		15	3.0	1.0	K	
2N3070A	N	J			0.5	2.5	1.0	50	DGO	750	2500	15	0.25	1.0	K	
2N3071	N	J	2N4220A	2N4220	0.1	0.6	1.0	50	DGO	500	2500	15	3.0	1.0	K	
2N3084	N	J	MFE2095	MFE2093	0.8	3.0	0.1	15	DGO	400	2000	14				
2N3085	N	J	MFE2095	MFE2093	0.8	3.0	0.1	15	DGO	400	2000	14				
2N3086	N	J	MFE2095	MFE2093	0.8	3.0	1.0	30	DGS	400	2000	14				
2N3087	N	J	MFE2095	MFE2093	0.8	3.0	1.0	30	DGS	400	2000	14				
2N3088	N	J	MFE2094-5	MFE2093	0.5	2.0	1.0	10	DGS	300	2000	14	3.0			
2N3088A	N	J	MFE2094-5	MFE2093	0.5	2.0	1.0	10	DGS	300	2000	14	0.5	10	H	
2N3089	N	J	MFE2094-5	MFE2093	0.5	2.0	1.0	10	DGS	300	2000	14	3.0			
2N3089A	N	J	MFE2094-5	MFE2093	0.5	2.0	1.0	10	DGS	300	2000	14	0.5	10	H	
2N3112	P	J	2N5471-3	2N5471	0.035	0.175	0.05	20	GDS	50	115	3.5				
2N3113	P	J	2N5471-3	2N5471	0.035	0.175	0.05	20	GDS	50	115	2.0				
2N3277	P	J	2N5473-4	2N5471	0.15	0.5	0.4	25	DGO	100		3.0				
2N3278	P	J	2N5475	2N5471	0.4	0.9	0.4	25	DGO	150		3.0				
2N3328	P	J	2N5473-5	2N5471	1.0		1.0	20	GSS	100		3.0	3.0			
2N3329	P	J	2N5266-7	2N5265	1.0	3.0	10	20	GSS	1000	2000	20	3.0			
2N3330	P	J	2N5267-8	2N5265	2.0	6.0	10	20	GSS	1500	3000	20	3.0			
2N3331	P	J	2N5269-70	2N5265	5.0	15	10	20	GSS	2000	4000	20	4.0			
2N3332	P	J	2N5267-8	2N5265	1.0	6.0	10	20	GSS	1000	2200	20	1.0			
2N3333	P	J			0.3	1.0	10	20	GSS	600	1800	30				Dual
2N3334	P	J			0.3	1.0	10	20	GSS	600	1800	30				Dual
2N3335	P	J			0.3	1.0	10	20	GSS	600	1800	30				Dual
2N3336	P	J			0.3	1.0	10	20	GSS	600	1800	30				Dual
2N3365	N	J	2N4220A 1A	2N4220	0.8	4.0	5.0	40	DGO	250	1000	15				
2N3366	N	J	MFE2093-4	MFE2093	0.2	1.0	5.0	40	DGO	250	1000	15				
2N3367	N	J	MFE2093	MFE2093	0.005	0.25	5.0	40	DGO	100	1000	15				
2N3368	N	J	2N4221A 2A	2N4220	2.0	12	5.0	40	DGO	1000	4000	20				
2N3369	N	J	2N4220A	2N4220	0.5	2.5	5.0	40	DGO	600	2500	20				
2N3370	N	J	MFE2093	MFE2093	0.1	0.6	5.0	40	DGO	300	2500	20				
2N3376	P	J	2N5265-8	2N5265	0.6	6.0	3.0	30	DGS	800		5.0				
2N3377	P	J	2N5265-8	2N5265	0.6	6.0	3.0	30	DGS	800	2300	4.0				
2N3378	P	J	2N5268	2N5265	3.0	6.0	3.0	30	DGS	1500	2300	5.0				
2N3379	P	J	2N5268	2N5265	3.0	6.0	3.0	30	DGS	1500	2300	4.0				
2N3380	P	J	2N5268-70	2N5265	3.0	20	3.0	30	DGS	1500	3000	4.0				
2N3381	P	J	2N5268-70	2N5265	3.0	20	3.0	30	DGS	1500	3000	4.0				
2N3382	P	J			3.0	30	15	30	DGS	4500	12500					
2N3383	P	J			3.0	30	15	30	DGS	4500	12500					
2N3384	P	J			15	30	15	30	DGS	7500	12500					
2N3385	P	J			15	30	15	30	DGS	7500	12500					
2N3386	P	J			13	50	15	30	DGS	7500	12500					
2N3387	P	J			13	50	15	30	DGS	5000	10000					
2N3436	N	J			3.0	15	0.5	50	DGO	2500	10000	18	2.0			
2N3437	N	J			0.8	4.0	0.5	50	DGO	1500	6000	18	2.0			
2N3438	N	J			0.2	1.0	0.5	50	DGO	800	4500	18	2.0			
2N3452	N	J	MFE2095	MFE2093	0.8	4.0	0.1	50	DGO	200	1200	6.0	2.0			
2N3453	N	J	MFE2094	MFE2093	0.2	1.0	0.1	50	DGO	150	900	6.0	2.0			
2N3454	N	J	MFE2093	MFE2093	0.05	0.25	0.1	50	DGO	100	600	6.0	2.0			
2N3455	N	J	MFE2095	MFE2093	0.8	4.0	0.04	50	DGO	400	1200	5.0	4.0			
2N3456	N	J	MFE2094	MFE2093	0.2	1.0	0.04	50	DGO	300	900	5.0	4.0			
2N3457	N	J	MFE2093	MFE2093	0.05	0.25	0.04	50	DGO	150	600	5.0	4.0			
2N3458	N	J			3.0	15	0.25	50	DGO	2500	10000	18	6.0			
2N3459	N	J			0.8	4.0	0.25	50	DGO	1500	6000	18	4.0			
2N3460	N	J			0.2	1.0	0.25	50	DGO	800	4500	18	4.0			
2N3465	N	J	MFE2095	MFE2093	1.0	5.0	1.0	40	DGO	400	1200	15	5.0			
2N3466	N	J	MFE2095	MFE2093	1.0	5.0	1.0	40	DGO	400	1200	15	5.0			
2N3573	P	J	2N5471-2	2N5471	0.02	0.1	0.6	25	GSS	100	300	6.0	3.0			
2N3574	P	J	2N5472-4	2N5471	0.075	0.375	0.6	25	GSS	200	600	6.0	3.0			
2N3575	P	J	2N5474-5	2N5471	0.2	1.0	0.6	25	GSS	300	900	6.0	3.0			
2N3578	P	J	2N5266-8	2N5265	0.9	4.5	15	20	GSS	1200	3500	65				
2N3608	P	M	2N4352	2N4352	30	0.025										
2N3609	P	M			35	0.02										
2N3610	P	M	2N4352	2N4352	10	0.02										
2N3631	N	M	2N3797	2N3796	2.0	10		20	DSX	1400	2800	7.5				
2N3684	N	J	2N4221A	2N4221	2.5	7.5	0.1	50	GS	2000	3000	4.0	0.5			

FIELD-EFFECT TRANSISTORS INDEX (continued)

TYPE	POLARITY	CONST.	Nearest Equivalent	Reference	I_{DSS}		I_{GSS} I_{DGO}*	Breakdown Voltage		y_{fs}		C_{ISS}	NF	@ f		NOTE
					Min mA	Max mA(nA*)	nA	$V_{(BR)}$ Volts	Sub-script	Min µmhos	Max µmhos	pF	dB µV*/$\sqrt{Hz}$		Units	
2N3685	N	J	2N4220A	2N4221	1.0	3.0	0.1	50	GS	1500	2500	4.0	0.5			
2N3686	N	J	2N4220A	2N4221	0.4	1.2	0.1	50	GS	1000	2000	4.0	0.5			
2N3687	N	J	2N5358	2N5358	0.1	0.5	0.1	50	GS	500	1500	4.0	0.15*			
2N3695	P	J	2N5267	2N5265	1.25	3.75	0.1	30	GS	1000	1750	5.0	0.2*			
2N3696	P	J	2N5266	2N5265	0.5	1.5	0.1	30	GS	750	1250	5.0	0.2*			
2N3697	P	J	2N5265	2N5265	0.2	0.6	0.1	30	GS	500	1000	5.0	0.2*			
2N3698	P	J	2N5265	2N5265	0.05	0.25	0.1	30	GS	250	750	5.0	0.2*			
2N3796	N	M		2N3796	0.5	3.0	0.001	25	DSX	900	1800	6.0	4.0			
2N3797	N	M		2N3796	2.0	6.0	0.001	20	DSX	1500	3000	8.0	4.0			
2N3819	N	J	MPF102	MPF102	2.0	20	2.0	25	GSS	2000	6500	8.0				
2N3820	P	J	2N5460-2	2N5460	0.3	15	20	20	GSS	800	5000	32				
2N3821	N	J		2N3821	0.5	2.5	0.1	50	GSS	1500	4500	6.0	5.0	10	H	
2N3822	N	J		2N3821	2.0	10	0.1	50	GSS	3000	6500	6.0	5.0	10	H	
2N3823	N	J		2N3823	4.0	20	0.5	30	DGS	3500	6500	6.0	2.5	100	M	
2N3824	N	J		2N3821			0.1	50	GSS			6.0				
2N3882	P	M	MFE3003	MFE3003	0.25		0.1	30	DS	1000	2400	4.0	3.0			
2N3909	P	J	2N5460-2	2N5460	0.3	15	10	20	DGS	1000	5000	32				
2N3909A	P	J	2N5460-2		1.0	15	10	20	GSS	2000		9.0				
2N3921	N	J	MMF1,2	MMF1	1.0	10	0.25	50	GSS	1500	7500	18	2.0	1.0	K	Dual
2N3922	N	J	MMF3,4	MMF1	1.0	10	0.25	50	GSS	1500	7500	18	2.0	1.0	K	Dual
2N3934	N	J	MMF1,2	MMF1	0.25	1.3	0.1	50	GSS	300	900	7.0	2.0	100	H	Dual
2N3935	N	J	MMF5,6	MMF1	0.25	1.3	0.1	50	GSS	300	900	7.0	2.0	100	H	Dual
2N3954	N	J	MMF1,2	MMF1	0.5	5.0	0.1	50	GSS	1000		4.0	0.5	100	H	Dual
2N3954A	N	J	MMF1,2	MMF1	0.5	5.0	0.1	50	GSS	1000		4.0	0.5	100	H	
2N3955	N	J	MMF1,2	MMF1	0.5	5.0	0.1	50	GSS	1000		4.0	0.5	100	H	Dual
2N3955A	N	J	MMF1,2	MMF1	0.5	5.0	0.1	50	GSS	1000		4.0	0.5	100	H	
2N3956	N	J	MMF5,6	MMF1	0.5	5.0	0.1	50	GSS	1000		4.0	0.5	100	H	Dual
2N3957	N	J	MMF5,6	MMF1	0.5	5.0	0.1	50	GSS	1000		4.0	0.5	100	H	Dual
2N3958	N	J	MMF5,6	MMF1	0.5	5.0	0.1	50	GSS	1000		4.0	0.5	100	H	Dual
2N3966	N	J	2N4221	2N4220	2.0		0.1	30	DGS			6.0				
2N3967	N	J	2N4221A-2A	2N4220	2.5	10	0.1	30	DGS	1600	2400	5.0				
2N3967A	N	J	2N4221A-2A	2N4220	2.5	10	0.1	30	GSS	1600	2400	5.0	1.5	100	H	
2N3968	N	J	2N4221A	2N4220	1.0	5.0	0.1	30	DGS	1400	2000	5.0				
2N3968A	N	J	2N4221A	2N4220	1.0	5.0	0.1	30	GSS	1400	2000	5.0	1.5	100	H	
2N3969	N	J	2N4220A	2N4220	0.4	2.0	0.1	30	DGS	950	1450	5.0				
2N3969A	N	J	2N4220A	2N4220	0.4	2.0	0.1	30	GSS	950	1450	5.0	1.5	100	H	
2N3970	N	J	2N4091	2N4091	50	150	0.25*	40	DGS			25				
2N3971	N	J	2N4091-2	2N4091	25	75	0.25*	40	DGS			25				
2N3972	N	J	2N4093	2N4091	5.0	30	0.25*	40	DGS			25				
2N3993	P	J			10		1.2*	25	GSS	6000	12000	16				
2N3994	P	J			2.0		1.2*	25	GSS	4000	10000	16				
2N4038	N	M				0.1		15	DSX							
2N4039	N	M			0.1	1.5		15	DSX							
2N4065	P	M	2N4352	2N4352		0.005	0.0025	25	GSS			4.5				
2N4066	P	M					0.0025	25	GSS			7.0				
2N4067	P	M				1.0*		30	DSS	2500		7.0				
2N4082	N	J	MMF1,2	MMF1	0.25	1.3	0.1	50		300		7.0				Dual
2N4083	N	J	MMF3,4	MMF1	0.25	1.3	0.1	50		300		7.0				Dual
2N4084	N	J	MMF1,2	MMF1	1.0	10	0.25	50		1500		18				Dual
2N4085	N	J	MMF3,4	MMF1	1.0	10	0.25	50		1500		18				Dual
2N4088	P	J			5.0	15	0.1	30	GSS	1000	1600	10	1.5	1.0	K	
2N4089	P	J			2.0	8.0	0.1	30	GSS	800	1300	10	1.5	1.0	K	
2N4090	P	J			0.4	2.5	0.1	30	GSS	500	900	10	1.5	1.0	K	
2N4091	N	J		2N4091	30		0.2*	40	DGO			16				
2N4092	N	J		2N4091	15		0.2*	40	DGO			16				
2N4093	N	J		2N4091	8.0		0.2*	40	DGO			16				
2N4094	N	J	2N4091	2N4091	75			40	GSS			32				
2N4095	N	J	2N4092	2N4091	20			40	GSS			32				
2N4117	N	J	MFE2093	MFE2093	0.03	0.09	0.01	40	GSS	70	210	3.0				
2N4117A	N	J	MFE2093	MFE2093	0.03	0.09	0.001	40	DGO			3.0				
2N4118	N	J	MFE2093	MFE2093	0.08	0.24	0.01	40	GSS	80	250	3.0				
2N4118A	N	J	MFE2093	MFE2093	0.08	0.24	0.001	40	DGO			3.0				
2N4119	N	J	MFE2093	MFE2093	0.2	0.6	0.01	40	GSS	100	330	3.0				
2N4119A	N	J	MFE2093	MFE2093	0.2	0.6	0.001	40	DGO			3.0				
2N4120	P	M	2N4352	2N4352		500*	0.0025	30	DSS	700		0.7				
2N4139	N	J	2N4222A	2N4221	8.0	11	1.0	50	DGO			18				
2N4220	N	J		2N4220	0.5	3.0	0.1	30	GSS	1000	4000	6.0				
2N4220A	N	J		2N4220	0.5	3.0	0.1	30	GSS	1000	4000	6.0	2.5	1.0	H	
2N4221	N	J		2N4220	2.0	6.0	0.1	30	GSS	2000	5000	6.0				
2N4221A	N	J		2N4220	2.0	6.0	0.1	30	GSS	2000	5000	6.0	2.5	1.0	H	
2N4222	N	J		2N4220	5.0	15	0.1	30	GSS	2500	6000	6.0				
2N4222A	N	J		2N4220	5.0	15	0.1	30	GSS	2500	6000	6.0	2.5	1.0	H	
2N4223	N	J			3.0	18	0.25	30	GSS	3000	7000	6.0	5.0	200	M	
2N4224	N	J		2N4223	2.0	20	0.5	30	GSS	2000	7500	6.0				
2N4267	P	M	2N4352	2N4223		0.001	0.005	30	GSS			15				
2N4268	P	M	2N4352	2N4352		0.001	0.005	30	GSS			15				
2N4302	N	J	2N5457	2N4352		5.0	1.0	30	DGO			6.0				
2N4303	N	J	2N5458	2N5457		10	1.0	30	DGO			6.0				
2N4304	N	J	2N5457-9	2N5457		15	1.0	30	DGO			6.0				
2N4338	N	J	2N4220A	2N4220	0.2	0.6	0.1	50	DGO			6.0				
2N4339	N	J	2N4220A	2N4220	0.5	1.5	0.1	50	DGO			6.0				
2N4340	N	J	2N4220A-1A	2N4220	1.2	3.6	0.1	50	DGO			6.0				
2N4341	N	J	2N4221A-2A	2N4220	3.0	9.0	0.1	50	DGO			6.0				
2N4342	P	J			4.0	12	10	25	DGO			5.0				
2N4343	P	J			10	30	10	25	DGO			5.0				
2N4351	N	M		2N4351		0.01	0.01	25	DSS	1000		5.5				
2N4352	P	M		2N4352		0.005	0.01	25	DSS	1000		6.5				
2N4353	P	M	2N4352	2N4352				3.0	GSS	1000	4000	12				
2N4360	P	J			3.0	30	10	20	GSS	2000	8000	20	5.0	100	H	

TYPE	POLARITY	CONST.	Nearest Equivalent	Reference	I_{DSS}		I_{GSS} I_{DGO}*	Breakdown Voltage		y_{fs}		C_{ISS}	NF @ f			NOTE
					Min mA	Max mA(nA*)	nA	$V_{(BR)}$ Volts	Sub-script	Min µmhos	Max µmhos	pF	dB µV* / $\sqrt{Hz}$		Units	
2N4382	P	J			10	30	1.0	25	GSS			5.0				
2N4391	N	J			50	100	0.1	40	GSS							
2N4392	N	J			25	75	0.1	40	GSS							
2N4393	N	J			5.0	30	0.1	40	GSS							
2N4416	N	J		2N4416	5.0	15		30	GSS			4.0				
2N4416A	N	J	2N4416	2N4416	5.0	15	0.1	35	GSS	4500	7500	4.0	4.0	400	M	
2N4417	N	J	2N4416	2N4416	5.0	15		30	GSS			3.5				
2N4445	N	J	MFE2012	MFE2010			3.0	25	GSS			50				
2N4446	N	J	MFE2012	MFE2010			3.0	25	GSS			50				
2N4447	N	J	MFE2012	MFE2010			3.0	20	GSS			50				
2N4448	N	J	MFE2012	MFE2010			3.0	20	GSS			50				
2N4856	N	J	2N4091	2N4091	50		0.25	40	GSS			18				
2N4856A	N	J	2N4091	2N4091	50		0.25	40	GSS			10				
2N4857	N	J	2N4092	2N4091	20	100	0.25	40	GSS			18				
2N4857A	N	J	2N4092	2N4091	20	100	0.25	40	GSS			10				
2N4858	N	J	2N4093	2N4091	8.0	80	0.25	40	GSS			18				
2N4858A	N	J	2N4093	2N4091	8.0	80	0.25	40	GSS			10				
2N4859	N	J	2N4091	2N4091	50		0.25	30	GSS			18				
2N4859A	N	J	2N4091	2N4091	50		0.25	30	GSS			10				
2N4860	N	J	2N4092	2N4091	20	100	0.25	30	GSS			18				
2N4860A	N	J	2N4092	2N4091	20	100	0.25	30	GSS			10				
2N4861	N	J	2N4093	2N4091	8.0	80	0.25	30	GSS			15				
2N4861A	N	J	2N4093	2N4091	8.0	80	0.25	30	GSS			10				
2N4867	N	J	2N4220A	2N4220	0.4	1.2	0.25	40	GSS	700	2000	25	1.0	1.0	K	
2N4867A	N	J	2N4220A	2N4220	0.4	1.2	0.25	40	GSS	700	2000	25	1.0	1.0	K	
2N4868	N	J	2N4220A	2N4220	1.0	3.0	0.25	40	GSS	1000	3000	25	1.0	1.0	K	
2N4868A	N	J	2N4220A	2N4220	1.0	3.0	0.25	40	GSS	1000	3000	25	1.0	1.0	K	
2N4869	N	J	2N4221A-2A	2N4220	2.5	7.5	0.25	40	GSS	1300	4000	25	1.0	1.0	K	
2N4869A	N	J	2N4221A-2A	2N4220	2.5	7.5	0.25	40	GSS	1300	4000	25	1.0	1.0	K	
2N4881	N	J			0.4	2.0	2.0	100	GSS			15				
2N4882	N	J			1.5	7.5	2.0	100	GSS			15				
2N4883	N	J			0.4	2.0	1.0	100	GSS			15				
2N4884	N	J			1.5	7.5	1.0	100	GSS			15				
2N4885	N	J			0.4	2.0	1.0	75	GSS			15				
2N4886	N	J			1.5	7.5	1.0	75	GSS			15				
2N4977	N	J	MFE2009	MFE2007	50		0.5	30	GSS			35				
2N4978	N	J	MFE2008	MFE2007	15		0.5	30	GSS			35				
2N4979	N	J	MFE2007	MFE2007	7.5		0.5	30	GSS			35				
2N5018	P	J			10		2.0	30	GSS			45				
2N5019	P	J			5.0		2.0	30	GSS			45				
2N5020	P	J	2N5265-6	2N5265	0.3	1.2	1.0	25	GSS			25				
2N5021	P	J	2N5266-7	2N5265	1.0	3.5	1.0	25	GSS			25				
2N5033	P	J	2N5265-7	2N5265	0.3	3.5	10	20	GSS	1000	5000	25	2.0	1.0	K	
2N5045	N	J	MMF5,6	MMF1	0.5	8.0	0.25					8.0				
2N5046	N	J	MMF5,6	MMF1	0.5	8.0	0.25					8.0				
2N5047	N	J	MMF5,6	MMF1	0.5	8.0	0.25					8.0				
2N5078	N	J	2N4416	2N4416	4.0	25	0.25	30	GSS	4500	10000	6.0	3.0	200	M	
2N5103	N	J	2N3823	2N3823	1.0	8.0	0.1	25	GSS	2000	8000	5.0	1.5	100	H	
2N5104	N	J	2N3823	2N3823	2.0	6.0	0.1	25	GSS	3500	7500	5.0	1.5	100	H	
2N5105	N	J	2N3823	2N3823	5.0	15	0.1	25	GSS	5000	10000	5.0	1.5	100	H	
2N5114	P	J			30	90	0.5	30	GSS			25				
2N5115	P	J			15	60	0.5	30	GSS			25				
2N5116	P	J			5.0	25	0.5	30	GSS			25				
2N5158	N	J	MFE2012	MFE2010			1.0	40	GSS			50				
2N5159	N	J	MFE2012	MFE2010			1.0	40	GSS			50				
2N5163	N	J	MPF102	MPF102	1.0	40	10	25	GSS	2000	9000	12				
2N5196	N	J	MMF1,2	MMF1	0.7	7.0	0.025	50	GSS	1000	4000	6.0	1.0	100	H	
2N5197	N	J	MMF1,2	MMF1	0.7	7.0	0.025	50	GSS	1000	4000	6.0	1.0	100	H	
2N5198	N	J	MMF3,4	MMF1	0.7	7.0	0.025	50	GSS	1000	4000	6.0	1.0	100	H	
2N5199	N	J	MMF5,6	MMF1	0.7	7.0	0.025	50	GSS	1000	4000	6.0	1.0	100	H	
2N5245	N	J	2N5486	2N5484	5.0	15	1.0	30	GSS	4500	7500	4.5	2.0	100	M	
2N5246	N	J	2N5485	2N5484	1.5	7.0	1.0	30	GSS	3000	6000	4.5				
2N5247	N	J	2N5486	2N5484	8.0	24	1.0	30	GSS	4500	8000	4.5				
2N5248	N	J	MPF102	MPF102	4.0	20	5.0	30	GSS	3500	6500	6.0				
2N5265	P	J		2N5265	0.5	1.0	2.0	60	GSS	900	2700	7.0	2.5	100	H	
2N5266	P	J		2N5265	0.8	1.6	2.0	60	GSS	1000	3000	7.0	2.5	100	H	
2N5267	P	J		2N5265	1.5	3.0	2.0	60	GSS	1500	3500	7.0	2.5	100	H	
2N5268	P	J		2N5265	2.5	5.0	2.0	60	GSS	2000	4000	7.0	2.5	100	H	
2N5269	P	J		2N5265	4.0	8.0	2.0	60	GSS	2200	4500	7.0	2.5	100	H	
2N5270	P	J		2N5265	7.0	14.0	2.0	60	GSS	2500	5000	7.0	2.5	100	H	
2N5277	N	J	2N3822	2N3821	2.5	12.5	5.0	150	GSS	2000	5000	25	3.0	1.0	K	
2N5278	N	J			10	25	5.0	150	GSS	3000	6000	25	3.0	1.0	K	
2N5358	N	J		2N5358	0.5	1.0	0.1	40	GSS	1000	3000	6.0	2.5	100	H	
2N5359	N	J		2N5358	0.8	1.6	0.1	40	GSS	1200	3600	6.0	2.5	100	H	
2N5360	N	J		2N5358	1.5	3.0	0.1	40	GSS	1400	4200	6.0	2.5	100	H	
2N5361	N	J		2N5358	2.5	5.0	0.1	40	GSS	1500	4500	6.0	2.5	100	H	
2N5362	N	J		2N5358	4.0	8.0	0.1	40	GSS	2000	5500	6.0	2.5	100	H	
2N5363	N	J		2N5358	7.0	14	0.1	40	GSS	2500	6000	6.0	2.5	100	H	
2N5364	N	J		2N5358	9.0	18	0.1	40	GSS	2700	6500	6.0	2.5	100	H	
2N5391	N	J	2N5358	2N5358	0.5	1.5	0.2	70	GSS	1500	4500	18	1.0	100	H	
2N5392	N	J	2N5360	2N5358	1.0	3.0	0.2	70	GSS	2000	6000	18	1.0	100	H	
2N5393	N	J	2N5360	2N5358	2.5	4.5	0.2	70	GSS	3000	6500	18	1.0	100	H	
2N5394	N	J	2N5361	2N5358	4.0	6.0	0.2	70	GSS	4000	7000	18	1.0	100	H	
2N5395	N	J	2N5362	2N5358	5.5	8.0	0.2	70	GSS	4500	7000	18	1.0	100	H	
2N5396	N	J	2N5362	2N5358	7.5	10	0.2	70	GSS	4500	7500	18	1.0	100	H	
2N5397	N	J	MFE2001	MFE2000	10	30	0.1	25	GSS	6000	10000	5.0	3.5	450	M	
2N5398	N	J	MFE2001	MFE2000	5.0	40	0.1	25	GSS	5500	10000	5.5				
2N5432	N	J			150		0.2	25	GSS			30				
2N5433	N	J			100		0.2	25	GSS			30				
2N5434	N	J			30		0.2	25	GSS			30				

TYPE	POLARITY	CONST.	Nearest Equivalent	Reference	I_{DSS}		I_{GSS} I_{DGO}*	Breakdown Voltage		y_{fs}		C_{ISS}	NF	@ f		NOTE
					Min mA	Max mA(nA*)	nA	$V_{(BR)}$ Volts	Sub-script	Min µmhos	Max µmhos	pF	dB µV*/$\sqrt{Hz}$		Units	
2N5452	N	J	MMF1,2	MMF1	0.5	5.0	0.1	50	GSS	1000	3000	4.0	0.02*	1.0	K	
2N5453	N	J	MMF1,2	MMF1	0.5	5.0	0.1	50	GSS	1000	3000	4.0	0.02*	1.0	K	
2N5454	N	J	MMF3,4	MMF1	0.5	5.0	0.1	50	GSS	1000	3000	4.0	0.02*	1.0	K	
2N5457	N	J		2N5457	1.0	5.0	1.0	25	GSS	1000	5000	7.0				
2N5458	N	J		2N5457	2.0	9.0	1.0	25	GSS	1500	5500	7.0				
2N5459	N	J		2N5457	4.0	16	1.0	25	GSS	2000	6000	7.0				
2N5460	P	J		2N5460	1.0	5.0	5.0	40	GSS	1000	4000	7.0	2.5	100	H	
2N5461	P	J		2N5460	2.0	9.0	5.0	40	GSS	1500	5000	7.0	2.5	100	H	
2N5462	P	J		2N5460	4.0	16	5.0	40	GSS	2000	6000	7.0	2.5	100	H	
2N5463	P	J		2N5460	1.0	5.0	5.0	60	GSS	1000	4000	7.0	2.5	100	H	
2N5464	P	J		2N5460	2.0	9.0	5.0	60	GSS	1500	5000	7.0	2.5	100	H	
2N5465	P	J		2N5460	4.0	16	5.0	60	GSS	2000	6000	7.0	2.5	100	H	
2N5471	P	J		2N5471	0.02	0.06	0.5	40	GSS	60	180	5.0	2.5	1.0	K	
2N5472	P	J		2N5471	0.05	0.12	0.5	40	GSS	90	225	5.0	2.5	1.0	K	
2N5473	P	J		2N5471	0.10	0.25	0.5	40	GSS	120	300	5.0	2.5	1.0	K	
2N5474	P	J		2N5471	0.20	0.50	0.5	40	GSS	160	400	5.0	2.5	1.0	K	
2N5475	P	J		2N5471	0.40	1.0	0.5	40	GSS	200	500	5.0	2.5	1.0	K	
2N5476	P	J		2N5471	0.80	2.0	0.5	40	GSS	260	650	5.0	2.5	1.0	K	
2N5484	N	J		2N5484	1.0	5.0	1.0	25	GSS	3000	6000	5.0	3.0	100	M	
2N5485	N	J		2N5484	4.0	10	1.0	25	GSS	3500	7000	5.0	2.0	100	M	
2N5486	N	J		2N5484	8.0	20	1.0	25	GSS	4000	8000	5.0	2.0	100	M	
2N5505	P	J					0.25	30	GSS	1000	3500	16	2.0	1.0	K	Dual
2N5506	P	J					0.25	30	GSS	1000	3500	16	2.0	1.0	K	Dual
2N5507	P	J					0.25	30	GSS	1000	3500	16	2.0	1.0	K	Dual
2N5508	P	J					0.25	30	GSS	1000	3500	16	2.0	1.0	K	Dual
2N5509	P	J					0.25	30	GSS	1000	3500	16	2.0	1.0	K	Dual
2N5510	P	J					0.25	30	GSS	500	3000	16	2.0	1.0	K	Dual
2N5511	P	J					0.25	30	GSS	500	3000	16	2.0	1.0	K	Dual
2N5512	P	J					0.25	30	GSS	500	3000	16	2.0	1.0	K	Dual
2N5513	P	J					0.25	30	GSS	500	3000	16	2.0	1.0	K	Dual
2N5514	P	J					0.25	30	GSS	500	3000	16	2.0	1.0	K	Dual
2N5515	N	J			0.5	7.5	0.25	40	GSS	1000	4000	25	2.0	1.0	H	Dual
2N5516	N	J			0.5	7.5	0.25	40	GSS	1000	4000	25	2.0	1.0	H	Dual
2N5517	N	J			0.5	7.5	0.25	40	GSS	1000	4000	25	2.0	1.0	H	Dual
2N5518	N	J			0.5	7.5	0.25	40	GSS	1000	4000	25	2.0	1.0	H	Dual
2N5519	N	J			0.5	7.5	0.25	40	GSS	1000	4000	25	2.0	1.0	H	Dual
2N5520	N	J			0.5	7.5	0.25	40	GSS	1000	4000	25	1.0	1.0	H	Dual
2N5521	N	J			0.5	7.5	0.25	40	GSS	1000	4000	25	1.0	1.0	H	Dual
2N5522	N	J			0.5	7.5	0.25	40	GSS	1000	4000	25	1.0	1.0	H	Dual
2N5523	N	J			0.5	7.5	0.25	40	GSS	1000	4000	25	1.0	1.0	H	Dual
2N5524	N	J			0.5	7.5	0.25	40	GSS	1000	4000	25	1.0	1.0	H	Dual
2N5543	N	J			2.0	10	1000			750	3000	10				
2N5544	N	J			2.0	10	1000			750	3000	10				
2N5545	N	J			0.5	8.0	0.1			1500	6000	6.0	3.5	10	H	Dual
2N5546	N	J			0.5	8.0	0.1			1500	6000	6.0	5.0	10	H	Dual
2N5547	N	J			0.5	8.0	0.1			1500	6000	6.0				Dual
2N5548	P	M				10*	0.05			3500	6500	10				
2N5549	N	J			10	60	0.25	40	GSS	6000	15000	8.0				
2N5555	N	J		2N5555	15		1.0	25	GSS			5.0				
2N5556	N	J		2N5556	0.5	2.5	0.1	30	GSS	1500	6500	6.0	1.0	10	H	
2N5557	N	J		2N5556	2.0	5.0	0.1	30	GSS	1500	6500	6.0	1.0	10	H	
2N5558	N	J		2N5556	4.0	10	0.1	30	GSS	1500	6500	6.0	1.0	10	H	
3N89	P	J			0.5	2.5	5.0	30		450	1300	3.0				
3N96	P	J			0.5	2.5	5.0	30		450	1300	4.0				Dual
3N97	P	J			0.5	2.5	5.0	30		450	1300	4.0				Dual
3N98	N	M	MFE3004-5	MFE3004	3.5	7.7	0.05	32		1000	3000	7.0				
3N99	N	M	MFE3004-5	MFE3004	5.0	10.5	0.05	32		1000	4500	7.0				
3N124	N	J		3N124	0.2	2.0	0.25	50	GSS	500	2000	14	4.0	1.0	K	
3N125	N	J		3N124	1.5	4.5	0.25	50	GSS	800	2400	14	4.0	1.0	K	
3N126	N	J		3N124	3.0	9.0	0.25	50	GSS	1200	3600	14	4.0	1.0	K	
3N128	N	M	MFE3004-5	MFE3004	5.0	25	0.05			5000	12000	7.0	5.0	200	M	
3N138	N	M	MFE3004-5	MFE3004			0.010	45	GD			5.0				
3N139	N	M	MFE3004-5	MFE3004	5.0	25	1.0	45	GD	3000	7500	7.0				
3N140	N	M		3N140	5.0	30	1.0	20	DS			7.0	4.5	200	M	
3N141	N	M	MFE3006-7	MFE3006	5.0	30	1.0	20	DS			7.0				
3N142	N	M	MFE3004-5	MFE3004	5.0	50	5.0	20	DS			10				
3N143	N	M	MFE3004-5	MFE3004	10	50	1.0					7.0				
3N145	P	M	2N4352	2N4352				30	DB							
3N146	P	M	3N157A	3N157				30	DB							
3N147	P	M						30	DB							
3N148	P	M						30	DB							
3N149	P	M	3N157A-8A	3N157				30	DB							
3N150	P	M	3N157A-8A	3N157				30	DB							
3N151	P	M			0.2typ			30	DSS	2000typ						
3N152	N	M	MFE3004-5	MFE3004	5.0	30	1.0						3.5	200	M	
3N153	N	M	MFE3004-5	MFE3004			0.05					8.0				
3N154	N	M	MFE3004-5	MFE3004	10	25	0.05						5.0	200	M	
3N155	P	M		3N155		1.0	1.0	35	DSS	1000	4000	5.0				
3N155A	P	M		3N155		0.25	1.0	35	DSS	1000	4000	5.0				
3N156	P	M		3N155		1.0	1.0	35	DSS	1000	4000	5.0				
3N156A	P	M		3N155		0.25	1.0	35	DSS	1000	4000	5.0				
3N157	P	M		3N157		1.0	0.010	35	DSS	1000	4000	5.0				
3N157A	P	M		3N157		0.25	0.010	50	DSS	1000	4000	5.0				
3N158	P	M		3N157		1.0	0.010	35	DSS	1000	4000	5.0				
3N158A	P	M		3N157		0.25	0.010	50	DSS	1000	4000	5.0				
3N159	N	M			5.0	30	1.0			7000	18000	7.0	3.5	200	M	
3N160	P					10*	0.01			3500	6500	10				
3N161	P					10*				3500	6500	10				

REFERENCE AMPLIFIERS

INDEX AND SHORT-FORM SPECIFICATIONS

This table contains a numerical listing and short-form specifications for reference amplifiers, with EIA-registered 3N numbers. In addition, short-form specifications are also provided for special house numbered reference amplifiers.

KEY

TYPE	REF.	V_{REF} (volts)	Tol ±%	ΔV_{REF} (volts) *TC (%/°C)	I_{ZT} (mA)	Z_{ZT} (ohms)	T_1 °C	T_2 °C
Numerical Listing of Registered Type Numbers	Reference device number indicates specific Data Sheet on which device is characterized.	Nominal Reference Voltage	Tolerance of Nominal Reference Voltage	Maximum Voltage Variation over the Temperature Range from T_1 to T_2 *Temperature Coefficient $\frac{\Delta V_1\, 100}{V\,(T_2 - T_1)}$	Zener Test Current	Maximum Zener Impedance	Temperature Range over which ΔV_{REF} is specified *Maximum Operating Temperature	

REFERENCE AMPLIFIER INDEX

TYPE	REF.	V_{REF} (volts)	Tol ±%	ΔV_{REF} (volts) / *TC (%/°C)	I_{ZT} (mA)	Z_{ZT} (ohms)	T_1 °C	T_2 °C
3N39		9.0	9.0	0.005*	5.0			71*
3N40		9.0	9.0	0.003*	5.0			71*
3N41		9.0	9.0	0.002*	5.0			71*
3N42		9.0	9.0	0.005*	5.0			100*
3N43		9.0	9.0	0.003*	5.0			100*
3N44		9.0	9.0	0.002*	5.0			100*
3N44A		9.0	10	0.001*	5.0			150*
MCA1911	MCA1911	6.8	10	0.051	5.0	40	0	75
MCA1912	MCA1911	6.8	10	0.025	5.0	40	0	75
MCA1913	MCA1911	6.8	10	0.010	5.0	40	0	75
MCA1914	MCA1911	6.8	10	0.005	5.0	40	0	75
MCA1921	MCA1911	6.8	5.0	0.105	5.0	40	-55	100
MCA1922	MCA1911	6.8	5.0	0.052	5.0	40	-55	100
MCA1923	MCA1911	6.8	5.0	0.020	5.0	40	-55	100
MCA1924	MCA1911	6.8	5.0	0.010	5.0	40	-55	100
MCA1931	MCA1911	6.8	5.0	0.139	5.0	40	-55	150
MCA1932	MCA1911	6.8	5.0	0.069	5.0	40	-55	150
MCA1933	MCA1911	6.8	5.0	0.026	5.0	40	-55	150
MCA1934	MCA1911	6.8	5.0	0.013	5.0	40	-55	150
MCA2011	MCA1911	8.6	10	0.060	5.0	40	0	75
MCA2012	MCA1911	8.6	10	0.030	5.0	40	0	75
MCA2013	MCA1911	8.6	10	0.012	5.0	40	0	75
MCA2014	MCA1911	8.6	10	0.006	5.0	40	0	75
MCA2021	MCA1911	8.6	5.0	0.124	5.0	40	-55	100
MCA2022	MCA1911	8.6	5.0	0.062	5.0	40	-55	100
MCA2023	MCA1911	8.6	5.0	0.024	5.0	40	-55	100
MCA2024	MCA1911	8.6	5.0	0.012	5.0	40	-55	100
MCA2031	MCA1911	8.6	5.0	0.164	5.0	40	-55	150
MCA2032	MCA1911	8.6	5.0	0.082	5.0	40	-55	150
MCA2033	MCA1911	8.6	5.0	0.032	5.0	40	-55	150
MCA2034	MCA1911	8.6	5.0	0.016	5.0	40	-55	150
MCA2111	MCA1911	9.5	10	0.071	5.0	40	0	75
MCA2112	MCA1911	9.5	10	0.035	5.0	40	0	75
MCA2113	MCA1911	9.5	10	0.014	5.0	40	0	75
MCA2114	MCA1911	9.5	10	0.007	5.0	40	0	75
MCA2121	MCA1911	9.5	5.0	0.147	5.0	40	-55	100
MCA2122	MCA1911	9.5	5.0	0.073	5.0	40	-55	100
MCA2123	MCA1911	9.5	5.0	0.028	5.0	40	-55	100
MCA2124	MCA1911	9.5	5.0	0.014	5.0	40	-55	100
MCA2131	MCA1911	9.5	5.0	0.194	5.0	40	-55	150
MCA2132	MCA1911	9.5	5.0	0.097	5.0	40	-55	150
MCA2133	MCA1911	9.5	5.0	0.038	5.0	40	-55	150
MCA2134	MCA1911	9.5	5.0	0.019	5.0	40	-55	150
MCA2211	MCA1911	11.0	10	0.082	5.0	40	0	75
MCA2212	MCA1911	11.0	10	0.041	5.0	40	0	75
MCA2213	MCA1911	11.0	10	0.016	5.0	40	0	75
MCA2214	MCA1911	11.0	10	0.008	5.0	40	0	75
MCA2221	MCA1911	11.0	5.0	0.170	5.0	40	-55	100
MCA2222	MCA1911	11.0	5.0	0.085	5.0	40	-55	100
MCA2223	MCA1911	11.0	5.0	0.034	5.0	40	-55	100
MCA2224	MCA1911	11.0	5.0	0.017	5.0	40	-55	100
MCA2231	MCA1911	11.0	5.0	0.225	5.0	40	-55	150
MCA2232	MCA1911	11.0	5.0	0.112	5.0	40	-55	150
MCA2233	MCA1911	11.0	5.0	0.044	5.0	40	-55	150
MCA2234	MCA1911	11.0	5.0	0.022	5.0	40	-55	150

UNIJUNCTION TRANSISTORS

This table contains a numerical listing and short-form specifications for unijunction transistors with EIA-registered 2N numbers.

KEY

P_D = Power Dissipation @ 25°C
R_{BB} = Interbase Resistance
η = Intrinsic Standoff Ratio
$I_{V(min)}$ = Minimum Valley Current
$I_{P(max)}$ = Maximum Peak Point Current
I_{EO} = Maximum Emitter Reverse Current at Indicated V_{B2E}
$V_{EB1(sat)}$ = Emitter Saturation Voltage @ I_E = 50 mA, V_{BB} = 10 V

UNIJUNCTION TRANSISTORS INDEX

TYPE	REPLACEMENT	REF.	P_D (mW)	R_{BB} (kΩ)	η	I_V(min) (mA)	I_P(max) (μA)	I_{EO} @ V_{B2E} (μA @ V max)	$V_{EB1(SAT)}$ I_E@50 mA)
2N489			450	6.8	0.62	8.0	20	12 @ 60	5.0
2N489A			450	6.8	0.62	8.0	15	12 @ 60	4.0
2N489B			450	6.8	0.62	8.0	6.0	0.2 @ 60	4.0
2N490			450	9.1	0.62	8.0	20	12 @ 60	5.0
2N490A			450	9.1	0.62	8.0	15	12 @ 60	4.0
2N490B			450	9.1	0.62	8.0	6.0	0.2 @ 60	4.0
2N490C			450	9.1	0.51				
2N491			450	6.8	0.68	8.0	20	12 @ 60	5.0
2N491A			450	6.8	0.68	8.0	15	12 @ 60	4.3
2N491B			450	6.8	0.68	8.0	6.0	0.2 @ 60	4.3
2N492			450	9.1	0.68	8.0	20	12 @ 60	5.0
2N492A			450	9.1	0.68	8.0	15	12 @ 60	4.3
2N492B			450	9.1	0.68	8.0	6.0	0.2 @ 60	4.3
2N492C			450	9.1	0.56				
2N493			450	6.8	0.75	8.0	20	12 @ 60	5.0
2N493A			450	6.8	0.75	8.0	15		
2N493B			450	6.8	0.75	8.0	6.0	0.2 @ 60	5.0
2N494			450	9.1	0.75	8.0	20	12 @ 60	5.0
2N494A			450	9.1	0.75	8.0	15	12 @ 60	4.6
2N494B			450	9.1	0.75	8.0	6.0	0.2 @ 60	4.6
2N494C			450	9.1	0.62	8.0	2.0	0.02 @ 60	4.6
2N1671			450	9.1	0.62	8.0	25	12 @ 30	5.0
2N1671A			450	9.1	0.62	8.0	25	12 @ 30	5.0
2N1671B			450	9.1	0.62	8.0	6.0	0.2 @ 30	5.0
2N1671C			450	4.1 -9.1					
2N2160			450	4.0 -12	0.47 -0.80	8.0	25	12 @ 30	
2N2417			390	0.68	0.62	8.0	20	12 @ 60	5.0
2N2417A			390	0.68	0.62	8.0	20	12 @ 60	4.0
2N2417B			300	6.8	0.51 -0.62	8.0	6.0	0.2 @ 30	4.0
2N2418			390	0.68	0.62	8.0	20	12 @ 60	5.0
2N2418A			390	9.1	0.62	8.0	20	12 @ 60	4.0
2N2418B			300	9.1	0.51 - 0.62	8.0	6.0	0.2 @ 60	4.0
2N2419			390	4.7 -6.8	0.68	8.0	20	12 @ 60	5.0
2N2419A			390	6.8	0.68	8.0	20	12 @ 60	4.3
2N2419B			300	6.8	0.56 -0.68	8.0	6.0	0.2 @ 30	4.3
2N2420			390	9.1	0.68	8.0	20	12 @ 60	5.0
2N2420A			390	9.1	0.68	8.0	20	12 @ 60	4.3
2N2420B			300	9.1	0.56 -0.68	8.0	6.0	0.2 @ 30	4.3
2N2421			390	6.8	0.75	8.0	20	12 @ 60	5.0
2N2421A			390	6.8	0.75	8.0	20	12 @ 60	4.6
2N2421B			300	6.8	4.7 -6.8	8.0	6.0	0.2 @ 30	4.6
2N2422			390	9.1	0.75	8.0	20	12 @ 60	5.0
2N2422A			390	9.1	0.75	8.0	20	12 @ 60	4.6
2N2422B			300	9.1	0.62 -0.75	8.0	6.0	0.2 @ 30	
2N2646		2N2646	300	4.7 (min)	0.56	4.0	25	12 @ 30	2.0
2N2647		2N2646	300	4.7 (min)	0.68	8.0	2.0	0.2 @ 30	2.0
2N2840			300	4.7 -9.1	1.3 -1.5	0.70	10	1.0 @ 30	
2N3406			450			8.0			
2N3479			400	4.7 -9.1	0.47 -0.62	6.0	20	12 @ 30	5.0
2N3480			400	9.1	0.75	4.0	15	12 @ 30	5.0
2N3481			400	9.1	0.85	6.0	15	12 @ 30	5.0
2N3482			400	4.7 -6.8	0.51 -0.62	8.0	2.0	0.02 @ 30	5.0
2N3483			400	9.1	0.72	8.0	2.0	1.0 @ 30	5.0
2N3484			400	9.1	0.85	8.0	2.0	0.2 @ 30	5.0
2N3679			250	9.1	0.80	4.2			
2N3980		2N3980	360	8.0					
2N4851		2N4851	300	4.7 (min)	0.56 (min)	2.0	2.0	0.1 @ 30	2.5
2N4852		2N4851	300	4.7 (min)	0.70 (min)	4.0	2.0	0.1 @ 30	2.5
2N4853		2N4851	300	4.7 (min)	0.70 (min)	6.0	0.4	0.05 @ 30	2.5
2N4870		2N4870	300	4.0 (min)	0.56 (min)	2.0	5.0	0.05 @ 30	2.5
2N4871		2N4870	300	4.0 (min)	0.70 (min)	4.0	5.0	0.05 @ 30	2.5
2N4891	MU4891	MU4891	300	4.0 (min)	0.55 (min)	2.0	5.0	0.01 @ 30	4.0
2N4892			300	4.0 (min)	0.51 (min)	4.0	2.0	0.01 @ 30	4.0
2N4893	MU4893	MU4891	300	4.0 (min)	0.55 (min)	2.0	2.0	0.01 @ 30	4.0
2N4894	MU4894	MU4891	300	4.0 (min)	0.74 (min)	2.0	1.0	0.01 @ 30	4.0
2N4947			360	4.0 -9.1	0.51 -0.69	4.0	2.0	0.01 @ 30	2.5
2N4948		2N4948	360	4.0 (min)	0.55 (min)	2.0	2.0	0.01 @ 30	2.5
2N4949		2N4948	360	4.0 (min)	0.74 (min)	2.0	1.0	0.01 @ 30	2.5
2N5431		2N5431	360	6.0 -8.5	0.72 -0.80	2.0	4.0		3.0

ALPHABETICAL INDEX of NON-REGISTERED TYPE NUMBERS

The following index lists all of the non-registered device types characterized in this book in alphabetical sequence. The data sheets in this book are arranged in alphanumerical sequence (registered device types) and in alphabetical sequence (non-registered device types). The key to proper identification of these non-registered devices is listed blow.

KEY

Type	Device Identification	REFERENCE
Non-registered device types		
C-REG	Diode, Current Regulator	
D-3L	Diode, 3 Layer	
D-4L	Diode, 4 Layer	
MD	Multiple Device	
PH	Photo Device	
PR. REF	Diode, Precision Reference	
RECT	Rectifier	
RECT-A	Rectifier Assemblies	
REF	Diode, Reference	
SCR	Silicon Controlled Rectifier	
SUP	Diode, Transient Suppressor	
T(BP)	Transistor, Bi-Polar	
T(FE)	Transistor, Field Effect	
T(QD)	Transistor, Quad	
T(UJ)	Transistor, Unijunction	
VAR-M	Varactor, Multiplier	
VAR-T	Varactor, Tuning	
ZD	Zener Diode	
Reference device number indicates specific Data Sheet on which device is characterized.		

ALPHABETICAL INDEX OF NON-REGISTERED TYPE NUMBERS

This table lists non-registered device types characterized in this book in alphabetical sequence.

TYPE	DEVICE IDENT.	REFERENCE
½M2.4AZ thru ½M200Z	ZD	½M2.4AZ
.4M.64FR10	REF	1N816
.4M1.36FR5	REF	1N816
.4M1.36FR2	REF	1N816
.4M2.04FR5	REF	1N816
.4M2.04FR2	REF	1N816
1M110ZS thru 1M200ZS	ZD	1N4728
AF239	T(BP)	AF239
MA100	T(BP)	MA100
MA112 thru MA117	T(BP)	MA112
MA200 thru MA206	T(BP)	MA200
MA286 thru MA288	T(BP)	MA286
MA881 thru MA889	T(BP)	MA881
MA909	T(BP)	MA909
MA910	T(BP)	MA909
MA1702 thru MA1708	T(BP)	MA1702
MAC1 thru MAC3	SCR	MAC1
MCxxxx See Integrated Circuits Section		
MCA1911 thru MCA1914	REF	MCA1911
MCA1921 thru MCA1924	REF	MCA1911
MCA1931 thru MCA1934	REF	MCA1911
MCA2011 thru MCA2014	REF	MCA1911
MCA2021 thru MCA2024	REF	MCA1911

TYPE	DEVICE IDENT.	REFERENCE
MCA2031 thru MCA2034	REF	MCA1911
MCA2111 thru MCA2114	REF	MCA1911
MCA2121 thru MCA2124	REF	MCA1911
MCA2131 thru MCA2134	REF	MCA1911
MCA2211 thru MCA2214	REF	MCA1911
MCA2221 thru MCA2224	REF	MCA1911
MCA2231 thru MCA2234	REF	MCA1911
MCHxxxx See Integrated Circuits Section		
MCL1300 thru MCL1304	C-REG	MCL1300
MCR406-1 thru MCR406-4	SCR	MCR406-1
MCR649-1 thru MCR649-7	SCR	MCR649-1
MCR729-5 thru MCR729-10	SCR	MCR729-5
MCR846-1 thru MCR846-4	SCR	MCR846
MCR1336-5 thru MCR1336-10	SCR	MCR1336-5
MCR1718-5 thru MCR1718-8	SCR	MCR1718-5
MCR1906-1 thru MCR1906-4	SCR	MCR1906-1
MCR1907-1 thru MCR1907-6	SCR	MCR1907-1

ALPHABETICAL INDEX OF NON-REGISTERED TYPE NUMBERS (continued)

TYPE	DEVICE IDENT.	REFERENCE
MCR2604-1 thru MCR2604-8	SCR	MCR1907-1
MCR2605-1 thru MCR2605-8	SCR	MCR1907-1
MCR2818-1,-3,-5,-7	SCR	MCR1907-1
MCR2835-1 thru MCR2835-8	SCR	MCR2835
MCR2918-1,-3,-5,-7	SCR	MCR1907-1
MCR2935-1 thru MCR2935-8	SCR	MCR2835
MD708,A,AF,B,BF,F	MD	MD708
MD918,A,AF,B,BF,F	MD	MD918
MD984	MD	MD984
MD986,F	MD	MD986
MD1120,F	MD	MD1120
MD1121,F	MD	MD1120
MD1122,F	MD	MD1120
MD1126	MD	MD1126
MD1127	MD	MD1126
MD1128	MD	MD1128
MD1129,F	MD	MD1129
MD1130,F	MD	MD1130
MD1131,F	MD	MD1131
MD1132,F	MD	MD1132
MD1134	MD	MD1134
MD2218,A,AF,F	MD	MD2218
MD2219,A,AF,F	MD	MD2218
MD2369,A,AF,B,BF,F	MD	MD2369
MD2904,A,AF,F	MD	MD2904
MD2905,A,AF,F	MD	MD2904
MD3133,F	MD	MD3133
MD3134,F	MD	MD3133
MD3250,A,AF,F	MD	MD3250
MD3251,A,AF,F	MD	MD3250
MD3467,F	MD	MD3467
MD3725,F	MD	MD3725
MD3762,F	MD	MD3762
MD4957	MD	MD4957
MD5000,A,B	MD	MD5000
MD6001	MD	MD6001
MD6002	MD	MD6001
MD6100	MD	MD6100
MDA920-1 thru MDA920-7	RECT-A	MDA920
MDA930-1 thru MDA930-7	RECT-A	MDA920
MDA940-1 thru MDA940-7	RECT-A	MDA920
MDA942-1 thru MDA942-6	RECT-A	MDA942
MDA950-1 thru MDA950-7	RECT-A	MDA920
MDA952-1 thru MDA952-6	RECT-A	MDA942
MDA960-1 thru MDA960-3	RECT-A	MDA960
MDA962-1 thru MDA962-5	RECT-A	MDA942
MDA970-1 thru MDA970-3	RECT-A	MDA960
MDA972-1 thru MDA972-5	RECT-A	MDA942
MDA1330H thru MDA1333H	RECT-A	MDA1330H
MDA1491-1 thru MDA1491-6	RECT-A	MDA942
MDA1505-1 thru MDA1505-6	RECT-A	MDA942
MDA1591-1 thru MDA1591-6	RECT-A	MDA942
MF3304	T(BP)	MF3304
MFE2000	T(FE)	MFE2000
MFE2001	T(FE)	MFE2000
MFE2004 thru MFE2006	T(FE)	MFE2004
MFE2007 thru MFE2009	T(FE)	MFE2007
MFE2010 thru MFE2012	T(FE)	MFE2010
MFE2093 thru MFE2095	T(FE)	MFE2093

ALPHABETICAL INDEX OF NON-REGISTERED TYPE NUMBERS (continued)

TYPE	DEVICE IDENT.	REFERENCE
MFE2097	T(FE)	MFE2097
MFE2098	T(FE)	MFE2097
MFE2133	T(FE)	MFE2133
MFE3001	T(FE)	MFE3001
MFE3002	T(FE)	MFE3002
MFE3003	T(FE)	MFE3003
MFE3004	T(FE)	MFE3004
MFE3005	T(FE)	MFE3004
MFE3006	T(FE)	MFE3006
MFE3007	T(FE)	MFE3007
MFE4007 thru MFE4012	T(FE)	MFE4007
MH745 MH746	See Hardware Section	
MJ400	T(BP)	MJ400
MJ413	T(BP)	MJ413
MJ420	T(BP)	MJ420
MJ421	T(BP)	MJ420
MJ423	T(BP)	MJ413
MJ431	T(BP)	MJ413
MJ2249	T(BP)	MJ2249
MJ2250	T(BP)	MJ2249
MJ2251	T(BP)	MJ2251
MJ2252	T(BP)	MJ2251
MJ2267	T(BP)	MJ2267
MJ2268	T(BP)	MJ2267
MJ3029	T(BP)	MJ3029
MJ3030	T(BP)	MJ3029
MJ3101	T(BP)	MJ2249
MJ3201	T(BP)	MJ3201
MJ3202	T(BP)	MJ3201
MJE105	T(BP)	MJE105
MJE205	T(BP)	MJE205
MJE340	T(BP)	MJE340
MJE2801	T(BP)	MJE2801
MJE2901	T(BP)	MJE2901
MJE2955	T(BP)	MJE2955
MJE3055	T(BP)	MJE3055
MK10 MK15 MK20 MK25 MK30 MK35	See Hardware Section	
MM380	T(BP)	MM380
MM709	T(BP)	MM709
MM1139	T(BP)	MM1139
MM1500	T(BP)	MM1500
MM1501	T(BP)	MM1501
MM1549 thru MM1551	T(BP)	MM1549
MM1557 thru MM1559	T(BP)	MM1557

TYPE	DEVICE IDENT.	REFERENCE
MM1603	T(BP)	MM1603
MM1748	T(BP)	MM1748
MM1803	T(BP)	2N3137
MM1812	T(BP)	MM1803
MM1941	T(BP)	MM1941
MM2258 thru MM2260	T(BP)	MM2258
MM2483	T(BP)	MM2483
MM2484	T(BP)	MM2483
MM2894	T(BP)	MM2894
MM3000 thru MM3003	T(BP)	MM3000
MM3008	T(BP)	MM3008
MM3009	T(BP)	MM3008
MM3724	T(BP)	MM3724
MM3725	T(BP)	MM3724
MM3726	T(BP)	MM3726
MM4000 thru MM4003	T(BP)	MM4000
MM4048	T(BP)	MM4048
MM5000 thru MM5002	T(BP)	MM5000
MM8000	T(BP)	MM8000
MM8001	T(BP)	MM8000
MM8002	T(BP)	MM8002
MM8003	T(BP)	MM8003
MMD6050	T(BP)	MMD6050
MMD6100	T(BP)	MMD6050
MMD6150	T(BP)	MMD6050
MMD7000	T(BP)	MMD6050
MMF1 thru MMF6	T(FE)	MMF1
MMT918	T(BP)	MMT918
MMT930	T(BP)	MMT930
MMT2222	T(BP)	MMT2222
MMT2369	T(BP)	MMT2369
MMT2484	T(BP)	MMT930
MMT2857	T(BP)	MMT2857
MMT2907	T(BP)	MMT2907
MMT3546	T(BP)	MMT3546
MMT3798	T(BP)	MMT3798
MMT3799	T(BP)	MMT3798
MMT3823	T(BP)	MMT3823
MMT3903	T(BP)	MMT3903
MMT3904	T(BP)	MMT3903
MMT3905	T(BP)	MMT3905
MMT3906	T(BP)	MMT3905
MMT3960A	T(BP)	MMT3960A

ALPHABETICAL INDEX OF NON-REGISTERED TYPE NUMBERS (continued)

TYPE	DEVICE IDENT.	REFERENCE
MP110	T(BP)	MP110
MP110B	T(BP)	MP110B
MP500 thru MP502	T(BP)	MP500
MP504 thru MP506	T(BP)	MP500
MP525	T(BP)	MP525
MP600 thru MP603	T(BP)	MP600
MP800	T(BP)	MP800
MP801	T(BP)	MP800
MP900 thru MP902	T(BP)	MP900
MP1612,A,B	T(BP)	MP1612
MP1613	T(BP)	MP1613
MP2000A	T(BP)	MP2000A
MP2060 thru MP2063	T(BP)	MP2060
MP2100A	T(BP)	MP2000A
MP2200A	T(BP)	MP2000A
MP2300A	T(BP)	MP2000A
MP2400A	T(BP)	MP2000A
MP3730	T(BP)	MP2100A
MP3731	T(BP)	MP2100A
MPF102	T(FE)	MPF102
MPF108	T(FE)	MPF108
MPF109	T(FE)	MPF109
MPF161	T(FE)	MPF161
MPS404,A	T(BP)	MPS404
MPS706,A	T(BP)	MPS706
MPS834	T(BP)	MPS834
MPS918	T(BP)	MPS918
MPS2369	T(BP)	MPS2369
MPS2711	T(BP)	MPS2711
MPS2712	T(BP)	MPS2711
MPS2713	T(BP)	MPS2713
MPS2714	T(BP)	MPS2713
MPS2923 thru MPS2925	T(BP)	MPS2923
MPS2926	T(BP)	MPS2926
MPS3392 thru MPS3395	T(BP)	MPS3392
MPS3563	T(BP)	MPS918
MPS3638,A	T(BP)	MPS3638
MPS3639	T(BP)	MPS3639
MPS3640	T(BP)	MPS3640
MPS3646	T(BP)	MPS3646
MPS3693	T(BP)	MPS3693
MPS3694	T(BP)	MPS3693
MPS3702	T(BP)	MPS3702
MPS3703	T(BP)	MPS3702
MPS3704 thru MPS3706	T(BP)	MPS3704
MPS3707 thru MPS3711	T(BP)	MPS3707
MPS3721	T(BP)	MPS2926
MPS6507	T(BP)	MPS6507
MPS6511	T(BP)	MPS6511
MPS6512 thru MPS6515	T(BP)	MPS6512
MPS6516 thru MPS6519	T(BP)	MPS6516
MPS6520	T(BP)	MPS6512
MPS6521	T(BP)	MPS6512
MPS6522	T(BP)	MPS6516
MPS6523	T(BP)	MPS6516
MPS6530 thru MPS6535	T(BP)	MPS6530
MPS6539	T(BP)	MPS6539
MPS6540	T(BP)	MPS6540
MPS6542	T(BP)	MPS6542
MPS6543	T(BP)	MPS6543
MPS6544	T(BP)	MPS6544
MPS6545	T(BP)	MPS6544
MPS6546	T(BP)	MPS6546
MPS6547	T(BP)	MPS6546
MPS6548	T(BP)	MPS6548
MPS6560 thru MPS6563	T(BP)	MPS6560
MPS6565	T(BP)	MPS6565
MPS6566	T(BP)	MPS6565
MPS6567	T(BP)	MPS6567
MPS6568 thru MPS6569	T(BP)	MPS6568
MPS6571	T(BP)	MPS6571
MPS-A09	T(BP)	MPS-A09
MPS-A10	T(BP)	MPS-A10
MPS-A12	T(BP)	MPS-A12
MPS-U01	T(BP)	MPS-U01
MPS-U02	T(BP)	MPS-U02
MPS-U03	T(BP)	MPS-U03

ALPHABETICAL INDEX OF NON-REGISTERED TYPE NUMBERS (continued)

TYPE	DEVICE IDENT.	REFERENCE
MPS-U04	T(BP)	MPS-U03
MPS-U51	T(BP)	MPS-U51
MPS-U52	T(BP)	MPS-U52
MPT20	D-3L	MPT20
MPT28	D-3L	MPT28
MPT32	D-3L	MPT28
MPZ5-16	SUP	MPZ5-16
MPZ5-32	SUP	MPZ5-16
MPZ5-180	SUP	MPZ5-16
MQ3467	T(QD)	MD3467
MQ3725	T(QD)	MD3725
MQ3762	T(QD)	MD3762
MQ3799,A	T(QD)	MQ3799
MR322 thru MR328	RECT	1N3491
MR330	RECT	1N3491
MR331	RECT	1N3491
MR810 thru MR812	RECT	MR322
MR814	RECT	MR322
MR816	RECT	MR322
MR830 thru MR836	RECT	MR830
MR840 thru MR842	RECT	MR322
MR844	RECT	MR322
MR846	RECT	MR322
MR880 thru MR882	RECT	MR322
MR884	RECT	MR322
MR886	RECT	MR322
MR890 thru MR892	RECT	MR322
MR894	RECT	MR322
MR896	RECT	MR322
MR990A thru MR996A	RECT	MR990A
MR1030 thru MR1036	RECT	1N4719

TYPE	DEVICE IDENT.	REFERENCE
MR1038	RECT	1N4719
MR1040	RECT	1N4719
MR1120 thru MR1126	RECT	MR1120
MR1128	RECT	MR1120
MR1130	RECT	MR1120
MR1200 thru MR1203	RECT	MR1200
MR1205	RECT	MR1200
MR1207 thru MR1209	RECT	MR1200
MR1210 thru MR1213	RECT	MR1210
MR1215	RECT	MR1210
MR1217 thru MR1219	RECT	MR1210
MR1220 thru MR1223	RECT	MR1220
MR1225	RECT	MR1220
MR1227 thru MR1229	RECT	MR1220
MR1230 thru MR1233	RECT	MR1230
MR1235	RECT	MR1230
MR1237 thru MR1239	RECT	MR1230
MR1240 thru MR1243	RECT	MR1240
MR1245	RECT	MR1240
MR1247 thru MR1249	RECT	MR1240
MR1260 thru MR1263	RECT	MR1260

ALPHABETICAL INDEX OF NON-REGISTERED TYPE NUMBERS (continued)

TYPE	DEVICE IDENT.	REFERENCE
MR1265	RECT	MR1260
MR1267 thru MR1269	RECT	MR1260
MR1290 thru MR1293	RECT	MR1290
MR1295	RECT	MR1290
MR1297 thru MR1299	RECT	MR1290
MR1337-1 thru MR1337-5	RECT	MR1337-1
MR1366	RECT	1N4933
MR1376	RECT	1N4933
MR1386	RECT	1N4933
MR1396	RECT	1N4933
MR2080HA thru MR2084HA	RECT	MR2080HA
MR2100HA thru MR2104HA	RECT	MR2100HA
MR2266	RECT	MR2266
MR2271	RECT	MR2271
MR2272	RECT	MR2272
MR2273	RECT	MR2266
MRA130 thru MRA134	RECT-A	MRA130
MRA160 thru MRA164	RECT-A	MRA160
MRA330 thru MRA334	RECT-A	MRA330
MRA360 thru MRA364	RECT-A	MRA360
MRD100	PH	MRD100
MRD150	PH	MRD100
MRD200	PH	MRD200
MRD210	PH	MRD210
MRD250	PH	MRD250
MRD300	PH	MRD300
MRD310	PH	MRD310
MRD450	PH	MRD450
MRD600	PH	MRD600
MS10 MS15	See Hardware Section	
MSD6100	MD	MSD6100
MSD6101	MD	MSD6101
MSD6102	MD	MSD6102
MSD6150	MD	MSD6150
MU4891 thru MU4894	T(UJ)	MU4891
MV830 thru MV840	VAR-T	MV830
MV1620	VAR-T	MV1620
MV1622	VAR-T	MV1620
MV1624	VAR-T	MV1620
MV1626	VAR-T	MV1620
MV1628	VAR-T	MV1620
MV1630	VAR-T	MV1620
MV1632	VAR-T	MV1620
MV1634	VAR-T	MV1620
MV1636	VAR-T	MV1620
MV1638	VAR-T	MV1620
MV1640	VAR-T	MV1620
MV1642	VAR-T	MV1620
MV1644	VAR-T	MV1620
MV1646	VAR-T	MV1620
MV1648	VAR-T	MV1620
MV1650	VAR-T	MV1620
MV1652	VAR-T	MV1652
MV1654	VAR-T	MV1652
MV1656	VAR-T	MV1652
MV1658	VAR-T	MV1652
MV1660	VAR-T	MV1652
MV1662	VAR-T	MV1652
MV1664	VAR-T	MV1652
MV1666	VAR-T	MV1652
MV1804	VAR-M	1N4387
MV1805C	VAR-M	MV1805C
MV1806	VAR-M	1N4388
MV1806C	VAR-M	1N5149
MV1807C1	VAR-M	1N5150A
MV1808A,B,C	VAR-M	1N5151
MV1808B1,C1	VAR-M	1N5150A
MV1809C,C1	VAR-M	MV1809C
MV1810A,B	VAR-M	1N5154
MV1810B1	VAR-M	1N5150A
MV1812A,B	VAR-M	1N5156
MV1816A,A1,B,B1	VAR-M	MV1816A
MV1817A,A1,B,B1	VAR-M	MV1817A
MV1858D	VAR-T	MV1858D
MV1860D	VAR-T	MV1858D
MV1862 thru MV1866	VAR-T	MV1858D
MV1868	VAR-T	MV1858D
MV1870	VAR-T	MV1858D
MV2101 thru MV2115	VAR-T	MV2101

ALPHABETICAL INDEX OF NON-REGISTERED TYPE NUMBERS (continued)

TYPE	DEVICE IDENT.	REFERENCE
MZ500-1 thru MZ500-40	ZD	MZ500-1
MZ605	PR.REF	MZ600
MZ610	PR.REF	MZ600
MZ620	PR.REF	MZ600
MZ640	PR.REF	MZ600
MZ805	PR.REF	MZ600
MZ810	PR.REF	MZ600
MZ820	PR.REF	MZ600
MZ840	PR.REF	MZ600
MZ1000-1 thru MZ1000-37	ZD	MZ1000-1
MZ4614 thru MZ4627	ZD	1N4099
M4L3052 thru M4L3056	D-4L	1N5158
XC63 XC72 XC73	See Hardware Section	
XC157 XC170 XC177	See Integrated Circuits Section	

SELECTOR GUIDES

(Including Glossary)

Page

- **GLOSSARY** 198
- **ZENER DIODES** 202
  Regulator Diodes / Reference Diodes / Transient Suppressors /
  Current Regulators / Precision Reference / Reference Amplifiers
- **SILICON RECTIFIERS** 210
- **SILICON POWER RECTIFIER ASSEMBLIES** 214
- **THYRISTORS** 216
  Silicon Controlled Rectifiers / Trigger Diodes / Triacs /
  4-Layer Diodes / Unijunction Transistors
- **PLASTIC ENCAPSULATED SMALL-SIGNAL TRANSISTORS** 220
- **SILICON POWER TRANSISTORS** 226
- **GERMANIUM POWER TRANSISTORS** 231
- **SILICON SMALL-SIGNAL HERMETIC ANNULAR TRANSISTORS** 234
- **FIELD-EFFECT TRANSISTORS** 242
- **MICRO-T TRANSISTORS AND DIODES** 246
- **OPTOELECTRONICS** 248
- **RF SEMICONDUCTORS AND POWER VARACTORS** 250
- **EPICAP TUNING DIODES** 256

GLOSSARY

There are many symbols and abbreviations used to classify the performance and characteristics of semiconductors. Often a particular symbol will have different meanings, depending on the product described. To aid the reader in the understanding of the data presented in this book, the following product-categorized glossary has been prepared. Standard terms that are common to all semiconductors or have obvious meanings have been omitted.

FET PARAMETERS

MAXIMUM RATINGS

V_{DS}	Drain-Source Voltage
V_{DG}	Drain-Gate Voltage
$V_{GS(r)}$	Reverse Gate-Source Voltage
I_D	Drain Current
$I_{G(f)}$	Forward Gate Current
P_D	Total Device Dissipation
T_J	Operating Junction Temperature
T_{stg}	Storage Temperature

ELECTRICAL CHARACTERISTICS

$V_{(BR)GSS}$	Gate-Source Breakdown Voltage with drain and source shorted at a given I_G.
$V_{GS(off)}$	Gate-Source Cutoff Voltage measured at a stated V_{DS} and I_D.
I_{GSS}	Gate Reverse Current specified at a given V_{GS} (usually 1/2 to 1 times $V_{(BR)GSS}$) with a $V_{DS} = 0$.
I_{DSS}	Zero-Gate Voltage Drain Current measured at a specific V_{DS} and $V_{GS} = 0$.
V_{GS}	Gate-Source Voltage at a given V_{DS} and I_D.
R_{GS}	Input Resistance at a stated V_{GS}.
$V_{GS(th)}$	Gate-Source Threshold Voltage. V_{DS} and I_D must be given.
$I_{D(on)}$	"ON" Drain Current at a specified V_{DS} and V_{GS}.
$\lvert y_{fs} \rvert$	Magnitude of the common-source forward transfer admittance measured at $V_{GS} = 0$ (unless otherwise specified) and at a given frequency.
$R_e(y_{fs})$	Common-Source forward transfer conductance measured at a given frequency with dc conditions the same as for I_{DSS}.
$\lvert y_{os} \rvert$	Output Admittance specified at a given V_{DS} and I_D or V_{GS}.
C_{iss}	Common-source input capacitance with output shorted at a given V_{DS}, V_{GS}, and frequency.
C_{rss}	Reverse Transfer Capacitance at a given V_{DS}, V_{GS}, and frequency with input shorted.
NF	Common-Source Noise Figure measured with specific V_{DS}, V_{GS} or I_D, R_G (generator resistance), frequency, and bandwidth.
e_n	Equivalent Short-Circuit Input Noise Voltage with given V_{DS}, V_{GS} or I_D, R_G, frequency and bandwidth.

OPTOELECTRONIC DEFINITIONS, CHARACTERISTICS, AND RATINGS

BV_{CBO}	Collector-Base Breakdown Voltage – The minimum dc breakdown voltage, collector to base, at stated collector current and ambient temperature. (Emitter open)
BV_{CEO}	Collector-Emitter Breakdown Voltage – The minimum dc breakdown voltage, collector to emitter, at stated collector current and ambient temperature. (Base open)
BV_{ECO}	Emitter-Collector Breakdown Voltage – The minimum dc breakdown voltage, emitter to collector, at stated emitter current and ambient temperature. (Base open)
E	Luminous Flux Density(Illuminance) [lumens/ft.^{2} = ft. candles] – The radiation flux density of wavelength within the band of visible light.
H	Radiation Flux Density (Irradiance) [mW/cm^2] – The total incident radiation energy measured in power per unit area.
I_{CEO}	Collector Dark Current – The maximum current through the collector terminal of the device measured under dark conditions, ($H \approx 0$), with a stated collector voltage, load resistance, and ambient temperature. (Base open)
P_D	Power Dissipation
S_{ICBO}	Collector-Base Illumination Sensitivity (μA/lumen/ft.^{2} = μA/ft. candle) – The ratio of photo-induced collector-base current to the incident luminous energy measured at the plane of the lens of the photo device under stated conditions of luminous flux density (E), collector voltage, base load resistance, and ambient temperature. (Emitter open)
S_{ICEO}	Collector-Emitter Illumination Sensitivity (μA/lumen/ft.^{2} = μA/ft. candle) – The ratio of photo-induced, collector-emitter current to the incident luminous energy measured at the plane of the lens of the photodevice under stated conditions of luminous flux density (E), collector voltage, load resistance, and ambient temperature. (Base open)
S_{RCBO}	Collector-Base Radiation Sensitivity (μA/mW/cm^2) – The ratio of photo-induced collector-base current to the incident radiant energy measured at the plane of the lens of the photo device under stated conditions of radiation flux density (H), collector voltage, base load resistance, and ambient temperature. (Emitter open)
S_{RCEO}	Collector-Emitter Radiation Sensitivity (mA/mW/cm^2) The ratio of photo-induced, collector-emitter current to the incident radiant energy measured at the plane of the lens of the photodevice under stated conditions of radiation flux density (H), collector voltage, load resistance, and ambient temperature. (Base open)
T_A	Ambient Temperature
t_f	Photo Current Fall Time – The response time for the photo-induced current to fall from the 90% point to the 10% point after removal of the GaAs (gallium-arsenide) source pulse under stated conditions of collector voltage, load resistance and ambient temperature.
$t_{f(sat)}$	Photo Current Saturated Fall Time – The response time for the photo-induced current to fall from the 90% point to the 10% point after removal of the saturating xenon light source pulse under stated conditions of collector voltage, load resistance, and ambient temperature.
T_J	Junction Temperature
t_r	Photo Current Rise Time – The response time for the photo-induced current to rise from the 10% point to the 90% point when pulsed with the stated GaAs (gallium-arsenide) source under stated conditions of collector voltage, load resistance, and ambient temperature.
$t_{r(sat)}$	Photo Current Saturated Rise Time – The response time for the photo-induced current to rise from the 10% point to the 90% point when driven into saturation by the stated xenon source under stated conditions of collector voltage, load resistance, and ambient temperature.
T_{stg}	Storage Temperature
V_{CBO}	Collector-Base Voltage – The maximum allowable value of the collector-base voltage which can be applied to the device at the rated temperature. (Base open)
V_{CEO}	Collector-Emitter Voltage – The maximum allowable value of collector-emitter voltage which can be applied to the device at the rated temperature. (Base open)
V_{ECO}	Emitter-Collector Voltage – The maximum allowable value of emitter-collector voltage which can be applied to the device at the rated temperature. (Base open)
θ	Angular Alignment – The axis of maximum sensitivity shall lie within a cone of this angle with reference to the central axis of the device.
$\lambda_s(\mu m)$	Wavelength of maximum sensitivity in micro meters.

EPICAP TUNING DIODES

MAXIMUM RATINGS

V_R	Reverse Voltage
P_{in}	RF Power Input
P_D	Total Device Dissipation

ELECTRICAL CHARACTERISTICS

BV_R	Reverse Breakdown Voltage measured at a given reverse current, I_R.
R_s	Series resistance at a specified reverse voltage and frequency.
C_J	Junction capacitance at a specified reverse voltage and frequency.
Q	Figure of Merit capacitance at a specified reverse voltage and frequency.
η	Efficiency at a given input power, input frequency, and output frequency.
C_T	Diode Capacitance (Junction + Case Capacitance, C_c).

POWER VARACTORS

MAXIMUM RATINGS

V_R	Reverse Voltage
I_F	Forward Current
P_D	Device Dissipation

ELECTRICAL CHARACTERISTICS

BV_R	Reverse Breakdown Voltage at a specified reverse current, I_R.
I_R	Reverse Voltage Leakage Current measured at a stated reverse voltage and ambient temperature.
L_s	Series Inductance measured at a given frequency and lead length. L_s can be determined from the self-resonant frequency and C_J by the formula: $L_s = \frac{1}{\omega^2_{res} C_J}$
C_J	Junction Capacitance
C_c	Case Capacitance
C_T	Diode Capacitance is $(C_c + C_J)$
TR	Tuning Ratio is the ratio of C_T measured at a low voltage divided by C_T at some voltage near BV_R. The voltages are specified by a subscript of C such as C4/C25.
TC_c	Diode Capacitance Temperature coefficient.
Q	Figure of Merit – calculated from G and C readings of an admittance bridge at a specified frequency: $Q = \frac{2\pi fC}{G}$

SELECTING THE BEST SEMICONDUCTOR

Selecting the best semiconductor for a given application can pose a significant challenge. This data book provides complete information on thousands of discrete semiconductors presently available, both new and older types. Obviously, this comprehensive listing includes some devices that are primarily useful only in applications requiring an exact replacement. Others, however, are recommended for new designs because they offer best characteristics, best value, or are popular and expected to continue to be readily available in the future.

To simplify the task of selecting a "best" transistor, diode or other device for new designs, this data book contains a section devoted to selection tables (pages 201 thru 258) including all popular semiconductor devices and applications. These guides permit a quick comparison of the preferred devices, and a preselection of semiconductors that are most suitable.

The selection tables are arranged to highlight the prime selection criteria in easy-to-use order. Since the important characteristics depend on the type of device, the selection tables take different forms. In silicon rectifiers, for example, peak reverse voltage, and average forward current, are the basic criteria, and the devices are listed in order of these ratings. For other devices, such as transistors, other important characteristics or suggested applications are listed.

The selection tables include only basic specifications. For complete information refer to the alphanumeric listing of data sheets.

ZENER DIODE SELECTOR GUIDE

The devices listed in the following tables represent a basic profile of the largest inventoried Zener diode line in the industry. These diodes may be employed where a nearly constant dc output voltage is required despite relatively large changes in input voltage or load resistance. Motorola's devices represent state-of-the-art with the superior capability of silicon-oxide passivated junction for low leakage, sharp breakdowns and long-term stability.

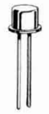
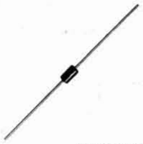
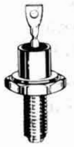
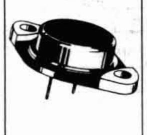
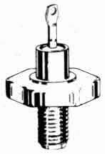
Nominal Zener Voltage	**250 MILLIWATT**	**400 MILLIWATT**	**500 MILLIWATT**	**1 WATT**	**1 WATT**
	Cathode = Polarity Mark	Cathode = Polarity Mark	Cathode = Polarity Mark	Cathode = Polarity Mark	Cathode to Case
	CASE 51	CASE 51	Surmetic 20 CASE 51	Surmetic 30 CASE 59	CASE 52
(NOTE 1, 6)	**INDUSTRIAL ±5% TOLERANCE LOW NOISE LOW LEVEL**	**INDUSTRIAL (NOTE 2, 3)**	**INDUSTRIAL (NOTE 5)**	**INDUSTRIAL (NOTE 2)**	**INDUSTRIAL (NOTE 2, 3)**
1.8	MZ4614				
2.0	MZ4615				
2.2	MZ4616				
2.4	MZ4617	1N4370	1N5221		
2.7	MZ4618	1N4371	1N5223		
3.0	MZ4619	1N4372	1N5225		
3.3	MZ4620	1N746	1N5226	1N4728	1N3821
3.6	MZ4621	1N747	1N5227	1N4729	1N3822
3.9	MZ4622	1N748	1N5228	1N4730	1N3823
4.3	MZ4623	1N749	1N5229	1N4731	1N3824
4.7	MZ4624	1N750	1N5230	1N4732	1N3825
5.1	MZ4625	1N751	1N5231	1N4733	1N3826
5.6	MZ4626	1N752	1N5232	1N4734	1N3827
6.2	MZ4627	1N753	1N5234	1N4735	1N3828
6.8	1N4099	1N754 1N957	1N5235	1N4736	1N3829 1N3016
7.5	1N4100	1N755 1N958	1N5236	1N4737	1N3830 1N3017
8.2	1N4101	1N756 1N959	1N5237	1N4738	1N3018
9.1	1N4103	1N757 1N960	1N5239	1N4739	1N3019
10	1N4104	1N758 1N961	1N5240	1N4740	1N3020
11	1N4105	1N962	1N5241	1N4741	1N3021
12	1N4106	1N759 1N963	1N5242	1N4742	1N3022
13	1N4107	1N964	1N5243	1N4743	1N3023
15	1N4109	1N965	1N5245	1N4744	1N3024
16	1N4110	1N966	1N5246	1N4745	1N3025
18	1N4112	1N967	1N5248	1N4746	1N3026
20	1N4114	1N968	1N5250	1N4747	1N3027
22	1N4115	1N969	1N5251	1N4748	1N3028
24	1N4116	1N970	1N5152	1N4749	1N3029
27	1N4118	1N971	1N5254	1N4750	1N3030
30	1N4120	1N972	1N5256	1N4751	1N3031
33	1N4121	1N973	1N5257	1N4752	1N3032
36	1N4122	1N974	1N5258	1N4753	1N3033
39	1N4123	1N975	1N5259	1N4754	1N3034
43	1N4124	1N976	1N5260	1N4755	1N3035
47	1N4125	1N977	1N5261	1N4756	1N3036
51	1N4126	1N978	1N5262	1N4757	1N3037
56	1N4127	1N979	1N5263	1N4758	1N3038
62	1N4129	1N980	1N5265	1N4759	1N3039
68	1N4130	1N981	1N5266	1N4760	1N3040
75	1N4131	1N982	1N5267	1N4761	1N3041
82	1N4132	1N983	1N5268	1N4762	1N3042
91	1N4134	1N984	1N5270	1N4763	1N3043
100	1N4135	1N985	1N5271	1N4764	1N3044
110		1N986	1N5272	1M110ZS10	1N3045
120		1N987	1N5273	1M120ZS10	1N3046
130		1N988	1N5274	1M130ZS10	1N3047
150		1N989	1N5276	1M150ZS10	1N3048
160		1N990	1N5277	1M160ZS10	1N3049
180		1N991	1N5279	1M180ZS10	1N3050
200		1N992	1N5281	1M200ZS10	1N3051

NOTES:

1. The Zener Voltage is measured at approximately ¼ the rated power except for the MZ4614 and 1N4099 series. This series is measured with an I_{ZT} = 250 μAdc. The 1N4370 and 1N746 series is measured with an I_{ZT} = 20 mAdc.
2. No suffix denotes ±10% tolerance. "A" suffix is ±5.0% tolerance. (1N4370-4372, 1N746-759; 1N3821-30, 1N3993-4000, 1N4728-64).
3. No suffix is ±20% tolerance; "A" suffix is ±10% tolerance, and "B" suffix is ±5.0% tolerance. (1N957-992; 1N3016-3051; 1N3785-3820; 1N2970&R-3015&R; 1N4549&R-4556&R; 1N4557&R-4564&R; 1N2804&R-2846&R; 1N3305&R-3350&R; 1N5333-1N5388).
4. R, RA & RB = Reverse Polarity Types Available.
5. No suffix is ±10% tolerance, "A" suffix is ±10% tolerance, "B" suffix is ±5.0% tolerance.
6. Contact your Motorola Semiconductor Representative for information on Military and Meg-A-Life II Types and intermediate voltages.

▨ JAN/JANTX and Meg-A-Life II available ±5.0% only. (Reverse polarity available on 10 W and 50 W devices)

ZENER DIODE SELECTOR GUIDE (continued)

	1-1/2 WATT	5 WATT	10 WATT	50 WATT	
	Cathode to Case	Cathode = Polarity Mark	Cathode to Case = 1N3993 series Anode to Case = 1N2970 series	Anode to Case	
Nominal Zener Voltage	 CASE 55	 Surmetic 40 CASE 17	 CASE 56	 CASE 54	 CASE 58
(NOTE 1, 6)	**INDUSTRIAL (NOTE 3)**	**INDUSTRIAL (NOTE 3)**	**INDUSTRIAL (NOTE 2, 3, 4)**	**INDUSTRIAL (NOTE 3, 4)**	**INDUSTRIAL (NOTE 3, 4)**
1.8					
2.0					
2.2					
2.4					
2.7					
3.0					
3.3		1N5333			
3.6		1N5334			
3.9		1N5335	1N3993&R	1N4557&R	1N4549&R
4.3		1N5336	1N3994&R	1N4558&R	1N4550&R
4.7		1N5337	1N3995&R	1N4559&R	1N4551&R
5.1		1N5338	1N3996&R	1N4560&R	1N4552&R
5.6		1N5339	1N3997&R	1N4561&R	1N4553&R
6.2		1N5341	1N3998&R	1N4562&R	1N4554&R
6.8	1N3785	1N5342	1N3999&R 1N2970&R	1N4563&R 1N2804&R	1N4555&R 1N3305&R
7.5	1N3786	1N5343	1N4000&R 1N2971&R	1N4564&R 1N2805&R	1N4556&R 1N3306&R
8.2	1N3787	1N5344	1N2972&R	1N2806&R	1N3307&R
9.1	1N3788	1N5346	1N2973&R	1N2807&R	1N3308&R
10	1N3789	1N5347	1N2974&R	1N2808&R	1N3309&R
11	1N3790	1N5348	1N2975&R	1N2809&R	1N3310&R
12	1N3791	1N5349	1N2976&R	1N2810&R	1N3311&R
13	1N3792	1N5350	1N2977&R	1N2811&R	1N3312&R
15	1N3793	1N5352	1N2979&R	1N2813&R	1N3314&R
16	1N3794	1N5353	1N2980&R	1N2814&R	1N3315&R
18	1N3795	1N5355	1N2982&R	1N2816&R	1N3317&R
20	1N3796	1N5357	1N2984&R	1N2818&R	1N3319&R
22	1N3797	1N5358	1N2985&R	1N2819&R	1N3320&R
24	1N3798	1N5359	1N2986&R	1N2820&R	1N3321&R
27	1N3799	1N5361	1N2988&R	1N2822&R	1N3323&R
30	1N3800	1N5363	1N2989&R	1N2823&R	1N3324&R
33	1N3801	1N5364	1N2990&R	1N2824&R	1N3325&R
36	1N3802	1N5365	1N2991&R	1N2825&R	1N3326&R
39	1N3803	1N5366	1N2992&R	1N2826&R	1N3327&R
43	1N3804	1N5367	1N2993&R	1N2827&R	1N3328&R
47	1N3805	1N5368	1N2995&R	1N2829&R	1N3330&R
51	1N3806	1N5369	1N2997&R	1N2831&R	1N3332&R
56	1N3807	1N5370	1N2999&R	1N2832&R	1N3334&R
62	1N3808	1N5372	1N3000&R	1N2833&R	1N3335&R
68	1N3809	1N5373	1N3001&R	1N2834&R	1N3336&R
75	1N3810	1N5374	1N3002&R	1N2835&R	1N3337&R
82	1N3811	1N5375	1N3003&R	1N2836&R	1N3338&R
91	1N3812	1N5377	1N3004&R	1N2837&R	1N3339&R
100	1N3813	1N5378	1N3005&R	1N2838&R	1N3340&R
110	1N3814	1N5379	1N3007&R	1N2840&R	1N3342&R
120	1N3815	1N5380	1N3008&R	1N2841&R	1N3343&R
130	1N3816	1N5381	1N3009&R	1N2842&R	1N3344&R
150	1N3817	1N5383	1N3011&R	1N2843&R	1N3346&R
160	1N3818	1N5384	1N3012&R	1N2844&R	1N3347&R
180	1N3819	1N5386	1N3014&R	1N2845&R	1N3349&R
200	1N3820	1N5388	1N3015&R	1N2846&R	1N3350&R

ZENER REFERENCE DIODES

For applications in which the output voltage must remain within narrow limits during changes in input voltage, load resistance, and temperature changes. These Temperature Compensated Zener Reference Diodes have low dynamic impedance and silicon oxide passivated junctions for long-term stability.

V_Z = 6.2 V

Case 51

Temperature Range

−55, 0, +25, +75, +100°C

*Type Number	ΔV_Z	Temp. Coeff. For Ref.
	Volts	%/°C
I_{ZT} = 7.5 mA		
1N821#	0.096	0.01
1N821A	0.096	0.01
1N823#	0.048	0.005
1N823A	0.048	0.005
1N825#	0.019	0.002
1N825A	0.019	0.002
1N827#	0.009	0.001
1N827A	0.009	0.001
1N829#	0.005	0.0005
1N829A	0.005	0.0005

V_Z = 6.4 V

Case 51

Temperature Range

Non-Suffix

0, +25, +75°C

"A" Suffix

−55, 0, +25, +75, +100°C

Type Number	ΔV_Z	Temp. Coeff. For Ref.
	Volts	%/°C
I_{ZT} = 0.5 mA		
1N4565	0.048	0.01
1N4565A	0.099	0.01
1N4566	0.024	0.005
1N4566A	0.050	0.005
1N4567	0.010	0.002
1N4567A	0.020	0.002
1N4568	0.005	0.001
1N4568A	0.010	0.001
1N4569	0.002	0.0005
1N4569A	0.005	0.0005
I_{ZT} = 1.0 mA		
1N4570	0.048	0.01
1N4570A	0.099	0.01
1N4571	0.024	0.005
1N4571A	0.050	0.005
1N4572	0.010	0.002
1N4572A	0.020	0.002
1N4573	0.005	0.001
1N4573A	0.010	0.001
1N4574	0.002	0.0005
1N4574A	0.005	0.0005
I_{ZT} = 2.0 mA		
1N4575	0.048	0.01
1N4575A	0.099	0.01
1N4576	0.024	0.005
1N4576A	0.050	0.005
1N4577	0.010	0.002
1N4577A	0.020	0.002
1N4578	0.005	0.001
1N4578A	0.010	0.001
1N4579	0.002	0.0005
1N4579A	0.005	0.0005
I_{ZT} = 4.0 mA		
1N4580	0.048	0.01
1N4580A	0.099	0.01
1N4581	0.024	0.005
1N4581A	0.050	0.005
1N4582	0.010	0.002
1N4582A	0.020	0.002
1N4583	0.005	0.001
1N4583A	0.010	0.001
1N4584	0.002	0.0005
1N4584A	0.005	0.0005

V_Z = 8.4 V

Case 51

Temperature Range

Non-Suffix

−55, 0, +25, +75, +100°C

"A" Suffix

−55, 0, +25, +75, +100, +150°C

Type Number	ΔV_Z	Temp. Coeff. For Ref.
	Volts	%/°C
I_{ZT} = 10 mA		
1N3154#	0.130	0.01
1N3154A	0.172	0.01
1N3155#	0.065	0.005
1N3155A	0.036	0.005
1N3156#	0.026	0.002
1N3156A	0.034	0.002
1N3157#	0.013	0.001
1N3157A	0.017	0.001

V_Z = 8.5 V

Case 51

Temperature Range

Non-Suffix

0, +25, +75°C

"A" Suffix

−55, 0, +25, +75, +100°C

Type Number	ΔV_Z	Temp. Coeff. For Ref.
	Volts	%/°C
I_{ZT} = 0.5 mA		
1N4775	0.064	0.01
1N4775A	0.132	0.01
1N4776	0.032	0.005
1N4776A	0.066	0.005
1N4777	0.013	0.002
1N4777A	0.026	0.002
1N4778	0.006	0.001
1N4778A	0.013	0.001
1N4779	0.003	0.0005
1N4779A	0.007	0.0005
I_{ZT} = 1.0 mA		
1N4780	0.064	0.01
1N4780A	0.132	0.01
1N4781	0.032	0.005
1N4781A	0.066	0.005
1N4782	0.013	0.002
1N4782A	0.026	0.002
1N4783	0.006	0.001
1N4783A	0.013	0.001
1N4784	0.003	0.0005
1N4784A	0.007	0.0005

V_Z = 9.0 V

Case 51

Temperature Range

Non-Suffix

0, +25, +75°C

"A" Suffix

−55, 0, +25, +75, +100°C

"B" Suffix

−55, 0, +25, +75, + 100, +150°C

Type Number	ΔV_Z	Temp. Coeff. For Ref.
	Volts	%/°C
I_{ZT} = 7.5 mA		
1N935	0.067	0.01
1N935A	0.139	0.01
1N935B#	0.184	0.01
1N936	0.033	0.005
1N936A	0.069	0.005
1N936B#	0.092	0.005
1N937	0.013	0.002
1N937A	0.027	0.002
1N937B#	0.037	0.002
1N938	0.006	0.001
1N938A	0.013	0.001
1N938B#	0.018	0.001
1N939	0.003	0.0005
1N939A	0.007	0.0005
1N939B#	0.009	0.0005

V_Z = 9.1 V

Case 51

Temperature Range

Non-Suffix

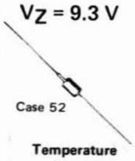
0, +25, +75°C

"A" Suffix

−55, 0, +25, +75, +100°C

Type Number	ΔV_Z	Temp. Coeff. For Ref.
	Volts	%/°C
I_{ZT} = 0.5 mA		
1N4765	0.068	0.01
1N4765A	0.141	0.01
1N4766	0.034	0.005
1N4766A	0.070	0.005
1N4767	0.014	0.002
1N4767A	0.028	0.002
1N4768	0.007	0.001
1N4768A	0.014	0.001
1N4769	0.003	0.0005
1N4769A	0.007	0.0005
I_{ZT} = 1.0 mA		
1N4770	0.068	0.01
1N4770A	0.141	0.01
1N4771	0.034	0.005
1N4771A	0.070	0.005
1N4772	0.014	0.002
1N4772A	0.028	0.002
1N4773	0.007	0.001
1N4773A	0.014	0.001
1N4774	0.003	0.0005
1N4774A	0.007	0.0005

V_Z = 9.3 V



Case 52

Temperature Range

Non-Suffix

0, +25, +75

"A" Suffix

−55, 0, +25, +75, +100°C

"B" Suffix

−55, 0, +25, +75, +100, +150°C

Type Number	ΔV_Z	Temp. Coeff. For Ref.
	Volts	%/°C
I_{ZT} = 10 mA		
1N2620	0.070	0.01
1N2620A	0.144	0.01
1N2620B	0.191	0.01
1N2621	0.035	0.005
1N2621A	0.072	0.005
1N2621B	0.095	0.005
1N2622	0.014	0.002
1N2622A	0.029	0.002
1N2622B	0.038	0.002
1N2623	0.007	0.001
1N2623A	0.014	0.001
1N2623B	0.019	0.001
1N2624	0.003	0.0005
1N2624A	0.007	0.0005
1N2624B	0.010	0.0005

V_Z = 9.4 ±0.4 V

(Suffix "A" ± 0.2 V)

Case 52

Temperature Range

0, +25, +70°C

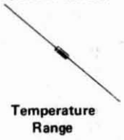
−55, 0, +25, +75, +125°C

−55, 0, +25, +75, +125, +185°C

Type Number	ΔV_Z	Temp. Coeff. For Ref.
	Volts	%/°C
I_{ZT} = 10 mA		
1N2163,A	0.033	0.005
1N2166,A	0.007	0.001
1N2169,A	0.004	0.0005
1N2164,A	0.086	0.005
1N2167,A	0.017	0.001
1N2170,A	0.009	0.0005
1N2165,A	0.115	0.005
1N2168,A	0.023	0.001
1N2171,A	0.112	0.0005

V_Z = 11.7 V

Case 51
(1N941 Series)



Temperature Range

Non-Suffix

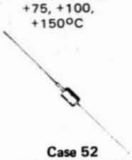
0, +25, +75°C

"A" Suffix

−55, 0, +25, +75, +100°C

"B" Suffix

−55, 0, +25, +75, +100, +150°C



Case 52
(1N3580 Series)

Type Number	ΔV_Z	Temp. Coeff. For Ref.
	Volts	%/°C
I_{ZT} = 7.5 mA		
1N941	0.088	0.01
1N941A	0.181	0.01
1N941B#	0.239	0.01
1N942	0.044	0.005
1N942A	0.090	0.005
1N942B	0.120	0.005
1N943	0.018	0.002
1N943A	0.036	0.002
1N943B#	0.047	0.002
1N944	0.009	0.001
1N944A	0.018	0.001
1N944B#	0.024	0.001
1N945	0.004	0.0005
1N945A	0.009	0.0005
1N945B	0.012	0.0005
1N946	0.002	0.0002
1N946A	0.004	0.0002
1N946B	0.005	0.0002
1N3580	0.088	0.01
1N3580A	0.181	0.01
1N3580B	0.239	0.01
1N3581	0.044	0.005
1N3581A	0.090	0.005
1N3581B	0.120	0.005
1N3582	0.018	0.002
1N3582A	0.036	0.002
1N3582B	0.048	0.002
1N3583	0.008	0.001
1N3583A	0.018	0.001
1N3583B	0.023	0.001

#Available as JAN/JANTX and MEG-A-LIFE II devices.

*Non-Suffix – Z_{ZT} = 15 Ω, "A" Suffix – Z_{ZT} = 10 Ω.

ZENER REFERENCE DIODES

LOW NOISE REFERENCE DIODES

V_Z = 12.8 V

Case 51

Temperature Range

Non-Suffix
+25, +75, +100°C

"A" Suffix
−55, 0, +25, +75, +100°C

Type Number	ΔV_Z	Temp. Coeff. For Ref.
	Volts	%/°C
I_{ZT} = 0.5 mA, $N_D = 0.8 \frac{\mu V}{\sqrt{Hz}}$		
1N4896	0.096	0.01
1N4896A	0.198	0.01
1N4897	0.048	0.005
1N4897A	0.099	0.005
1N4898	0.019	0.002
1N4898A	0.040	0.002
1N4899	0.010	0.001
1N4899A	0.020	0.001
I_{ZT} = 1.0 mA, $N_D = 0.4 \frac{\mu V}{\sqrt{Hz}}$		
1N4900	0.096	0.01
1N4900A	0.198	0.01
1N4901	0.048	0.005
1N4901A	0.099	0.005
1N4902	0.019	0.002
1N4902A	0.040	0.002
1N4903	0.010	0.001
1N4903A	0.020	0.001
I_{ZT} = 2.0 mA, $N_D = 0.25 \frac{\mu V}{\sqrt{Hz}}$		
1N4904	0.096	0.01
1N4904A	0.198	0.01
1N4905	0.048	0.005
1N4905A	0.099	0.005
1N4906	0.019	0.002
1N4906A	0.040	0.002
1N4907	0.010	0.001
1N4907A	0.020	0.001
I_{ZT} = 4.0 mA, $N_D = 0.22 \frac{\mu V}{\sqrt{Hz}}$		
1N4908	0.096	0.01
1N4908A	0.198	0.01
1N4909	0.048	0.005
1N4909A	0.099	0.005
1N4910	0.019	0.002
1N4910A	0.040	0.002
1N4911	0.010	0.001
1N4911A	0.020	0.001
I_{ZT} = 7.5 mA, $N_D = 0.20 \frac{\mu V}{\sqrt{Hz}}$		
1N4912	0.096	0.01
1N4912A	0.198	0.01
1N4913	0.048	0.005
1N4913A	0.099	0.005
1N4914	0.019	0.002
1N4914A	0.040	0.002
1N4915	0.010	0.001
1N4915A	0.020	0.001

V_Z = 19.2 V

Case 51

Temperature Range

Non-Suffix
+25, +75, +100°C

"A" Suffix
−55, 0, +25, +75, +100°C

Type Number	ΔV_Z	Temp. Coeff. For Ref.
	Volts	%/°C
I_{ZT} = 0.5 mA, $N_D = 1.0 \frac{\mu V}{\sqrt{Hz}}$		
1N4916	0.144	0.01
1N4916A	0.298	0.01
1N4917	0.072	0.005
1N4917A	0.149	0.005
1N4918	0.029	0.002
1N4918A	0.060	0.002
I_{ZT} = 1.0 mA, $N_D = 0.5 \frac{\mu V}{\sqrt{Hz}}$		
1N4919	0.144	0.01
1N4919A	0.298	0.01
1N4920	0.072	0.005
1N4920A	0.149	0.005
1N4921	0.029	0.002
1N4921A	0.060	0.002
I_{ZT} = 2.0 mA, $N_D = 0.25 \frac{\mu V}{\sqrt{Hz}}$		
1N4922	0.144	0.01
1N4922A	0.298	0.01
1N4923	0.072	0.005
1N4923A	0.149	0.005
1N4924	0.029	0.002
1N4924A	0.060	0.002
I_{ZT} = 4.0 mA, $N_D = 0.22 \frac{\mu V}{\sqrt{Hz}}$		
1N4925	0.144	0.01
1N4925A	0.298	0.01
1N4926	0.072	0.005
1N4926A	0.149	0.005
1N4927	0.029	0.002
1N4927A	0.060	0.002
1N4928	0.014	0.001
1N4928A	0.030	0.001
I_{ZT} = 7.5 mA, $N_D = 0.20 \frac{\mu V}{\sqrt{Hz}}$		
1N4929	0.144	0.01
1N4929A	0.298	0.01
1N4930	0.072	0.005
1N4930A	0.149	0.005
1N4931	0.029	0.002
1N4931A	0.060	0.002
1N4932	0.014	0.001
1N4932A	0.030	0.001

MOLDED ASSEMBLIES

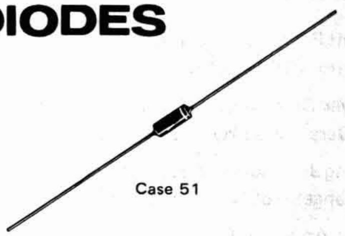
Case	V_Z Volts	Type Number	Temperature Range* +25 to +100°C ΔV_Z Volts	−55 to +25°C ΔV_Z Volts	Temp. Coeff. For Ref. %/°C
			I_{ZT} = 10 mA		
Case 41-8	12.4	1N4057 1N4057A	0.047 0.019	0.050 0.020	0.005 0.002
	14.6	1N4058 1N4058A	0.055 0.022	0.058 0.023	0.005 0.002
	16.8	1N4059 1N4059A	0.063 0.025	0.067 0.027	0.005 0.002
	18.5	1N4060 1N4060A	0.069 0.028	0.074 0.030	0.005 0.002
	21.0	1N4061 1N4061A	0.079 0.032	0.084 0.034	0.005 0.002
	23.0	1N4062 1N4062A	0.086 0.035	0.092 0.037	0.005 0.002
	27.0	1N4063 1N4063A	0.101 0.041	0.108 0.043	0.005 0.002
	30.0	1N4064 1N4064A	0.113 0.045	0.120 0.048	0.005 0.002
	33.0	1N4065 1N4065A	0.124 0.050	0.132 0.053	0.005 0.002
			I_{ZT} = 7.5 mA		
	37.0	1N4066 1N4066A	0.139 0.056	0.148 0.059	0.005 0.002
	43.0	1N4067 1N4067A	0.161 0.065	0.172 0.069	0.005 0.002
	47.0	1N4068 1N4068A	0.176 0.071	0.188 0.075	0.005 0.002
			I_{ZT} = 7.5 mA		
Case 41-9	51.0	1N4069 1N4069A	0.191 0.077	0.204 0.082	0.005 0.002
	56.0	1N4070 1N4070A	0.210 0.084	0.224 0.090	0.005 0.002
	62.0	1N4071 1N4071A	0.232 0.093	0.248 0.099	0.005 0.002
			I_{ZT} = 5.0 mA		
	68.0	1N4072 1N4072A	0.255 0.102	0.272 0.109	0.005 0.002
	75.0	1N4073 1N4073A	0.281 0.113	0.300 0.120	0.005 0.002
	82.0	1N4074 1N4074A	0.307 0.123	0.328 0.131	0.005 0.002
	87.0	1N4075 1N4075A	0.326 0.131	0.348 0.139	0.005 0.002
	91.0	1N4076 1N4076A	0.341 0.137	0.364 0.146	0.005 0.002
	100	1N4077 1N4077A	0.375 0.150	0.400 0.160	0.005 0.002
			I_{ZT} = 2.5 mA		
	105	1N4078 1N4078A	0.394 0.158	0.420 0.168	0.005 0.002
	110	1N4079 1N4079A	0.413 0.165	0.440 0.176	0.005 0.002
	120	1N4080 1N4080A	0.450 0.180	0.480 0.192	0.005 0.002
			I_{ZT} = 2.5 mA		
Case 41-10	130	1N4081 1N4081A	0.488 0.195	0.520 0.208	0.005 0.002
	140	1N4082 1N4082A	0.525 0.210	0.560 0.224	0.005 0.002
	150	1N4083 1N4083A	0.563 0.225	0.600 0.240	0.005 0.002
	175	1N4084 1N4084A	0.656 0.263	0.700 0.280	0.005 0.002
	200	1N4085 1N4085A	0.750 0.300	0.800 0.320	0.005 0.002

Case	V_Z Volts	Type Number	Temperature Range −55, +25, +100°C ΔV_Z Volts	Temp. Coeff. For Ref. %/°C
			I_{ZT} = 7.5 mA (*I_{ZT} = 10 mA)	
53	6.2	1N429#	0.050	0.01
41-6	6.2	1N1735	0.050	0.01
57	8.4 8.4	1N1530* 1N1530A*#	0.014 0.007	0.002 0.001
41-3	12.4 12.4	1N1736 1N1736A	0.100 0.050	0.01 0.005
41-5	18.6 18.6 24.8 24.8	1N1737 1N1737A 1N1738 1N1738A	0.150 0.075 0.200 0.100	0.01 0.005 0.01 0.005
41-4	31.0 31.0 37.2 37.2 43.4 43.4 49.6 49.6	1N1739 1N1739A 1N1740 1N1740A 1N1741 1N1741A 1N1742 1N1742A#	0.250 0.125 0.300 0.150 0.350 0.175 0.400 0.200	0.01 0.005 0.01 0.005 0.01 0.005 0.01 0.005

PRECISION REFERENCE DIODES

Case 51	Type Number	Voltage-Time Stability		ΔV_Z mV Max
		Max Change µV/1000 hr	Parts Per Million Change PPM/1000 hr	
		I_{ZT} = 7.5 mA		
V_Z = 6.2 V ± 5.0% Temp. Range +25, +75, +100°C	MZ605 MZ610 MZ620 MZ640	30 60 120 240	<5.0 <10 <20 <40	2.5 2.5 2.5 2.5
		I_{ZT} = 10 mA		
V_Z = 8.4 V ± 5.0% Temp. Range +25, +75, +100°C	MZ805 MZ810 MZ820 MZ840	45 90 180 360	<5.0 <10 <20 <40	3.5 3.5 3.5 3.5

CURRENT REGULATOR DIODES



Case 51

A diode is now available that works exactly the opposite of a Zener diode. It is called a current-regulator diode. Unlike a Zener, such a diode presents a constant current regardless of the terminal voltage over a wide operating range and appears as a very high circuit impedance. These devices are useful for a number of electronic applications, including overcurrent protection, transistor biasing, linear ramp and stairstep generators, differential amplifiers, precision reference voltage sources, and linear-scale ohmmeters, to name a few.

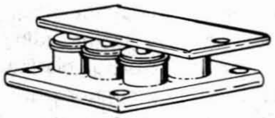
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted) POV = 100 Volt max

Type* Number Industrial	Regulator Current Ip (mA) @ V_T = 25 V			Minimum Dynamic Impedance @ V_T = 25 V Z_T (MΩ)	Minimum Knee Impedance @ V_K = 6.0 V Z_K (MΩ)	Maximum Limiting Voltage @ I_L = 0.8 Ip (min) V_L (Volts)
	nom	min	max			
1N5283	0.22	0.198	0.242	25.0	2.75	1.00
1N5284	0.24	0.216	0.264	19.0	2.35	1.00
1N5285	0.27	0.243	0.297	14.0	1.95	1.00
1N5286	0.30	0.270	0.330	9.0	1.60	1.00
1N5287	0.33	0.297	0.363	6.6	1.35	1.00
1N5288	0.39	0.351	0.429	4.10	1.00	1.05
1N5289	0.43	0.387	0.473	3.30	0.870	1.05
1N5290	0.47	0.423	0.517	2.70	0.750	1.05
1N5291	0.56	0.504	0.616	1.90	0.560	1.10
1N5292	0.62	0.558	0.682	1.55	0.470	1.13
1N5293	0.68	0.612	0.748	1.35	0.400	1.15
1N5294	0.75	0.675	0.825	1.15	0.335	1.20
1N5295	0.82	0.738	0.902	1.00	0.290	1.25
1N5296	0.91	0.819	1.001	0.880	0.240	1.29
1N5297	1.00	0.900	1.100	0.800	0.205	1.35
1N5298	1.10	0.990	1.210	0.700	0.180	1.40
1N5299	1.20	1.08	1.32	0.640	0.155	1.45
1N5300	1.30	1.17	1.43	0.580	0.135	1.50
1N5301	1.40	1.26	1.54	0.540	0.115	1.55
1N5302	1.50	1.35	1.65	0.510	0.105	1.60
1N5303	1.60	1.44	1.76	0.475	0.092	1.65
1N5304	1.80	1.62	1.98	0.420	0.074	1.75
1N5305	2.00	1.80	2.20	0.395	0.061	1.85
1N5306	2.20	1.98	2.42	0.370	0.052	1.95
1N5307	2.40	2.16	2.64	0.345	0.044	2.00
1N5308	2.70	2.43	2.97	0.320	0.035	2.15
1N5309	3.00	2.70	3.30	0.300	0.029	2.25
1N5310	3.30	2.97	3.63	0.280	0.024	2.35
1N5311	3.60	3.24	3.96	0.265	0.020	2.50
1N5312	3.90	3.51	4.29	0.255	0.017	2.60
1N5313	4.30	3.87	4.73	0.245	0.014	2.75
1N5314	4.70	4.23	5.17	0.235	0.012	2.90

*All Devices ±10% tolerance.

SILICON POWER TRANSIENT SUPPRESSORS

Power Zener diodes designed for applications requiring protection of voltage sensitive electronic devices in danger of destruction by high energy voltage transients. Individual cells are matched to insure current sharing under high current pulse conditions. Specials are available with higher power and/or voltage ratings (e.g. 1000 Wdc and 200 Vdc).



Case 119

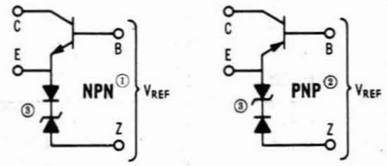
- Transient Power Dissipation: 40 kW
  Pulse Width: 0.1 ms
- DC Power Dissipation: 350 Watts @ T_C = 25°C
  (Derate 2.33 W/°C above 25°C)
- Operating Junction and Storage Temperature
  Range: −65°C to +175°C
- Polarity: Anode-to-Case is Standard
  Cathode-to-Case Available Upon Request

ELECTRICAL CHARACTERISTICS (T_A = 25°C) (V_F = 1.5 V max @ 10 A for all types)

Type	Nominal Operating Voltage (Note 1) $V_{OP(PK)}$ Vdc	Nominal Operating Voltage (Note 1) $V_{OP(RMS)}$ V rms	Maximum Device Clamping Factor $CF = \frac{V_Z @ I_{Z(pulse)}}{V_Z @ I_{ZT}}$	Minimum Zener Voltage $V_{Z(min)}$ Vdc	@ I_{ZT} Adc	Maximum Zener Voltage Pulse Width = 1.0 ms $V_{Z(max)}$ Vdc	@ $I_{Z(pulse)}$ Adc	Maximum Reverse Current $I_{R(max)}$ @ $V_R = V_{OP(PK)}$ μAdc	Typical Capacitance C (typ) @ $V_R = V_{OP(PK)}$ μF
MPZ5-16A	14	10	1.25	16	0.4	24	200	50	0.025
-16B	14	10	1.25	16	0.4	20	200	↓	0.025
-32A	28	20	1.25	32	0.2	50	100	↓	0.011
-32B	28	20	1.25	32	0.2	45	100	↓	0.011
-32C	28	20	1.25	32	0.2	40	100	↓	0.011
-180A	165	117	1.14	180	0.03	250	20	↓	0.0012
-180B	165	117	1.14	180	0.03	225	20	↓	0.0012
-180C	165	117	1.14	180	0.03	205	20	50	0.0012

REFERENCE AMPLIFIERS

Case 181



①Add Suffix N to type number.
②Add Suffix P to type number.
③MCA1911 Series uses only zener diode and transistor.

. . . designed for use in regulated power supplies as a combination voltage reference element and error voltage amplifier, providing temperature compensation for excellent reference voltage stability. Available with either PNP or NPN transistors for versatility of circuit design. Operation over three different temperature ranges: 0 to 75°C, −55 to 100°C, −55 to 150°C.

ELECTRICAL CHARACTERISTICS I_{ZT} = 5.0 mA, V_{CEO} = 30 V)

Type	V_{REF} Volts	Tolerance ±%	ΔV_{REF} Volts	@ Test Temperature °C
MCA1911	6.8	10	0.051	0, +25, +75
MCA1912	↓	↓	0.025	
MCA1913	↓	↓	0.010	
MCA1914	↓	↓	0.005	
MCA1921	↓	5.0	0.105	−55, 0, +25. +75, +100
MCA1922	↓	↓	0.052	
MCA1923	↓	↓	0.020	
MCA1924	↓	↓	0.010	
MCA1931	↓	↓	0.139	−55, 0, +25 +75, +100, +150
MCA1932	↓	↓	0.069	
MCA1933	↓	↓	0.026	
MCA1934	↓	↓	0.013	
MCA2011	8.6	10	0.060	0, +25, +75
MCA2012	↓	↓	0.030	
MCA2013	↓	↓	0.012	
MCA2014	↓	↓	0.006	
MCA2021	↓	5.0	0.124	−55, 0, +25, +75, +100
MCA2022	↓	↓	0.062	
MCA2023	↓	↓	0.024	
MCA2024	↓	↓	0.012	
MCA2031	↓	↓	0.164	−55, 0, +25, +75, +100, +150
MCA2032	↓	↓	0.082	
MCA2033	↓	↓	0.032	
MCA2034	↓	↓	0.016	

Type	V_{REF} Volts	Tolerance ±%	ΔV_{REF} Volts	@ Test Temperature °C
MCA2111	9.5	10	0.071	0, +25, +75
MCA2112	↓	↓	0.035	
MCA2113	↓	↓	0.014	
MCA2114	↓	↓	0.007	
MCA2121	↓	5.0	0.147	−55, 0, +25, +75, +100
MCA2122	↓	↓	0.073	
MCA2123	↓	↓	0.028	
MCA2124	↓	↓	0.014	
MCA2131	↓	↓	0.194	−55, 0, +25 +75, +100, +150
MCA2132	↓	↓	0.097	
MCA2133	↓	↓	0.038	
MCA2134	↓	↓	0.019	
MCA2211	11	10	0.082	0, +25, +75
MCA2212	↓	↓	0.041	
MCA2213	↓	↓	0.016	
MCA2214	↓	↓	0.008	
MCA2221	↓	5.0	0.170	−55, 0, +25, +75, +100
MCA2222	↓	↓	0.085	
MCA2223	↓	↓	0.034	
MCA2224	↓	↓	0.017	
MCA2231	↓	↓	0.225	−55, 0, +25 +75, +100, +150
MCA2232	↓	↓	0.112	
MCA2233	↓	↓	0.044	
MCA2234	↓	↓	0.022	

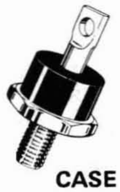
PREFERRED SILICON RECTIFIER SELECTOR GUIDE

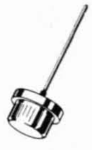
A DIGEST OF THE BROADEST LINE OF QUALITY RECTIFIERS AVAILABLE

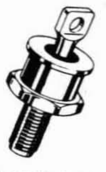
Reverse Polarity Available On All Types Except As Noted
Reversed polarity units can be obtained by adding suffix "R" to standard type number, e.g., 1N3879R.

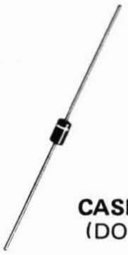
I_O, AVERAGE RECTIFIED FORWARD CURRENT		0.75 A	1.0 A		3.0 A				6.0 A
		CASE 59	CASE 59		CASE 60	CASE 70	CASE 60 *	*	CASE 56A
$V_{RM(REP)}$ MAX PEAK REPETITIVE REVERSE VOLTAGE	50 V	MR810	1N4933	1N4001	1N4719 (MR1030A)	1N4997 (MR1030B)	MR830	MR840	1N3879
	100 V	MR811	1N4934	1N4002	1N4720 (MR1031A)	1N4998 (MR1031B)	MR831	MR841	1N3880
	200 V	MR812	1N4935	1N4003 **1N3611	1N4721 (MR1032A)	1N4999 (MR1032B)	MR832	MR842	1N3881
	300 V				MR1033A	MR1033B			1N3882
	400 V	MR814	1N4936	1N4004 **1N3612	1N4722 (MR1034A)	1N5000 (MR1034B)	MR834	MR844	1N3883
	500 V				MR1035A	MR1035B			
	600 V	MR816	1N4937	1N4005 **1N3613	1N4723 (MR1036A)	1N5001 (MR1036B)	MR836	MR846	MR1366
	800 V			1N4006	1N4724 (MR1038A)	1N5002 (MR1038B)			
	1000 V			1N4007	1N4725 (MR1040A)	1N5003 (MR1040B)			
FAST RECOVERY TYPES ➡		f = 50 kHz t_{rr} = 1.0 µs	f = 250 kHz t_{rr} = 0.2 µs				f = 250 kHz t_{rr} = 0.2 µs	f = 50 kHz t_{rr} = 1.0 µs	f = 250 kHz t_{rr} = 0.2 µs

* Not available in reverse polarity.
** Available to JAN Spec MIL-S-19500/228.
*** Add proper two letter suffix to type number to indicate desired package style. e.g., MR1243FL.


CASE 42
(DO-5)


CASE 43
(DO-21)

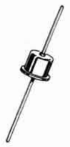

CASE 56A
(DO-4)

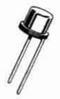

CASE 59
(DO-41)

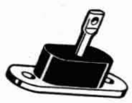
PREFERRED SILICON RECTIFIER SELECTOR GUIDE (continued)

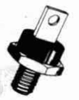
I_O, AVERAGE RECTIFIED FORWARD CURRENT		12 A			15 A	20 A		25 A
		CASE 56A			CASE 42	CASE 42		CASE 43
$V_{RM(REP)}$ MAX PEAK REPETITIVE REVERSE VOLTAGE	50 V	MR880	1N3889	MR1120	1N3208	1N3899	1N248B	1N3491 (MR322)
	100 V	MR881	1N3890	MR1121	1N3209	1N3900	1N249B	1N3492 (MR323)
	200 V	MR882	1N3891	MR1122	1N3210	1N3901	1N250B	1N3493 (MR324)
	300 V		1N3892	MR1123	1N3211	1N3902	1N1195	1N3494 (MR325)
	400 V	MR884	1N3893	MR1124	1N3212	1N3903	1N1196	1N3495 (MR326)
	500 V			MR1125	1N3213		1N1197	MR327
	600 V	MR886	MR1376	MR1126	1N3214	MR1386	1N1198	MR328
	800 V			MR1128				MR330
	1000 V			MR1130				MR331
FAST RECOVERY TYPES ➡		f = 50 kHz t_{rr} = 1.0 μs	f = 250 kHz t_{rr} = 0.2μ s			f = 250 kHz t_{rr} = 0.2 μs		

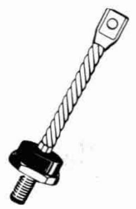
* Not available in reverse polarity.
** Available to JAN Spec MIL-S-19500/228.
*** Add proper two letter suffix to type number to indicate desired package style. e.g., MR1243FL.


CASE 60


CASE 70


CASE 100

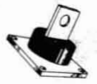

CASES 125,126,127,128
Suffix "SL"


CASES 129, 130, 131, 132
Suffix "SB"

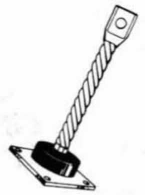
PREFERRED SILICON RECTIFIER SELECTOR GUIDE (continued)

I_O, AVERAGE RECTIFIED FORWARD CURRENT		30 A			35 A	50 A	100 A	
		CASE 42		CASE 43	CASE 42	CASE 100	CASE 167 CASE 168 ***	CASE 189 CASE 190 ***
$V_{RM(REP)}$ MAX PEAK REPETITIVE REVERSE VOLTAGE	50 V	1N3909	MR890	1N3659	1N1183	MR1200FL	MR1210	MR1810
	100 V	1N3910	MR891	1N3660	1N1184	MR1201FL	MR1211	MR1811
	200 V	1N3911	MR892	1N3661	1N1186	MR1203FL	MR1213	MR1813
	300 V	1N3912		1N3662	1N1187	MR1205FL	MR1215	MR1815
	400 V	1N3913	MR894	1N3663	1N1188	MR1207FL	MR1217	MR1817
	500 V				1N1189	MR1208FL	MR1218	MR1818
	600 V	MR1396	MR896		1N1190	MR1209FL	MR1219	MR1819
	800 V							
	1000 V							
FAST RECOVERY TYPES ➡		f = 250 kHz t_{rr} = 0.2 µs	f = 50 kHz t_{rr} = 1.0 µs					

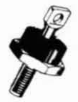
* Not available in reverse polarity.
** Available to JAN Spec MIL-S-19500/228.
*** Add proper two letter suffix to type number to indicate desired package style. e.g., MR1243FL.



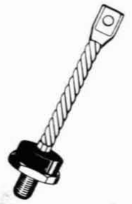
CASES 133, 134, 135, 136
Suffix "FL"



CASES 137, 138, 139
Suffix "FB"



CASES 167, 189
Suffix "SL"



CASES 168, 190
Suffix "SB"

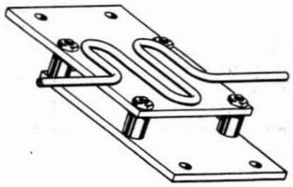
PREFERRED SILICON RECTIFIER SELECTOR GUIDE (continued)

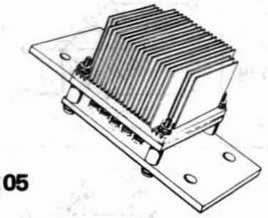
I_O, AVERAGE RECTIFIED FORWARD CURRENT		200 A	300 A	450 A	700 A	750 A	1000 A	1100 A
		CASE 126 CASE 130 CASE 133 CASE 137 ***	CASE 127 CASE 131 CASE 134 CASE 138 ***	CASE 128 CASE 132 CASE 135 CASE 139 ***	CASE 136	CASE 159	CASE 105	CASE 158
$V_{RM(REP)}$ MAX PEAK REPETITIVE REVERSE VOLTAGE	50 V	MR1220	MR1230	MR1240	MR1260	MR2080HA	MR1290	MR2100HA
	100 V	MR1221	MR1231	MR1241	MR1261	MR2081HA	MR1291	MR2101HA
	200 V	MR1223	MR1233	MR1243	MR1263	MR2082HA	MR1293	MR2102HA
	300 V	MR1225	MR1235	MR1245	MR1265	MR2083HA	MR1295	MR2103HA
	400 V	MR1227	MR1237	MR1247	MR1267	MR2084HA	MR1297	MR2104HA
	500 V	MR1228	MR1238	MR1248	MR1268		MR1298	
	600 V	MR1229	MR1239	MR1249	MR1269		MR1299	
	800 V							
	1000 V							

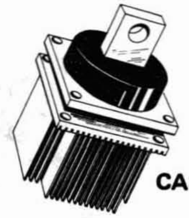
* Not available in reverse polarity.

** Available to JAN Spec MIL-S-19500/228.

*** Add proper two letter suffix to type number to indicate desired package style. e.g., MR1243FL.


CASE 105


CASE 158

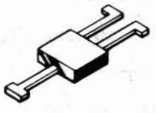

CASE 159

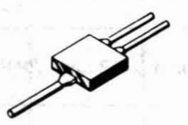
SILICON POWER RECTIFIER ASSEMBLIES SELECTOR GUIDE

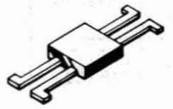
A DIGEST OF THE MOST COMPLETE LINE OF MOLDED ASSEMBLIES

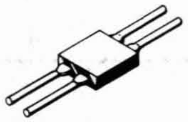
MIDA RECTIFIER ASSEMBLIES

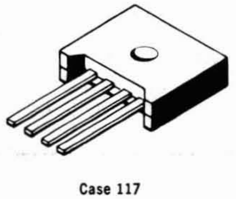
Low-cost, standard rectifier circuits in small, integral packages providing 0.5 to 25 Amp output current with $V_{RM(rep)}$ ratings to 600 Volts. Round leads available by adding suffix "A" to device type number (i.e. MDA920A-1).

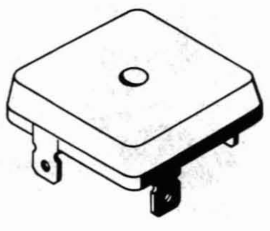

Case 106

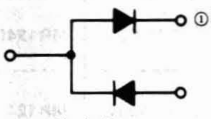
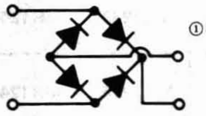
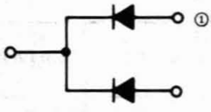
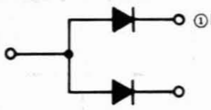
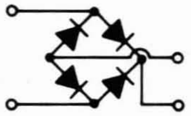
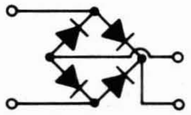
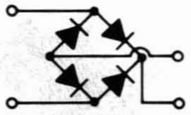
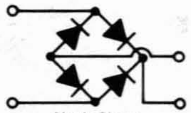

Case 107①


Case 108


Case 109①

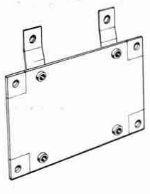

Case 117

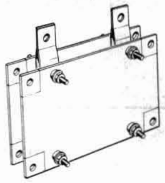

Case 179

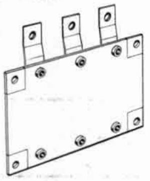
CASE	TYPE	$V_{RM(rep)}$ Volts	$I_{FM(surge)}$ Amps	$I_{FM(rep)}$ Amps	I_{out} Amps @ °C	
106 107	 Single-Phase Voltage Doubler ① MDA930-1	25	32	5.0	0.5	75
	-2	50				
	-3	100				
	-4	200				
	-5	300				
	-6	400				
	-7	600				
108 109	 Single-Phase Full-Wave Bridge ① MDA920-1	25	32	5.0	1.0	75
	-2	50				
	-3	100				
	-4	200				
	-5	300				
	-6	400				
	-7	600				
106 107	 Single-Phase Center Tap Common Cathode ① MDA940-1	25	32	5.0	1.0	75
	-2	50				
	-3	100				
	-4	200				
	-5	300				
	-6	400				
	-7	600				
108 109	 Single-Phase Center Tap Common Anode ① MDA950-1	25	32	5.0	1.0	75
	-2	50				
	-3	100				
	-4	200				
	-5	300				
	-6	400				
	-7	600				
117	 Single-Phase Full-Wave Bridge MDA960-1	50	100	15	2.5	55
	-2	100				
	-3	200				
117	 Single-Phase Full-Wave Bridge MDA970-1	50	150	25	4.0	55
	-2	100				
	-3	200				
179	 Single-Phase Full-Wave Bridge MDA980-1	50	—	—	12	55
	-2	100	—	—		
	-3	200	—	—		
	-4	300	—	—		
	-5	400	—	—		
	-6	600	—	—		
179	 Single-Phase Full-Wave Bridge MDA990-1	50	—	—	25	55
	-2	100	—	—		
	-3	200	—	—		
	-4	300	—	—		
	-5	400	—	—		
	-6	600	—	—		

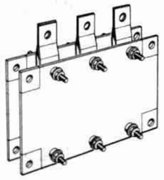
① Round leads. To order add suffix "A", i.e. MDA930A-1.

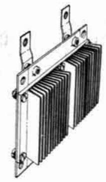
SILICON POWER RECTIFIER ASSEMBLIES SELECTOR GUIDE (continued)

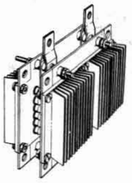

Case 154A
MRA130 Series

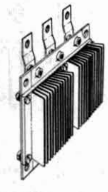

Case 155A
MRA130B Series

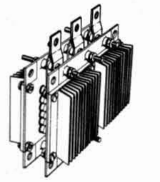

Case 154
MRA330 Series


Case 155
MRA330B Series


Case 156A
MRA160 Series

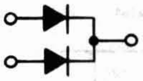
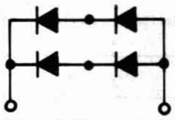

Case 157A
MRA160B Series

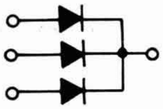
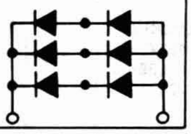

Case 156
MRA360 Series


Case 157
MRA360B Series

HIGH CURRENT RECTIFIER CIRCUITS

Motorola Multi-Cell II power rectifier diode circuits are air-cooled, integral-heatsink rectifier assemblies engineered for optimum diode/heatsink utilization.

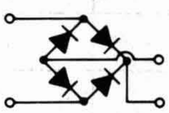
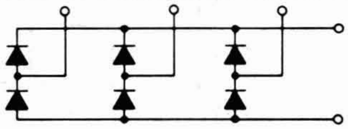
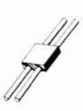
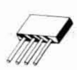
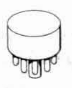
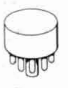
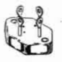
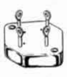
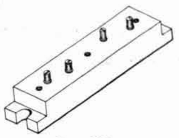
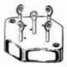
TYPE	$V_{RM(rep)}$ Volts	DC Output Current Amperes	Configuration
MRA130 MRA131 MRA132 MRA133 MRA134	50 100 200 300 400	300 @ 1500 LFM 75 Free Convection	Single-Phase Half-Wave Bridge 
MRA160 MRA161 MRA162 MRA163 MRA164	50 100 200 300 400	600 @ 1500 LFM 125 Free Convection	
MRA130B MRA131B MRA132B MRA133B MRA134B	50 100 200 300 400	300 @ 1500 LFM 75 Free Convection	Single-Phase Full-Wave Bridge 
MRA160B MRA161B MRA162B MRA163B MRA164B	50 100 200 300 400	600 @ 1500 LFM 125 Free Convection	

TYPE	$V_{RM(rep)}$ Volts	DC Output Current Amperes	Configuration
MRA330 MRA331 MRA332 MRA333 MRA334	50 100 200 300 400	300 @ 1500 LFM 75 Free Convection	Three-Phase Half-Wave Bridge 
MRA360 MRA361 MRA362 MRA363 MRA364	50 100 200 300 400	650 @ 1500 LFM 150 Free Convection	
MRA330B MRA331B MRA332B MRA333B MRA334B	50 100 200 300 400	300 @ 1500 LFM 75 Free Convection	Three-Phase Full-Wave Bridge 
MRA360B MRA361B MRA362B MRA363B MRA364B	50 100 200 300 400	650 @ 1500 LFM 150 Free Convection	

Bridge assembly is designated by a "B" suffix, i.e., MRA330B. Bridges are composed of one common cathode and one common anode assembly.

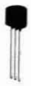
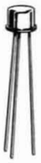
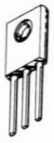
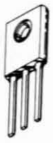
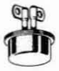
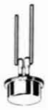
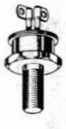
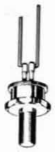
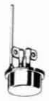
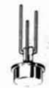
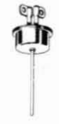
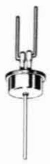
MOLDED RECTIFIER BRIDGE ASSEMBLIES

. . . individual hermetically-sealed rectifiers interconnected and encapsulated in molded assemblies for use as single-phase and three-phase full-wave bridge configurations, with output current range from 1.5 to 16 Amps, peak reverse voltage from 50 to 600 Volts. Series MDA952, MDA962 and MDA1505 for printed circuit insertion without solder lugs (Specify "A" Suffix).

	 Single-Phase Full-Wave Bridge							 Three-Phase Full-Wave Bridge
	 Case 110	 Case 111	 Case 112	 Case 112	 Case 113	 Case 114	 Case 116	 Case 115
$V_{RM(rep)}$ Volts	1.5 Amp			4.0 Amp	6.0 Amp	10 Amp	16 Amp	8.0 Amp
50	MDA942-1	MDA942A-1	MDA1491-1	MDA1591-1	MDA952-1	MDA962-1	MDA972-1	MDA1505-1
100	-2	-2	-2	-2	-2	-2	-2	-2
200	-3	-3	-3	-3	-3	-3	-3	-3
300	-4	-4	-4	-4	-4	-4	-4	-4
400	-5	-5	-5	-5	-5	-5	-5	-5
600	-6	-6	-6	-6	-6	—	—	-6

THYRISTOR SELECTOR GUIDE

This List Contains Only the Most Popular Types of Thyristors Made by Motorola. For Devices Not Listed Contact Your Nearest Motorola Field Office. For a Listing of all EIA Registered Thyristors, see pages 164 thru 175.

THYRISTORS – SILICON CONTROLLED RECTIFIERS		800 mA	1.6 AMP	4.0 AMP	8.0 AMP									
													
		Plastic Case 29(10) TO-92	Case 31 Style 2 TO-5	Plastic Case 90	Plastic Case 90	Case 85	Case 85L	Case 86	Case 86L	Case 87	Case 87L	Case 88	Case 88L
BLOCKING VOLTAGE (DC OR PEAK) VOLTS	25 V	–	2N2322 2N4212#	–	–	2N4151	2N4159	2N4167	2N4175	MCR2604-1	2N4183	MCR2605-1	2N4191
	30 V	2N5060#	–	MCR406-1# †MCR407-1	–	–	–	–	–	–	–	–	–
	50 V	–	2N1595 2N2323# 2N4213#	–	2N4441	2N4152	2N4160	2N4168	2N4176	MCR2604-2	2N4184	MCR2605-2	2N4192
	60 V	2N5061#	–	MCR406-2# †MCR407-2	–	–	–	–	–	–	–	–	–
	100 V	2N5062#	2N1596 2N2324# 2N4214#	MCR406-3# †MCR407-3	–	2N4153	2N4161	2N4169	2N4177	MCR2604-3	2N4185	MCR2605-3	2N4193
	150 V	2N5063#	2N2325# 2N4215#	–	–	–	–	–	–	–	–	–	–
	200 V	2N5064#	2N1597 2N2326# 2N4216#	MCR406-4# †MCR407-4	2N4442	2N4154	2N4162	2N4170	2N4178	MCR2604-4	2N4186	MCR2605-4	2N4194
	250 V	–	–	–	–	–	–	–	–	–	–	–	–
	300 V	–	2N1598	–	–	2N4155	2N4163	2N4171	2N4179	MCR2604-5	2N4187	MCR2605-5	2N4195
	400 V	–	2N1599	–	2N4443	2N4156	2N4164	2N4172	2N4180	MCR2604-6	2N4188	MCR2605-6	2N4196
	500 V	–	–	–	–	2N4157	2N4165	2N4173	2N4181	MCR2604-7	2N4189	MCR2605-7	2N4197
	600 V	–	–	–	2N4444	2N4158	2N4166	2N4174	2N4182	MCR2604-8	2N4190	MCR2605-8	2N4198
	700 V	–	–	–	–	–	–	–	–	–	–	–	–
	800 V	–	–	–	–	–	–	–	–	–	–	–	–

††Gate trigger specification in two modes only.

†Relaxed specification version.

#Sensitive gate devices.

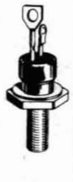
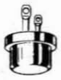
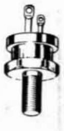
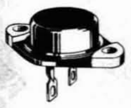
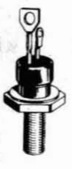
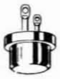
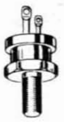
*Formerly MCR2818 and MCR2918, -2, -4, -6, -8 respectively.

**Available without lugs – Case 54, TO-3 (Pin) Package.

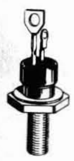
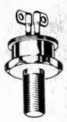
NOTES:

1. Reverse polarity available (add Suffix "R", i.e. 2N5164R).
2. MCR1907-1 thru MCR1907-6 (12 μs max t_{off}).
3. Meets (the requirements of) MIL-S-19500/372.

THYRISTOR SELECTOR GUIDE (continued)

		16 AMP	20 AMP			25 AMP		35 AMP	
THYRISTORS – SILICON CONTROLLED RECTIFIERS									
		Case 64 TO-48	Case 91 (Note 1)	Case 92 (Note 1)	Case 61 TO-41**		Case 64 (Note 2)	Case 91	Case 92
BLOCKING VOLTAGE (DC OR PEAK) VOLTS	25 V	2N1842	MCR2818-1	MCR2918-1	MCR649-1	2N2573	2N681 MCR1907-1	MCR2835-1	MCR2935-1
	30 V	–	–	–	–	–	–	–	–
	50 V	2N1843	2N5164*	2N5168*	MCR649-2	2N2574	2N682 MCR1907-2	MCR2835-2	MCR2935-2
	60 V	–	–	–	–	–	–	–	–
	100 V	2N1844	MCR2818-3	MCR2918-3	MCR649-3	2N2575	2N683 MCR1907-3	MCR2835-3	MCR2935-3
	150 V	2N1845	–	–	–	–	2N684	–	–
	200 V	2N1846	2N5165*	2N5169*	MCR649-4	2N2576	2N685 MCR1907-4	MCR2835-4	MCR2935-4
	250 V	2N1847	–	–	–	–	2N686	–	–
	300 V	2N1848	MCR2818-5	MCR2918-5	MCR649-5	2N2577	2N687 MCR1907-5	MCR2835-5	MCR2935-5
	400 V	2N1849	2N5166*	2N5170*	MCR649-6	2N2578	2N688 MCR1907-6	MCR2835-6	MCR2935-6
	500 V	2N1850	MCR2818-7	MCR2918-7	MCR649-7	2N2579	2N689	MCR2835-7	MCR2935-7
	600 V	–	2N5167*	2N5171*	–	–	–	MCR2835-8	MCR2935-8
	700 V	–	–	–	–	–	–	–	–
	800 V	–	–	–	–	–	–	–	–

THYRISTOR SELECTOR GUIDE (continued)

THYRISTORS — SILICON CONTROLLED RECTIFIERS	MODULATOR TYPES				8.0 AMP			BIDIRECTIONAL THYRISTORS (TRIACS)
	50 AMP (Pulse)	100 AMP (Pulse)	300 AMP (Pulse)	1000 AMP (Pulse)				
	Case 31 Style 2 TO-5	Fast Switching Case 63 (Note 3)		 Fast Switching Case 64 TO-48	Case 85	 Case 86	Case 87L	
BLOCKING VOLTAGE (DC OR PEAK) VOLTS								BLOCKING VOLTAGE (DC OR PEAK) VOLTS
25 V	–	–	–	–	–	–	–	25 V
30 V	–	–	–	–	–	–	–	30 V
50 V	–	–	–	–	MAC1-2 MAC4-2††	MAC2-2 MAC5-2††	MAC3-2 MAC6-2††	50 V
60 V	–	–	–	–	–	–	–	60 V
100 V	–	–	–	–	–	–	–	100 V
150 V	–	–	–	–	–	–	–	150 V
200 V	MCR2130-4	–	–	–	MAC1-4 MAC4-4††	MAC2-4 MAC5-4††	MAC3-4 MAC6-4††	200 V
250 V	–	–	–	–	–	–	–	250 V
300 V	MCR2130-5	2N4199 JAN2N4199	MCR1336-5	MCR1718-5	–	–	–	300 V
400 V	MCR2130-6	2N4200 JAN2N4200	MCR1336-6	MCR1718-6	MAC1-6 MAC4-6††	MAC2-6 MAC5-6††	MAC3-6 MAC6-6††	400 V
500 V	MCR2130-7	2N4201 JAN2N4201	MCR1336-7	MCR1718-7	–	–	–	500 V
600 V	MCR2130-8	2N4202 JAN2N4202	MCR1336-8	MCR1718-8	–	–	–	600 V
700 V	MCR2130-9	2N4203 JAN2N4203	MCR1336-9	–	–	–	–	700 V
800 V	MCR2130-10	2N4204 JAN2N4204	MCR1336-10	–	–	–	–	800 V

††Gate trigger specifications in two modes only.
Note 3 — Meets (the requirements of) MIL-S-19500/372.

TRIGGER AND UNIJUNCTION SELECTOR GUIDE

This list covers the most popular Motorola trigger and unijunction semiconductor products. Other devices are available from stock or are currently under development.

The three-and four-layer diodes are oxide passivated for superior reliability. All products offer parameter uniformity.

Motorola's unijunction transistors are manufactured by the modern Silicon Annular process. The annular process yield devices having low-emitter reverse current, fast switching time, and low peak-point currents.

BILATERAL TRIGGER DIODES

	Type Number	I_{pulse} Peak Pulse Current @ 30 μs, 120 Hz	$V_{(BR)}$ Breakover Voltage (Both Directions)	$I_{(BR)}$ Breakover Current (Both Directions)	ΔV Switchback Voltage (Both Directions)
		Amp (Max)	Volts (Nom)	μA (Max)	Volts (Min)
 Case 182 (formerly Case 29B)	MPT20	2.0	20	100	5.0
	MPT28	2.0	28	50	7.0
	MPT32	2.0	32	50	7.0

4-LAYER DIODES (Peak Pulse Current = 10 Amp @ PW = 50 μs Max)

	Type Number	$V_{(BR)F}$ Forward Breakover Voltage		$I_{(BR)F}$ @ $V_{(BR)F}$ Switching Current $T_A = 25^{\circ}C$	I_H Holding Current $T_A = 25^{\circ}C$	I_{FM} @ V_{FB} I_{RM} @ V_{RM} Maximum Forward And Reverse Leakage Current $T_A = 25^{\circ}C$	
		$T_A = 25^{\circ}C$ Min/Max	−60 to +125°C Min/Max	μA Max	mA Min/Max	nA Max	Volts Max
 Case 51 (DO-7)	I_F = 150 mA (Max)						
	1N5158(M4L3052)	8/10	–	50	1/20	–	–
	1N5159(M4L3053)	9/11	–	50	1/20	–	–
	1N5160(M4L3054)	10/12	–	50	1/20	–	–
	M4L3055	11/13	–	50	1/20	–	–
	M4L3056	12/14	–	50	1/20	–	–

UNIJUNCTION TRANSISTORS

	Type Number	P_D Power Dissipation mW (Max)	V_{B2B1} Interbase Voltage Volts (Max)	η Intrinsic Standoff Ratio Min	η Intrinsic Standoff Ratio Max	I_{EB2O} Emitter Reverse Current μA (Max)	I_P Peak Point Emitter Current μA (Max)	I_V Valley Point Current mA (Min)
 Case 29(9) (TO-92)	2N4870	300	35	0.56	0.75	1.0	5.0	2.0
	2N4871	↓	35	0.70	0.85	1.0	5.0	4.0
	MU4891	↓	–	0.55	0.82	0.01	5.0	2.0
	MU4892	↓	–	0.51	0.69	↓	2.0	↓
	MU4893	↓	–	0.55	0.82	↓	2.0	↓
	MU4894	↓	–	0.74	0.86	↓	1.0	↓

	Type Number	P_D Power Dissipation mW (Max)	V_{B2B1} Interbase Voltage Volts (Max)	η Intrinsic Standoff Ratio Min	η Intrinsic Standoff Ratio Max	I_{EB2O} Emitter Reverse Current μA (Max)	I_P Peak Point Emitter Current μA (Max)	I_V Valley Point Current mA (Min)
 Case 22A (TO-18)	2N2646	300	35	0.56	0.75	12.0	5.0	4.0
	2N2647	300	↓	0.68	0.82	0.2	2.0	8.0
	2N3980	360	↓	0.68	0.82	0.01	2.0	1.0
	2N4851	300	↓	0.56	0.75	0.1	2.0	2.0
	2N4852	300	↓	0.70	0.85	0.1	2.0	4.0
	2N4853	300	35	0.70	0.85	0.05	0.4	6.0
	2N4948	360	–	0.55	0.82	0.01	2.0	2.0
	JAN2N4948*	↓	–	0.55	0.82	↓	2.0	↓
	2N4949	↓	–	0.74	0.86	↓	1.0	↓
	JAN2N4949*	↓	–	0.74	0.86	↓	1.0	↓
	2N5431	300	35	0.72	0.80	↓	0.4	↓

*Meets (the requirements of) MIL-S-19500/388.

PLASTIC-ENCAPSULATED SMALL-SIGNAL TRANSISTOR SELECTOR GUIDE

Plastic-Encapsulated Small-Signal Silicon Transistors for Industrial Applications

Motorola plastic-encapsulated transistors offer the features the designer of industrial electronics equipment requires – *reliability, performance, convenience,* and *economy.*

has been well proven by extensive environmental and life testing, and by hundreds of millions of these transistors in use for industrial and consumer applications. Industrial plastic transistors are encapsulated by a high-temperature pressure-molded process that produces a rugged one-piece package resistant to humidity and shock.

is assured by careful design and testing. Geometric design and diffusion profiles are optimized to excel in specified applications such as high-speed switching, high-frequency amplification, and low-noise amplification. Motorola plastic transistors are 100% performance tested on high-speed, computer-controlled equipment, before shipment, to assure conformance to specifications.

in use is enhanced by a number of package variations – the popular D-shaped, Unibloc package which can dissipate 310 mW at an ambient temperature of 25°C, and the Uniwatt package used for applications requiring up to 8 watts dissipation.

is a prime concern of the industrial designer. Motorola's highly efficient plastic product lines are the most advanced in the industry. Devices are produced by strip-line techniques on highly mechanized equipment that reduces labor costs and provides high uniformity and quality.

TABLE OF CONTENTS

PACKAGE OUTLINES
Medium and low-power packages add flexibility to Motorola plastic-encapsulated transistor lines

DESIGN STOCK
A recommended list of 10 devices that handle almost all prototype design requirements

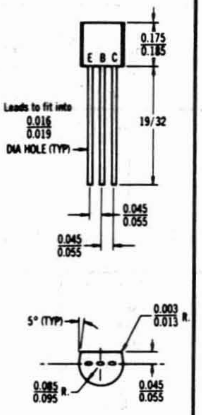
INDEX TO MOTOROLA PLASTIC-ENCAPSULATED TRANSISTORS
Complete alpha-numeric index of Motorola devices

DEVICE SELECTION TABLES
Short-form specifications of devices intended for specific applications. (For complete information, send for appropriate data sheet or refer to the Semiconductor Data Book.)

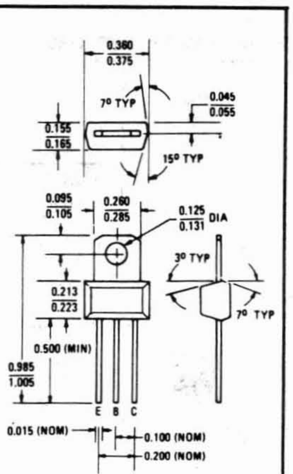
General-Purpose Saturated Switching Transistors Table 1
High-Speed Saturated Switching Transistors Table 2
General-Purpose Amplifier Transistors Table 3
Darlington Amplifier Transistors Table 4
Low-Noise Amplifier Transistors Table 5
High-Voltage Transistors Table 6
Medium-Power (Uniwatt) Transistors Table 7

CROSS-REFERENCE CHART
Motorola replacement for other transistors in common use

MOTOROLA PLASTIC PACKAGE OUTLINES



Case 29 (TO-92)
Low-Power package for all Unibloc devices



Case 152
Medium-Power package for Uniwatt devices

Collector connected to tab

PLASTIC-ENCAPSULATED SMALL-SIGNAL TRANSISTOR SELECTOR GUIDE (continued)

DESIGN STOCK

The transistor requirements of most small-signal industrial circuits can be met by a limited number of versatile devices. The ten inexpensive transistors listed below can satisfy most design requirements, while minimizing the number of transistors that must be stocked.

GENERAL-PURPOSE SWITCHES AND AMPLIFIERS

LOW-CURRENT – TO 100 mA

	NPN	PNP
LOW GAIN	2N3903	2N3905
HIGH GAIN	2N3904	2N3906

HIGH CURRENT – TO 500 mA
(these types generate Low Noise at Low Currents)

	NPN	PNP
LOW GAIN	2N4400	2N4402
HIGH GAIN	2N4401	2N4403

HIGH SPEED SATURATED SWITCHES

	NPN
LOW GAIN	2N4264
HIGH GAIN	2N4265

INDEX TO MOTOROLA PLASTIC-ENCAPSULATED SMALL-SIGNAL TRANSISTORS

This index includes all plastic-encapsulated small-signal transistors available from Motorola. Devices for which no Table Number is given are recommended for exact replacement purposes only and should not be considered for new designs.

Device	Table
2N3903	1,3,5
2N3904	1,3,5
2N3905	1,3,5
2N3906	1,3,5
2N4123	1,3
2N4124	1,3
2N4125	1,3
2N4126	1,3
2N4264	2
2N4265	2
2N4400	1,3
2N4401	1,3
2N4402	1,3
2N4403	1,3
2N4409	6
2N4410	6
2N5086	3,5
2N5087	3,5
2N5088	3,5
2N5089	3,5
2N5208	–
2N5209	3,5
2N5210	3,5
2N5219	–
2N5220	–
2N5221	–
2N5222	–
2N5223	–
2N5224	–
2N5225	–
2N5226	–
2N5227	–
2N5228	–
2N5400	6
2N5401	6
2N5550	6
2N5551	6
MPS404	1
MPS404A	1
MPS706	2
MPS706A	2
MPS708	–
MPS834	2
MPS835	2
MPS918	–
MPS2369	2
MPS2711	–
MPS2712	–
MPS2713	–
MPS2714	–
MPS2923	–
MPS2924	–
MPS2925	–
MPS2926	–
MPS3390	–
MPS3391	–
MPS3391A	–
MPS3392	–
MPS3393	–
MPS3394	–
MPS3395	–
MPS3563	–
MPS3638	1,3
MPS3638A	1,3
MPS3639	2
MPS3640	2
MPS3646	2
MPS3693	3
MPS3694	3
MPS3702	–
MPS3703	–
MPS3704	–
MPS3705	–
MPS3706	–
MPS3707	–
MPS3708	–
MPS3709	–
MPS3710	–
MPS3711	–
MPS3721	3
MPS6507	–
MPS6511	3
MPS6512	3
MPS6513	3
MPS6514	3
MPS6515	3
MPS6516	3
MPS6517	3
MPS6518	3
MPS6519	3
MPS6520	5
MPS6521	5
MPS6522	5
MPS6523	5
MPS6530	3
MPS6531	3
MPS6532	3
MPS6533	3
MPS6534	3
MPS6535	3
MPS6539	–
MPS6540	–
MPS6542	–
MPS6543	–
MPS6544	–
MPS6545	–
MPS6546	–
MPS6547	–
MPS6548	–
MPS6560	3
MPS6561	3
MPS6562	3
MPS6563	3
MPS6565	3,5
MPS6566	3,5
MPS6567	–
MPS6568	–
MPS6569	–
MPS6570	–
MPS6571	5
MPS-A09	3,5
MPS-A10	3
MPS-A12	4
MPS-A13	4
MPS-A14	4
MPS-A65	4
MPS-A66	4
MPS-L01	6
MPS-L51	6
MPS-U01	7
MPS-U02	7
MPS-U03	7
MPS-U04	7
MPS-U05	7
MPS-U06	7
MPS-U51	7
MPS-U52	7
MPS-U55	7
MPS-U56	7

PLASTIC-ENCAPSULATED SMALL-SIGNAL TRANSISTOR SELECTOR GUIDE (continued)

TABLE 1
GENERAL-PURPOSE SATURATED SWITCHING TRANSISTORS

The transistors in this table are characterized for general medium-voltage, medium-speed switching applications. These transistors also may be used as general-purpose amplifiers. All have base-emitter voltages of 4 to 6 volts, output capacitances of 4 to 20 pF, and power dissipation ratings of 310 mW. The devices are listed in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing collector test current (I_C).

Type	BV_{CEO} Volts	Collector Test Current for h_{FE} I_C in mA	h_{FE} min	$V_{CE(sat)}$ max Volts	@ I_C mA	f_T min MHz	@ I_C mA	Switching Times ns max t_{on}	t_{off}	@ I_C/I_B mA	Complement
NPN											
2N4401	40	150	100	0.75	500	250	20	35	255	150/15	2N4403
2N4400	40	150	50	0.75	500	200	20	35	255	150/15	2N4402
2N3904	40	10	100	0.3	50	300	10	70	250	10/1.0	2N3906
2N3903	40	10	50	0.3	50	250	10	70	225	10/1.0	2N3905
2N4123	30	2.0	50	0.3	50	250	10	37*	136*	10/1.0	2N4125
2N4124	25	2.0	120	0.3	50	300	10	37*	136*	10/1.0	2N4126
PNP											
2N4403	40	150	100	0.75	500	200	20	35	255	150/15	2N3903
2N4402	40	150	50	0.75	500	150	20	35	255	150/15	2N4400
2N3906	40	10	100	0.4	50	250	10	70	300	10/1.0	2N3904
2N3905	40	10	50	0.4	50	200	10	70	260	10/1.0	2N3903
MPS404A‡	35	12	30	0.2	24	–	–	265	385	10/1.0	
2N4125	30	2.0	50	0.4	50	200	10	43*	155*	10/1.0	2N4123
MPS3638A	25	50	100	2.0	300	150	50	90	210	300/30	
MPS3638	25	50	30	1.0	300	100	50	90	210	300/30	
2N4126	25	2.0	120	0.4	50	250	10	43*	155*	10/1.0	2N4124
MPS404†	24	12	30	0.2	24	–	–	265	385	10/1.0	

*Typical †V_{EB} = 12 Vdc ‡V_{EB} = 24 Vdc

TABLE 2
HIGH-SPEED SATURATED SWITCHING TRANSISTORS

The transistors listed in this table are optimized for high-speed saturated switching. They are heavily gold doped and otherwise processed to provide very short storage times and low capacitance. (Output capacitances below 6 pF). The power dissipation is rated at 310 mW. The transistors are listed in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing collector test current (I_C).

Type	BV_{CEO} Volts	Collector Test Current for h_{FE} I_C in mA	h_{FE} min	$V_{CE(sat)}$ max Volts	@ I_C mA	f_T min MHz	@ I_C mA	Switching Times ns max t_{on}	t_{off}	@ I_C/I_B mA
NPN										
MPS834	30	10	25	0.25	10	350	10	16	30	10/3.0
MPS835	20	10	20	0.3	10	300	10	20	35	10/3.0
2N4264	15	30	40	0.35	100	300	10	23	35	100/10
MPS3646	15	30	30	0.5	300	350	30	25	35	300/30
MPS2369	15	10	40	0.25	10	–	–	12	18	10/3.0
MPS706,A	15	10	20	0.6	10	200	10	40	75	10/–
2N4265	12	10	100	0.35	100	300	10	23	35	100/10
PNP										
MPS3640	12	10	30	0.2	10	500	10	40	32	50/5.0
MPS3639	6.0	10	30	0.16	10	500	10	40	32	50/5.0

PLASTIC-ENCAPSULATED SMALL-SIGNAL TRANSISTOR SELECTOR GUIDE (continued)

TABLE 3
GENERAL-PURPOSE AMPLIFIER TRANSISTORS

These general-purpose transistors are designed for small-signal amplification from dc to low radio frequencies. They are also useful as oscillators and general-purpose switches. The transistors are listed in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing collector test current (I_C). P_D = 310 mW at T_A = 25°C unless otherwise specified.

Type	BV_{CEO} Volts	Collector Test Current for h_{FE} I_C in mA	h_{FE} min/max	f_T min MHz	@ I_C mA	Complement
NPN						
2N5210	50	1.0	250/–	30	0.5	2N5087
2N5209	50	1.0	150/–	30	0.5	2N5086
MPS-A09	50	0.1	100/600	30	0.5	
MPS6566	45	10	100/400	200	10	
MPS6565	45	10	40/160	200	10	
2N4400	40	150	100/300	200	20	2N4402
2N4401	40	150	50/150	250	20	2N4403
MPS6531	40	100	90/270	390†	50	MPS6534
MPS6530	40	100	40/120	390†	50	MPS6533
2N3904	40	10	100/300	300	10	2N3906
2N3903	40	10	50/150	250	10	2N3905
MPS-A10**	40	5.0	40/400	20	5.0	
MPS6532	30	100	30/–	390†	50	MPS6535
MPS6513	30	2.0	90/180	250†	2.0	MPS6517
2N4123	30	2.0	50/150	250	10	2N4125
MPS6512	30	2.0	50/100	250†	2.0	MPS6516
2N5088	30	1.0	350/–	50	0.5	
MPS6515	25	2.0	250/500	390†	2.0	MPS6519
MPS6514	25	2.0	150/300	390†	2.0	MPS6518
2N4124	25	2.0	120/360	300	10	2N4126
2N5089	25	1.0	450/–	50	0.5	
MPS6560*	20	500	50/200	60	10	MPS6562
MPS6561*	20	350	50/200	60	10	MPS6563
MPS3721	18	2.0	60/660‡	–	–	
PNP						
2N5087	50	1.0	250/–	40	0.5	2N5210
2N5086	50	1.0	150/–	40	0.5	2N5209
2N4403	40	150	100/300	200	20	2N4401
2N4402	40	150	50/150	150	20	2N4400
MPS6534	40	100	90/270	260†	50	MPS6531
MPS6533	40	100	40/120	260†	50	MPS6530
2N3906	40	10	100/300	250	10	2N3904
2N3905	40	10	50/150	200	10	2N3903
MPS6518	40	2.0	150/300	340†	2.0	MPS6514
MPS6517	40	2.0	90/180	200†	2.0	MPS6513
MPS6516	40	2.0	50/100	200†	2.0	MPS6512
MPS6535	30	100	30/–	260†	50	MPS6532
2N4125	30	2.0	50/150	200	10	2N4123
MPS3638A	25	50	100/–	150	50	
MPS3638	25	50	30/–	100	50	
MPS6519	25	2.0	250/500	340†	2.0	MPS6515
2N4126	25	2.0	120/360	250	10	2N4124
MPS6562*	20	500	50/200	60	10	MPS6560
MPS6563*	20	350	50/200	60	10	MPS6561

*P_D = 500 mW @ T_A = 25°C †Typical ‡h_{fe} @ f = 1.0 kHz **P_D = 210 mW @ T_A = 25°C

PLASTIC-ENCAPSULATED SMALL-SIGNAL TRANSISTOR SELECTOR GUIDE (continued)

TABLE 4
DARLINGTON AMPLIFIER TRANSISTORS

Darlington amplifiers are compound-connected transistors that provide extremely high current gain and input impedance. Power dissipation is rated at 310 mW. These devices are listed in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing collector test current (I_C).

Type	BV_{CEO} Volts	Collector Test Current for h_{FE} I_C in mA	h_{FE} min	f_T min MHz	@ I_C mA
NPN					
MPS-A14	30	10	10,000	125	10
MPS-A13	30	10	5,000	125	10
MPS-A12	20	10	20,000	–	–
PNP					
MPS-A66	30	10	75,000	100	10
MPS-A65	30	10	50,000	100	10

TABLE 5
LOW-NOISE AMPLIFIER TRANSISTORS

The small-signal transistors listed in this table are characterized for low-noise amplification at low frequencies. The power dissipation is rated at 310 mW. The transistors are listed in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing collector test current (I_C).

Type	BV_{CEO} Volts	Collector Test Current for h_{FE} I_C in mA	h_{FE} min/max	Noise Figure NF max dB	@ I_C μA	@ f Hz	f_T min MHz	@ I_C mA
NPN								
2N5210	50	0.1	200/600	3.0	20	1.0 kHz	30	0.5
2N5209	50	0.1	100/300	4.0	20	1.0 kHz	30	0.5
MPS-A09	50	0.1	100/600	1.4*	100	1.0 kHz	30	0.5
MPS6566	45	10	100/400	4.0*	100	10 Hz-15.7 kHz	100	10
MPS6565	45	10	40/160	4.0*	100	10 Hz-15.7 kHz	40	10
2N3904	40	0.1	40/–	5.0	100	10 Hz-15.7 kHz	300	10
2N3903	40	0.1	20/-	6.0	100	10 Hz-15.7 kHz	300	10
2N5088	30	0.1	300/900	3.0	100	10 Hz-15.7 kHz	50	0.5
2N5089	25	0.1	400/1200	2.0	100	10 Hz-15.7 kHz	50	0.5
MPS6521	25	0.1	150/–	3.0	10	10 Hz-10 kHz	480*	10
MPS6520	25	0.1	100/–	3.0	10	10 Hz-10 kHz	480*	10
MPS6571	20	0.1	250/1000	1.2*	100	100 Hz	50	0.5
PNP								
2N5087	50	0.1	250/800	2.0	20	10 Hz-15.7 kHz	40	0.5
2N5086	50	0.1	150/500	3.0	20	10 Hz-15.7 kHz	40	0.5
2N3906	40	0.1	60/–	4.0	100	10 Hz-15.7 kHz	250	10
2N3905	40	0.1	30/–	5.0	100	10 Hz-15.7 kHz	200	10
MPS6523	25	0.1	150/–	3.0	10	10 Hz-15.7 kHz	420	10
MPS6522	25	0.1	100/–	3.0	10	10 Hz-15.7 kHz	420	10

*Typical

TABLE 6
HIGH-VOLTAGE TRANSISTORS

These high-voltage transistors are designed for driving neon bulbs and Nixie® indicator tubes, for direct line operation, and for other applications requiring high-voltage capability at relatively low collector current. See Table 7–Medium-Power (Uniwatt) Transistors also. Power Dissipation is rated at 310 mW. These devices are listed in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing collector test current (I_C).

Type	BV_{CEO} Volts	Collector Test Current for h_{FE} I_C in mA	h_{FE} min/max	$V_{CE(sat)}$ @	I_C	f_T @	I_C
				max Volts	mA	min/max MHz	mA
NPN							
2N5551	160	10	80/250	0.15	10	100/300	10
2N5550	140	10	60/250	0.15	10	100/300	10
MPSL01	120	10	50/300	0.2	10	60/–	10
2N4410	80	1.0	60/400	0.2	1.0	60/300	10
2N4409	50	1.0	60/400	0.2	1.0	60/300	10
PNP							
2N5401	150	10	60/240	0.2	10	150/300	10
2N5400	120	10	40/180	0.2	10	100/400	10
MPSL51	100	50	40/250	0.25	10	60/–	10

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TABLE 7
MEDIUM-POWER (UNIWATT) TRANSISTORS

For applications requiring higher power dissipation than that of the standard Unibloc package, Motorola has developed the Uniwatt case. In this plastic-encapsulated package, which is slightly larger than the small-signal case, the collector is mounted on a metal tab that extends out of the plastic. The tab can be attached to a heat sink to conduct heat away from the junction. With a satisfactory sink, Uniwatt transistors can dissipate 5 to 8 watts. Without a heat sink, power dissipation at an ambient temperature of 25°C is 1 watt. The transistors are listed in order of decreasing collector test current (I_C).

Type	BV_{CEO} Volts	Collector Test Current for h_{FE} I_C in mA	h_{FE} min/max	$V_{CE(sat)}$ @ I_C		f_T @ I_C		P_D Watts $T_C = 25^oC$	Complement	Comments
				max Volts	mA	min MHz	mA			
NPN										
MPS-U04	180	10	40/–	0.5	200	100	50	5.0		High-Voltage Amplifier
MPS-U03	120	10	40/–	0.5	200	100	50	5.0		High-Voltage Amplifier
MPS-U06	80	250	100/–	0.6	250	50	250	5.0	**MPS-U56**	General Purpose
MPS-U05	60	250	100/–	0.6	250	50	250	5.0	**MPS-U55**	General Purpose
MPS-U02	40	150	50/300	0.4	150	150	20	6.0	**MPS-U52**	General Purpose
MPS-U01	30	150	70/–	1.0	1000	50	50	8.0	**MPS-U51**	Audio Transistor
PNP										
MPS-U56	80	250	100/–	0.6	250	50	250	5.0	**MPS-U06**	General Purpose
MPS-U55	60	250	100/–	0.6	250	50	250	5.0	**MPS-U05**	General Purpose
MPS-U52	40	150	50/300	0.4	150	150	20	6.0	**MPS-U02**	General Purpose
MPS-U51	30	150	70/–	1.0	1000	50	50	8.0	**MPS-U01**	Audio Transistor

SILICON POWER TRANSISTOR SELECTOR GUIDE

This Selector Guide is presented to help the designer choose the best silicon power transistors for his new equipment and find suitable replacements for devices used in older designs.

INDEX

This index lists silicon power transistors manufactured by Motorola. The table numbers reference the table that characterizes the device.

Within each table, the transistors are separated by case, with the cases suitable for highest power shown last. For a given case, the transistors are grouped into NPN and PNP devices, then by power dissipation, voltage rating, and h_{FE}.

Device Type	Table #	Device Type	Table #	Device Type	Table #	Device Type	Table #	Device Type	Table #
2N1724	10	2N3771	16	2N4912	9	2N5427	11	MJ2865	13
2N1725	10	2N3772	15	2N4913	10	2N5428	11	MJ2901	13
2N3021	7	2N3773	14	2N4914	10	2N5429	11	MJ2940	13
2N3022	7	2N3788	5	2N4915	10	2N5430	11	MJ2941	13
2N3023	7	2N3789	13	2N4918	7	2N5477	11	MJ3010	8
2N3024	7	2N3790	13	2N4919	7	2N5478	11	MJ3011	8
2N3025	7	2N3791	13	2N4920	7	2N5479	11	MJ3013	5
2N3026	7	2N3792	13	2N4921	7	2N5480	11	MJ3014	5
2N3054	9	2N3867	7	2N4922	7	MJ400	2	MJ3029	8
2N3055	13	2N3868	7	2N4923	7	MJ413	13	MJ3030	8
2N3232	12	2N3902	6	2N5050	5	MJ420	1	MJ3101	5
2N3235	13	2N4231	10	2N5051	5	MJ421	1	MJ3201	1
2N3439	1	2N4232	10	2N5052	5	MJ423	13	MJ3202	1
2N3440	1	2N4233	10	2N5067	10	MJ430	7	MJ3701	7
2N3441	7	2N4234	7	2N5068	10	MJ431	13	MJ4502	16
2N3442	13	2N4235	7	2N5069	10	MJ440	4	MJ8100	10
2N3445	12	2N4236	7	2N5190	9	MJ450	16	MJ8101	10
2N3446	12	2N4237	7	2N5191	9	MJ480	9	MJE101	10
2N3447	12	2N4238	7	2N5192	9	MJ481	9	MJE102	10
2N3448	12	2N4239	7	2N5193	9	MJ490	9	MJE103	10
2N3487	12	2N4348	13	2N5194	9	MJ491	9	MJE104	10
2N3488	12	2N4398	16	2N5195	9	MJ802	16	MJE105	10
2N3489	12	2N4399	16	2N5301	16	MJ2249	5	MJE201	10
2N3490	12	2N4877	9	2N5302	16	MJ2250	5	MJE202	10
2N3491	12	2N4898	9	2N5303	16	MJ2251	3	MJE203	10
2N3492	12	2N4899	9	2N5334	7	MJ2252	3	MJE204	10
2N3713	13	2N4900	9	2N5335	7	MJ2253	7	MJE205	10
2N3714	13	2N4901	10	2N5336	10	MJ2254	7	MJE340	3
2N3715	13	2N4902	10	2N5337	10	MJ2267	10	MJE344	3
2N3716	13	2N4903	10			MJ2268	10	MJE345	3
2N3719	7	2N4904	10	2N5338	10	MJ2801	13	MJE370	7
2N3720	7	2N4905	10	2N5339	10	MJ2802	13	MJE371	7
2N3738	7	2N4906	10	2N5344	4	MJ2814	13	MJE488	9
2N3739	7	2N4907	13	2N5345	4	MJ2816	13	MJE520	7
2N3740	9	2N4908	13	2N5346	11	MJ2832	12	MJE521	7
2N3741	9	2N4909	13	2N5347	11	MJ2840	13	MJE2801	13
2N3766	9	2N4910	9	2N5348	11	MJ2841	13	MJE2901	13
2N3767	9	2N4911	9	2N5349	11	MJ2855	13	MJE2955	13
								MJE3055	13

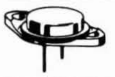
COMPLEMENTARY TRANSISTORS

This list represents the large number of "off-the-shelf" complementary silicon power transistors in the line. For convenience in choosing complements, a selection can be made on the basis of maximum collector current, case, and voltage.

I_C max	Case	BV_{CEO}	NPN	PNP	Table
3.0 A	31	40	2N4237	2N4234	7
		60	2N4238	2N4235	
		80	2N4239	2N4236	
	77	40	2N4921	2N4918	
		60	2N4922	2N4919	
		80	2N4923	2N4920	
	77	30	MJE520	MJE370	
		40	MJE521	MJE371	
4.0 A	80	60	2N3766	2N3740	9
		80	2N3767	2N3741	
		40	2N4910	2N4898	
		60	2N4911	2N4899	
		80	2N4912	2N4900	
	77	40	2N5190	2N5193	
		60	2N5191	2N5194	
		80	2N5192	2N5195	
	11	40	MJ480	MJ490	
		60	MJ481	MJ491	
5.0 A	90	40	MJE201	MJE101	10
		50	MJE205	MJE105	
		60	MJE202	MJE102	

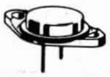
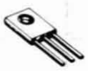
I_C max	Case	BV_{CEO}	NPN	PNP	Table
5.0 A (cont)	90	60	MJE203	MJE103	10
		80	MJE204	MJE104	
	11	40	2N5067	2N4901	
		60	2N5068	2N4902	
		80	2N5069	2N4903	
	11	40	2N4913	2N4904	
		60	2N4914	2N4905	
		80	2N4915	2N4906	
10 A	90	60	MJE2801	MJE3055	13
		60	MJE2901	MJE2955	
	11	60	2N3713	2N3789	
		80	2N3714	2N3790	
	11	60	2N3715	2N3791	
		80	2N3716	2N3792	
	11	60	2N3055	2N4908	
		60	MJ2840	MJ2940	
		80	MJ2841	MJ2941	
	11	40	MJ2801	MJ2901	
30 A	12	40	2N5301	2N4398	16
		60	2N5302	2N4399	
		90	MJ802	MJ4502	

SELECTION TABLES TO SILICON POWER TRANSISTORS

		Type NPN PNP	V_{CEO}	h_{FE} @	I_C	$V_{CE(sat)}$ @	I_C/I_B	f_T
			Volts (Max)	Min/Max	Amp	Volts (Max)	Amp	MHz
100 mA TABLE 1								
Case 31 (TO-5)	T_J(Max) = 175°C P_D = 4.0 W	MJ420	250	25/250	0.03	5.0	0.03/0.003	30
		MJ421	325	25/250	0.03	5.0	0.03/0.003	30
	P_D = 5.0 W	2N3440	300	40/160	0.02	–	–	–
		2N3439	350	40/160	0.02	–	–	–
Case 80 (TO-66)	P_D = 8.0 W	MJ3201	225	30/200	0.05	5.0	0.05/0.005	15
		MJ3202	300	30/200	0.05	5.0	0.05/0.005	15
250 mA TABLE 2								
Case 80 (TO-66)	T_J(Max) = 175°C P_D = 6.67 W	MJ400	325	30/300	0.05	5.0	0.05/0.005	15
500 mA TABLE 3								
Case 80 (TO-66)	T_J(Max) = 150°C P_D = 10 W	MJ2251	225	25/200	0.05	–	–	–
		MJ2252	300	25/200	0.05	–	–	–
Case 77	P_D = 20.8 W	MJE344	200	30/300	0.05	5.0	0.05/0.005	15
		MJE340	300	30/240	0.05	–	–	–
		MJE345	325	30/300	0.05	5.0	0.05/0.005	15
1.0 A TABLE 4								
Case 31 (TO-5)	T_J(Max) = 200°C P_D = 6.0 W	MJ440	40	25/150	0.25	0.5	0.750/0.075	3.0
Case 80 (TO-66)	P_D = 40 W	2N5344	250	25/100	0.50	3.0	1.0/0.1	60
		2N5345	300	25/100	0.50	3.0	1.0/0.1	60
2.0 A TABLE 5								
Case 80 (TO-66)	T_J(Max) = 175°C P_D = 20 W	MJ3101	40	25/200	0.5	2.5	0.75/0.075	10
		MJ2249	60	25/200	0.5	2.5	1.0/0.100	10
		MJ2250	80	25/200	0.5	2.5	1.0/0.100	10
	P_D = 40 W	2N5050	120	25/100	0.75	1.0	0.75/0.100	–
		2N5051	150	25/100	0.75	1.0	0.75/0.100	–
		2N5052	200	25/100	0.75	1.0	0.75/0.100	–
 Case 11 (TO-3)	T_J(Max) = 150°C P_D = 100 W	MJ3013	140	10/-	1.0	1.5	1.0/0.2	–
		MJ3014	200	10/	1.0	1.5	1.0/0.2	–
		2N3788	325	20/180	0.5	1.0	1.5/0.3	–
2.5 A TABLE 6								
Case 11 (TO-3)	T_J(Max) = 150°C P_D = 100 W	2N3902	400	20/100	1.0	2.5	2.5/0.5	–
3.0 A TABLE 7								
Case 31 (TO-5)	T_J(Max) = 200°C P_D = 6.0 W	2N4237	40	30/150	0.25	0.6	1.0/0.1	2.0
		2N4238	60	30/150	0.25	0.6	1.0/0.1	2.0
		2N4239	80	30/150	0.25	0.6	1.0/0.1	2.0
		2N3719	40	25/180	1.0	1.5	3.0/0.3	60
		2N4234	40	30/150	0.25	0.6	1.0/0.125	3.0
		MJ430	40	25/150	0.25	0.5	0.75/0.075	3.0
		2N3867	40	40/200	1.5	1.3	2.5/0.25	–
		2N3720	60	25/180	1.0	1.5	3.0/0.3	60
		2N4235	60	30/150	0.25	0.6	1.0/0.125	3.0
		2N3868	60	30/150	1.5	1.3	2.5/0.25	–
		2N4236	80	30/150	0.25	0.6	1.0/0.125	3.0

SILICON POWER TRANSISTOR SELECTOR GUIDE (continued)

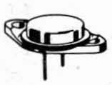
3.0 A TABLE 7 (continued)

		Type NPN PNP	V_{CEO}	h_{FE} @	I_C	$V_{CE(sat)}$ @	I_C/I_B	f_T
			Volts (Max)	Min/Max	Amp	Volts (Max)	Amp	MHz
Case 79 (TO-39)	T_J(Max) = 200°C P_D = 6.0 W	2N5334	60	30/150	1.0	0.7	2.0/0.2	60
		2N5335	80	30/150	1.0	0.7	2.0/0.2	60
Case 80 (TO-66)	T_J(Max) = 175°C P_D = 20 W	2N3738	225	40/200	0.25	2.5	0.25/0.025	10
		2N3739	300	40/200	0.25	2.5	0.25/0.025	10
	T_J(Max) = 200°C P_D = 25 W	2N3441	140	20/80	0.5	6.0	2.7/0.9	–
		MJ3701	40	20/100	0.25	0.8	1.0/0.125	3.0
		MJ2253	60	20/100	0.25	0.8	1.0/0.125	3.0
		MJ2254	80	20/100	0.25	0.8	1.0/0.125	3.0
Case 1 (TO-3)  Except 0.36 max. can height and lead length 0.32/0.42	T_J(Max) = 175°C P_D = 25 W	2N3021	30	20/60	1.0	1.5	3.0/0.3	–
		2N3024	30	50/180	1.0	1.0	3.0/0.3	–
		2N3022	45	20/60	1.0	1.5	3.0/0.3	–
		2N3025	45	50/180	1.0	1.0	3.0/0.3	–
		2N3023	60	20/60	1.0	1.5	3.0/0.3	–
		2N3026	60	50/180	1.0	1.0	3.0/0.3	–
Case 77 	T_J(Max) = 150°C P_D = 25 W	MJE520	30	40/-	1.0	–	–	–
		MJE521	40	40/-	1.0	–	–	–
		MJE370	30	40/-	1.0	–	–	–
		MJE371	40	40/-	1.0	–	–	–
	P_D = 30 W	2N4921	40	20/100	0.5	0.6	1.0/0.1	3.0
		2N4922	60	20/100	0.5	0.6	1.0/0.1	3.0
		2N4923	80	20/100	0.5	0.6	1.0/0.1	3.0
		2N4918	40	20/100	0.5	0.6	1.0/0.1	3.0
		2N4919	60	20/100	0.5	0.6	1.0/0.1	3.0
		2N4920	80	20/100	0.5	0.6	1.0/0.1	3.0

3.5 A TABLE 8

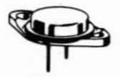
Case 11 (TO-3)	T_J(Max) = 150°C P_D = 100 W	MJ3010	200	20/180	0.5	2.0	3.0/0.8	–
		MJ3011	325	20/180	0.5	2.0	3.0/0.8	–
	P_D = 125 W	MJ3029	250	30/-	0.4	–	–	–
		MJ3030	325	3.75/-	3.0	2.0	3.0/0.8	–

4.0 A TABLE 9

Case 79 (TO-39)	T_J(Max) = 200°C P_D = 10 W	2N4877	60	20/100	4.0	1.0	4.0/0.4	–
Case 80 (TO-66)	T_J(Max) = 175°C P_D = 20 W	2N3766	60	40/160	0.5	2.5	1.0/0.1	10
		2N3767	80	40/160	0.5	2.5	1.0/0.1	10
	T_J(Max) = 200°C P_D = 25 W	2N4910	40	20/100	0.5	0.6	1.0/0.1	3.0
		2N3054	60	25/100	0.5	1.0	0.5/0.05	4.0
		2N4911	60	20/100	0.5	0.6	1.0/0.1	3.0
		2N4912	80	20/100	0.5	0.6	1.0/0.1	3.0
		2N4898	40	20/100	0.5	0.6	1.0/0.1	3.0
		2N4899	60	20/100	0.5	0.6	1.0/0.1	3.0
		2N3740	60	30/100	0.25	0.6	1.0/0.125	4.0
		2N4900	80	20/100	0.5	0.6	1.0/0.1	3.0
		2N3741	80	30/100	0.25	0.6	1.0/0.125	4.0
Case 77	T_J(Max) = 150°C P_D = 40 W	2N5190	40	25/100	1.5	1.4	4.0/1.0	2.0
		MJE488	50	25/-	1.5	0.5	1.0/0.1	2.0
		2N5191	60	25/100	1.5	1.4	4.0/1.0	2.0
		2N5192	80	20/80	1.5	1.4	4.0/1.0	2.0
		2N5193	40	25/100	1.5	1.4	4.0/1.0	2.0
		2N5194	60	25/100	1.5	1.4	4.0/1.0	2.0
		2N5195	80	20/80	1.5	1.4	4.0/1.0	2.0
Case 11 (TO-3) 	T_J(Max) = 200°C P_D = 87.5 W	MJ480	40	30/200	1.0	1.2	3.0/0.3	4.0
		MJ481	60	30/200	1.0	1.2	3.0/0.3	4.0
		MJ490	40	30/200	1.0	1.2	3.0/0.3	4.0
		MJ491	60	30/200	1.0	1.2	3.0/0.3	4.0

SILICON POWER TRANSISTOR SELECTOR GUIDE (continued)

5.0 A TABLE 10

		Type NPN PNP	V_{CEO} Volts (Max)	h_{FE} @ Min/Max	I_C Amp	$V_{CE(sat)}$ @ Volts (Max)	I_C/I_B Amp	f_T MHz
Case 79 (TO-39)	T_J(Max) = 200°C P_D = 6.0 W	2N5336	80	30/120	2.0	1.2	5.0/0.5	30
		2N5337	80	60/240	2.0	1.2	5.0/0.5	30
		2N5338	100	30/120	2.0	1.2	5.0/0.5	30
		2N5339	100	60/240	2.0	1.2	5.0/0.5	30
		MJ8100	60	40/200	2.0	1.2	5.0/0.5	30
		MJ8101	80	40/200	2.0	1.2	5.0/0.5	30
Case 80 (TO-66)	T_J(Max) = 200°C P_D = 35 W	2N4231	40	25/100	1.5	2.0	3.0/0.3	4.0
		2N4232	60	25/100	1.5	2.0	3.0/0.3	4.0
		2N4233	80	25/100	1.5	2.0	3.0/0.3	4.0
Case 90	T_J(Max) = 150°C P_D = 65 W	MJE205	50	25/100	2.0	–	–	–
		MJE105	50	25/100	2.0	–	–	–
	P_D = 75 W	MJE201	40	25/150	2.0	2.0	5.0/0.5	–
		MJE202	60	25/150	2.0	2.0	5.0/0.5	–
		MJE203	60	30/150	1.0	1.5	5.0/1.0	–
		MJE204	80	30/150	1.0	1.5	5.0/1.0	–
		MJE101	40	25/150	2.0	2.0	5.0/0.5	–
		MJE102	60	25/150	2.0	2.0	5.0/0.5	–
		MJE103	60	30/150	1.0	1.5	5.0/1.0	–
		MJE104	80	30/150	1.0	1.5	5.0/1.0	–
 Case 11 (TO-3)	T_J(Max) = 200°C P_D = 87.5 W	2N5067	40	20/80	1.0	1.5	5.0/1.0	4.0
		2N4913	40	25/100	2.5	1.5	5.0/1.0	4.0
		2N5068	60	20/80	1.0	1.5	5.0/1.0	4.0
		2N4914	60	25/100	2.5	1.5	5.0/1.0	4.0
		2N5069	80	20/80	1.0	1.5	5.0/1.0	4.0
		2N4915	80	25/100	2.5	1.5	5.0/1.0	4.0
		2N4901	40	20/80	1.0	1.5	5.0/1.0	4.0
		2N4904	40	25/100	2.5	1.5	5.0/1.0	4.0
		2N4902	60	20/80	1.0	1.5	5.0/1.0	4.0
		2N4905	60	25/100	2.5	1.5	5.0/1.0	4.0
		2N4903	80	20/80	1.0	1.5	5.0/1.0	4.0
		2N4906	80	25/100	2.5	1.5	5.0/1.0	4.0
	P_D = 150 W	MJ2267	40	20/100	4.0	1.0	4.0/0.4	3.0
		MJ2268	55	20/100	4.0	1.0	4.0/0.4	3.0
Case 9 (TO-61)	T_J(Max) = 200°C P_D = 115 W	2N1724	80	20/90	2.0	1.0	2.0/0.2	–
		2N1725	80	50/150	2.0	1.0	2.0/0.2	–

7.0 A TABLE 11

		Type	V_{CEO}	h_{FE}	I_C	$V_{CE(sat)}$	I_C/I_B	f_T
Case 80 (TO-66)	T_J(Max) = 200°C P_D = 40 W	2N5427	80	30/120	2.0	1.2	7.0/0.7	30
		2N5428	80	60/240	2.0	1.2	7.0/0.7	30
		2N5429	100	30/120	2.0	1.2	7.0/0.7	30
		2N5430	100	60/240	2.0	1.2	7.0/0.7	30
Isolated Collector Case 160 (TO-59)	T_J(Max) = 200°C P_D = 60 W	2N5346	80	30/120	2.0	1.2	7.0/0.7	30
		2N5347	80	60/240	2.0	1.2	7.0/0.7	30
		2N5348	100	30/120	2.0	1.2	7.0/0.7	30
		2N5349	100	60/240	2.0	1.2	7.0/0.7	30
Collector Common to Case Case 160A (TO-59)	T_J(Max) = 200°C P_D = 60 W	2N5477	80	30/120	2.0	1.2	7.0/0.7	30
		2N5478	80	60/240	2.0	1.2	7.0/0.7	30
		2N5479	100	30/120	2.0	1.2	7.0/0.7	30
		2N5480	100	60/240	2.0	1.2	7.0/0.7	30

7.5 A TABLE 12

		Type	V_{CEO}	h_{FE}	I_C	$V_{CE(sat)}$	I_C/I_B	f_T
Case 11 (TO-3)	T_J(Max) = 200°C P_D = 110 W	2N3232	60	15/75	3.0	2.5	3.0/0.2	–
	P_D = 115 W	2N3445	80	20/60	3.0	1.5	3.0/0.3	–
		2N3447	80	40/120	5.0	1.5	5.0/0.5	–
		MJ2832	100	15/75	3.0	2.5	3.0/0.2	–
		2N3446	100	20/60	3.0	1.5	3.0/0.3	–
		2N3448	100	40/120	5.0	1.5	5.0/0.5	–
Case 9 (TO-61)	T_J(Max) = 200°C P_D = 115 W	2N3487	80	20/60	3.0	1.2	3.0/0.3	–
		2N3490	80	40/120	5.0	1.0	3.0/0.3	–
		2N3488	100	20/60	3.0	1.2	3.0/0.3	–
		2N3491	100	40/120	5.0	1.0	3.0/0.3	–
		2N3489	120	15/45	3.0	1.2	3.0/0.3	–
		2N3492	120	30/90	5.0	1.0	3.0/0.3	–

SILICON POWER TRANSISTOR SELECTOR GUIDE (continued)

10 A TABLE 13

		Type NPN	V_{CEO}	h_{FE} @	I_C	$V_{CE(sat)}$ @	I_C/I_B	f_T
		PNP	Volts (Max)	Min/Max	Amp	Volts (Max)	Amp	MHz
Case 90	T_J(Max) = 150°C P_D = 90 W	MJE2801	60	25/100	3.0	–	–	–
		MJE3055	60	20/70	4.0	8.0	10/3.3	2.2
		MJE2901	60	25/100	3.0	–	–	–
		MJE2955	60	20/70	4.0	8.0	10/3.3	2.0
 Case 11 (TO-3)	T_J(Max) = 200°C P_D = 110 W	2N3235	55	20/70	4.0	1.1	4.0/0.4	–
	P_D = 115 W	MJ2865	60	20/70	4.0	1.1	4.0/0.4	–
		2N3055	60	20/70	4.0	8.0	10/3.3	–
		MJ2855	100	20/70	4.0	1.1	4.0/0.4	–
	P_D = 117 W	2N3442	140	20/70	3.0	5.0	10/2.0	–
	P_D = 120 W	MJ2801	40	15/60	8.0	1.5	8.0/0.8	–
		MJ2802	60	15/60	8.0	1.5	8.0/0.8	–
		2N4348	120	15/60	5.0	2.0	10/1.25	–
		MJ2901	40	15/60	8.0	1.5	8.0/0.8	–
	P_D = 125 W	MJ413	400†	20/80	0.5	0.8	0.5/0.05	2.5
		MJ423	400†	30/90	1.0	0.8	1.0/0.1	2.5
		MJ431	400†	15/35	2.5	0.7	2.5/0.5	2.5
	P_D = 150 W	2N3713	60	15/-	3.0	1.0	5.0/0.5	–
		MJ2840	60	20/100	3.0	–	–	4.0
		2N3715	60	30/-	3.0	0.8	5.0/0.5	–
		2N3714	80	15/-	3.0	1.0	5.0/0.5	–
		MJ2841	80	20/100	4.0	–	–	4.0
		2N3716	80	30/-	3.0	0.8	5.0/0.5	–
		MJ2814	100	25/90	1.0	1.0	5.0/0.5	–
		MJ2816	100	50/150	1.0	0.8	5.0/0.5	–
		2N4907	40	20/80	4.0	2.0	10/2.0	–
		2N3789	60	15/-	3.0	1.0	4.0/0.4	4.0
		2N3791	60	30/-	3.0	1.0	5.0/0.5	4.0
		MJ2940	60	20/100	3.0	–	–	4.0
		2N4908	60	20/80	4.0	2.0	10/2.0	–
		2N3790	80	15/-	3.0	1.0	4.0/0.4	4.0
		2N3792	80	30/-	3.0	1.0	5.0/0.5	4.0
		2N4909	80	20/80	4.0	2.0	10/2.0	–
		MJ2941	80	20/100	4.0	–	–	4.0

†V_{CEX}

16 A TABLE 14

 Case 11 (TO-3)	T_J(Max) = 200°C P_D = 150 W	2N3773	140	15/60	8.0	4.0	16/3.2	0.8

20 A TABLE 15

 Case 11 (TO-3)	T_J(Max) = 200°C P_D = 150 W	2N3772	60	15/60	10	1.4	10/1.0	0.8

30 A TABLE 16

 Case 12 (TO-3)	T_J(Max) = 200°C P_D = 150 W	2N3771	40	15/60	15	2.0	15/1.5	0.8
		MJ450	40	20/-	10	1.0	10/1.0	2.0
	P_D = 200 W	2N5301	40	15/60	15	3.0	30/6.0	2.0
		2N5302	60	15/60	15	3.0	30/6.0	2.0
		2N5303	80	15/60	10	2.0	20/4.0	2.0
		MJ802	90	25/100	7.5	–	–	–
		2N4398	40	15/60	15	2.0	20/2.0	4.0
		2N4399	60	15/60	15	2.0	20/2.0	4.0
		MJ4502	90	25/100	7.5	–	–	–

GERMANIUM POWER TRANSISTOR SELECTOR GUIDE

This selector guide reflects the "preferred" Motorola germanium power transistors and can be used as a quick reference to find the best device for your applications.

FOR MILITARY APPLICATIONS

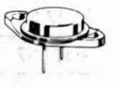
JAN 2N174A	MIL-S-19500/13	JAN 2N1412	MIL-S-19500/76	JAN 2N1554A	MIL-S-19500/331
JAN 2N297A	MIL-S-19500/36	JAN 2N1412A	MIL-S-19500/76	JAN 2N1555A	MIL-S-19500/331
JAN 2N665	MIL-S-19500/58	JAN 2N1549A	MIL-S-19500/332	JAN 2N1556A	MIL-S-19500/331
JAN 2N1011	MIL-S-19500/67	JAN 2N1550A	MIL-S-19500/332	JAN 2N2079A	MIL-S-19500/340
JAN 2N1120	MIL-S-19500/68	JAN 2N1551A	MIL-S-19500/332	JAN 2N2528	MIL-S-19500/309
JAN 2N1165	MIL-S-19500/178	JAN 2N1552A	MIL-S-19500/332	JAN 2N2834	MIL-S-19500/310
JAN 2N1358	MIL-S-19500/122	JAN 2N1553A	MIL-S-19500/331		

Also available as standard devices.

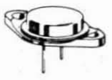
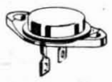
ALLOY TRANSISTORS

Low-cost devices featuring high current gain and low saturation voltage.

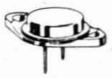
3-AMP

 TO-3 (Case 11) TO-41② (Case 4-04)	**HIGH-FREQUENCY DRIVER** **LOW I_{CBO}** **$P_D = 62.5$ W** **$f_T = 0.4$ MHz**	**h_{FE}** $I_C = 0.5$ A, $V_{CE} = 2.0$ V	**V_{CES}**	**30 V**	**45 V**	**60 V**	**75 V**	**90 V**
			V_{CB}	**30 V**	**45 V**	**60 V**	**75 V**	**90 V**
		30-60		2N2137	2N2138	2N2139	2N2140	2N2141
		50-100		2N2142	2N2143	2N2144	2N2145	2N2146

5-AMP

 TO-3 (Case 11)	**GENERAL-PURPOSE SWITCH AND AMPLIFIER** **$P_D = 106$ W** **$f_T = 0.25$ MHz**	**h_{FE}** $I_C = 3.0$ A, $V_{CE} = 2.0$ V	**V_{CES}**	**30 V**	**45 V**	**60 V**	**75 V**	**90 V**
			V_{CB}	**40 V**	**60 V**	**80 V**	**100 V**	**120 V**
		20-40		2N1529	2N1530	2N1531	2N1532	2N1533
		35-70		2N1534	2N1535	2N1536	2N1537	2N1538
 TO-41③ (Case 4-04)	**HIGH-GAIN GENERAL-PURPOSE SWITCH AND AMPLIFIER** **$P_D = 106$ W** **$f_T = 0.35$ MHz**	**h_{FE}** $I_C = 3.0$ A, $V_{CE} = 2.0$ V	**V_{CES}**	**30 V**	**45 V**	**60 V**	**75 V**	**90 V**
			V_{CB}	**40 V**	**60 V**	**80 V**	**100 V**	**120 V**
		50-100		2N1539	2N1540	2N1541	2N1542	2N1543
		75-150		2N1544	2N1545	2N1546	2N1547	2N1548

7-AMP

 TO-3 (Case 11) TO-41③ (Case 4-04)	**ECONOMY LINE GENERAL-PURPOSE AMPLIFIER AND SWITCH** **$P_D = 77$ W** **$f_T = 0.3$ MHz**	**h_{FE}** $I_C = 3.0$ A, $V_{CE} = 2.0$ V	**V_{CES}**	**30 V**	**45 V**	**60 V**	**60 V**	**75 V**	**75 V**
			V_{CB}	**40 V**	**60 V**	**75 V**	**80 V**	**90 V**	**100 V**
		30-60					2N3615		2N3616
		35-70		2N3611	2N3612				
		45-90					2N3617		2N3618
		60-120		2N3613	2N3614				
		30-200		④ MP2060	④ MP2061	④ MP2062		④ MP2063	

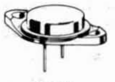
Notes:

① For epoxy encapsulated "PAC" add "A" to device type (i.e. MP801A)
② TO-41, add the prefix "MP" in place of "2N" (i.e. MP2137)
③ TO-41, order odd numbered devices (i.e. 2N1163)
④ Special order for TO-41; contact your local Motorola Sales office
⑤ Alloy Diffused Epitaxial Process

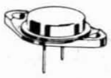
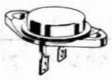
GERMANIUM POWER TRANSISTOR SELECTOR GUIDE (continued)

ALLOY TRANSISTORS (continued)

15-AMP

 TO-36 (Case 5)	**GENERAL-PURPOSE SWITCH AND AMPLIFIER** $P_D = 170$ W $f_T = 0.25$ MHz	h_{FE} $I_C = 5.0$ A, $V_{CE} = 2.0$ V	V_{CES}	**40 V**	**50 V**	**70 V**	**80 V**
			V_{CB}	**40 V**	**50 V**	**70 V**	**80 V**
		20-40		2N2078	2N2077	2N2076	2N2075
		35-70		2N2082	2N2081	2N2080	2N2079
 TO-3 (Case 11A)	**HIGH-SPEED SWITCH AND AMPLIFIER** $P_D = 106$ W $f_T = 0.40$ MHz	h_{FE} $I_C = 10$ A, $V_{CE} = 2.0$ V	V_{CES}	**30 V**	**45 V**	**60 V**	**75 V**
			V_{CB}	**40 V**	**60 V**	**80 V**	**100 V**
		10-30		2N1549	2N1550	2N1551	2N1552
 TO-41③ (Case 4-04)	**HIGH-GAIN SWITCH AND AMPLIFIER** $P_D = 106$ W $f_T = 0.35$ MHz	h_{FE} $I_C = 10$ A, $V_{CE} = 2.0$ V	V_{CES}	**30 V**	**45 V**	**60 V**	**75 V**
			V_{CB}	**40 V**	**60 V**	**80 V**	**100 V**
		30-60		2N1553	2N1554	2N1555	2N1556
		50-100		2N1557	2N1558	2N1559	2N1560

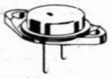
25-AMP

 TO-3 (Case 11A)  TO-41③ (Case 4-04)	**HIGH-GAIN SWITCH AND AMPLIFIER** $P_D = 106$ W $f_T = 0.35$ MHz	h_{FE} $I_C = 25$ A, $V_{CE} = 1.0$ V	V_{CES}	**35 V**	**60 V**	**75 V**
			V_{CB}	**50 V**	**80 V**	**100 V**
		15-65		2N1162	2N1164	2N1166
				2N1163	2N1165	2N1167

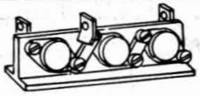
30-AMP

 TO-36 (Case 5)	**MEDIUM-CURRENT SWITCH** $P_D = 170$ W $f_T = 0.25$ MHz	h_{FE} $I_C = 5.0$ A, $V_{CE} = 2.0$ V ($h_{FE} = 15$ min @ $I_C = 25$ A)	V_{CES}	**45 V**	**60 V**	**75 V**	**90 V**
			V_{CB}	**45 V**	**60 V**	**75 V**	**90 V**
		50-100		2N2152	2N2153	2N2154	2N2155
		80-160		2N2156	2N2157	2N2158	2N2159

60-AMP

 CASE 7	**HIGH-CURRENT — HIGH-GAIN SWITCH** $P_D = 170$ W $f_T = 0.25$ MHz	h_{FE} $I_C = 15$ A, $V_{CE} = 2.0$ V ($h_{FE} = 12$ min @ $I_C = 50$ A)	V_{CES}	**45 V**	**60 V**	**75 V**	**90 V**
			V_{CB}	**45 V**	**60 V**	**75 V**	**90 V**
		30-60		MP500	MP501	MP502	MP503
		50-100		MP504	MP505	MP506	MP507
	HIGH-CURRENT — HIGH-GAIN SWITCH $P_D = 170$ W $f_T = 0.45$ MHz	h_{FE} $I_C = 15$ A, $V_{CE} = 2.0$ V ($h_{FE} = 15$ min @ $I_C = 60$ A)	V_{CES}	**45 V**	**60 V**	**75 V**	
			V_{CB}	**45 V**	**60 V**	**75 V**	
		60-120		2N4048	2N4049	2N4050	
		80-180		2N4051	2N4052	2N4053	
 TO-3 (Case 3A) TO-41② (Case 161)	**ECONOMY LINE HIGH-CURRENT — HIGH-GAIN SWITCH** $P_D = 170$ W $f_T = 0.4$ MHz	h_{FE} $I_C = 15$ A, $V_{CE} = 2.0$ V ($h_{FE} = 15$ min @ $I_C = 60$ A)	V_{CES}	**30 V**	**45 V**	**60 V**	**75 V**
			V_{CB}	**30 V**	**45 V**	**60 V**	**75 V**
		60-120		2N4276	2N4278	2N4280	2N4282
		80-180		2N4277	2N4279	2N4281	2N4283

150-AMP

 CASE 118	**"POWER-PAC" ASSEMBLY MEDIUM VOLTAGE SWITCH** $P_D = 250$ W $\theta_{JC} = 0.33$°C/W	h_{FE} $I_C = 150$ A, $V_{CE} = 2.0$ V	V_{CES}	**60 V**	**75 V**
			V_{CEO}	**45 V**	**60 V**
		15 min		MP801①	MP800①

GERMANIUM POWER TRANSISTOR SELECTOR GUIDE (continued)

DIFFUSED BASE TRANSISTORS

features graded-base profile for:

- **Low emitter-base resistance and high-temperature stability**
- **High breakdown voltage capability**
- **Higher frequency response, faster switching speeds**

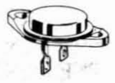
10-AMP

TO-3 (Case 11A) TO-41 ② (Case 4-04)	**HIGH-VOLTAGE SWITCH** **P_D = 85 W** **f_T = 0.7 MHz**	h_{FE} I_C = 3.0 A, V_{CE} = 2.0 V	V_{CEO}	**80 V**	**120 V**		**160 V**
			V_{CB}	**80 V**	**120 V**		**160 V**
		20-50		2N2526	2N2527		2N2528
TO-3 (Case 11) TO-41② (Case 4-04)	**HIGH-VOLTAGE MEDIUM-SPEED SWITCH** **P_D = 56 W** **f_T = 5.5 MHz**	h_{FE}	†V_{CES} V_{CEO}	**200 V†**	**150 V**	**320 V†**	**200 V**
			V_{CB}		**250 V**		**325 V**
		20-60 I_C = 5.0 A, V_{CE} = 2.0 V			2N5324		2N5325
		15 min I_C = 2.25 A, V_{CE} = 4.0 V		④ MP3730			
		15 min I_C = 6.0 A, V_{CE} = 3.0 V				④ MP3731	

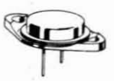
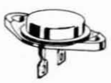
20-AMP

TO-3 (Case 11A) TO-41 (Case 4-04)	**HIGH-SPEED HIGH-VOLTAGE SWITCH** **P_D = 85 W** **f_T = 20 MHz**	h_{FE} I_C = 10 A, V_{CE} = 2.0 V	V_{CEO}	**50 V**	**50 V**	**75 V**	**75 V**	**100 V**	**100 V**
			V_{CB}	**80 V**	**100 V**	**120 V**	**140 V**	**140 V**	**160 V**
		25-100		② 2N2832	④ MP1612	② 2N2833	④ MP1612A	② 2N2834	④ MP1612B

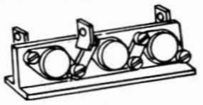
25-AMP

TO-3 (Case 11A)	**MEDIUM-CURRENT "ADE"⑤ SWITCH HIGH-GAIN** **P_D = 106 W** **f_T = 0.7 MHz**	h_{FE} I_C = 5.0 A, V_{CE} = 2.0 V	V_{CEO}	**30 V**	**50 V**	**60 V**	**70 V**	**80 V**
			V_{CB}	**40 V**	**75 V*** **80 V**	**75 V**	**90 V*** **120 V**	**90 V**
		20-60		2N2288	2N2289		2N2290	
		50-120		2N2291	2N2292		2N2293	
		50 min			④ MP600*	④ MP601	④ MP602*	④ MP603
 TO-41② (Case 4-04)	**MEDIUM-CURRENT "ADE"⑤ SWITCH HIGH-VOLTAGE** **P_D = 106 W** **f_T = 0.4 MHz**	h_{FE} I_C = 8.0 A, V_{CE} = 2.0 V	V_{CEO}	**30 V**	**60 V**	**80 V**	**100 V**	**120 V**
			V_{CEX}	**60 V**	**80 V**	**100 V**	**120 V**	**140 V**
		25-100						2N5155
		25 min		④ MP2000A	④ MP2100A	④ MP2200A	④ MP2300A	④ MP2400A

60-AMP

 TO-3 (Case 3A)  TO-41② (Case 161)	**HIGH-CURRENT — HIGH-VOLTAGE "ADE"⑤ SWITCH** **P_D = 120 W** **f_T = 1.0 MHz**	h_{FE} I_C = 25 A, V_{CE} = 2.0 V	V_{CEO}	**60 V**	**90 V**	**120 V**
			V_{CB}	**80 V**	**110 V**	**140 V**
		20-60 (h_{FE} = 10 min @ I_C = 60 A)		2N5435	2N5436	2N5437
		40-120 (h_{FE} = 15 min @ I_C = 60 A)		2N5438	2N5439	2N5440

150-AMP

 CASE 118	**"POWER-PAC" ASSEMBLY HIGH VOLTAGE SWITCH** **P_D = 250 W** **θ_{JC} = 0.33°C/W**	h_{FE} I_C = 150 A, V_{CE} = 2.0 V	V_{CB}	**80 V**	**110 V**	**140 V**
			V_{CEO}	**60 V**	**90 V**	**120 V**
		20 min		MP900	MP901	MP902

SILICON SMALL-SIGNAL HERMETIC ANNULAR TRANSISTOR SELECTOR GUIDE

This Selector Guide covers Motorola's broad line of silicon hermetic Annular transistors. It includes over 160 proven transistors suitable for all low-level switching and amplifying applications: transistors with PNP and NPN polarities, breakdown voltages to 400 V, capacitances below 3.0 pF, and collector current ratings to 3.0 amperes. For maximum convenience, transistors are available in all popular metal cases, and in ceramic and metal packages containing two and four transistors. Many of the transistors are high-reliability devices that meet the requirements of military and aerospace specifications.

The major part of this guide is composed of selection tables. These tables list silicon small-signal hermetic annular transistors (single and multiple devices) in an order that makes it easy for the user to find a device that satisfies his requirements.

INDEX TO SELECTOR GUIDE

Quick Selection Guide
High-Reliability Transistors
Index

Selection Tables
Table 1 General-Purpose Switching and Amplifier Transistors
Table 2 Current-Mode Switching Transistors
Table 3 High-Speed Saturated Switching Transistors
Table 4 Chopper Transistors
Table 5 Low-Noise Amplifier Transistors
Table 6 High-Voltage Transistors
Table 7 Matched Dual Transistors
Table 8 Darlington Amplifier Transistors
Table 9 Complementary Transistor Pairs
Table 10 Dual Transistors
Table 11 Quad Transistors

QUICK SELECTION GUIDE

**This table lists
the best all-around choices for given applications:**

General-Purpose Switching and Amplifier Transistors	NPN – 2N2222A PNP – 2N2907A
High-Speed Saturated Switching Transistors	NPN – 2N2369A PNP – 2N3546
High-Voltage, High-Speed Core-Driver Transistors	NPN – 2N3735 PNP – 2N3468
Current-Mode Switching Transistors	NPN – 2N3960 PNP – 2N4261
Low-Level Chopper Transistors	NPN – 2N2331 PNP – 2N5230
Low-Noise Amplifier Transistors	NPN – MM2484 PNP – 2N3799
High-Voltage Amplifier Transistors	NPN – 2N4927 PNP – 2N5357
Matched Dual Transistors	NPN – 2N2060A PNP – 2N3726
Dual Transistors (Un-matched)	NPN – MD2219A PNP – MD2905A
Darlington Amplifier Transistors	NPN – 2N999 PNP – 2N4974
Complementary Transistor Pairs	2N3838
Quad Transistors	NPN – MQ2219A PNP – MQ2905A

SILICON SMALL-SIGNAL HERMETIC ANNULAR TRANSISTOR SELECTOR GUIDE (continued)

HIGH RELIABILITY TRANSISTORS

Motorola produces many semiconductors that meet military specification MIL-S-19500. These devices have proven themselves by their reliability and stability in the most demanding defense and aerospace applications. All of the following types are available.

JAN Transistors (TX version)

NPN	PNP
JAN TX2N708	JAN TX2N2904
JAN TX2N718A	JAN TX2N2904A
JAN TX2N914	JAN TX2N2905
JAN TX2N918	JAN TX2N2905A
JAN TX2N929	JAN TX2N2906
JAN TX2N930	JAN TX2N2906A
JAN TX2N2060*	JAN TX2N2907
JAN TX2N2218	JAN TX2N2907A
JAN TX2N2218A	JAN TX2N3250A
JAN TX2N2219	JAN TX2N3251A
JAN TX2N2219A	JAN TX2N3485A
JAN TX2N2221	JAN TX2N3486A
JAN TX2N2221A	JAN TX2N3634
JAN TX2N2222	JAN TX2N3635
JAN TX2N2222A	JAN TX2N3636
JAN TX2N2369A	JAN TX2N3637
JAN TX2N2481	
JAN TX2N2857	

*Dual Transistor

JAN Transistors (MIL-STD-701 types)

NPN		PNP
JAN 2N708	JAN 2N2222	JAN 2N2904
JAN 2N718A	JAN2N2222A	JAN 2N2904A
JAN 2N869A	JAN 2N2369A	JAN 2N2905
JAN 2N914	JAN 2N2481	JAN 2N2905A
JAN 2N916	JAN 2N2857	JAN 2N2906
JAN 2N918	JAN 2N3253	JAN 2N2906A
JAN 2N930	JAN 2N3444	JAN 2N2907
JAN 2N1613	JAN 2N3498	JAN 2N2907A
JAN 2N2060*	JAN 2N3499	JAN 2N3251A
JAN 2N2218	JAN 2N3500	JAN 2N3467
JAN 2N2218A	JAN 2N3501	JAN 2N3468
JAN 2N2219	JAN 2N3506	JAN 2N3634
JAN 2N2219A	JAN 2N3507	JAN 2N3635
JAN 2N2221		JAN 2N3636
JAN 2N2221A		JAN 2N3637
		JAN 2N3810*
		JAN 2N3811*

INDEX TO SILICON SMALL-SIGNAL HERMETIC ANNULAR TRANSISTORS

The following table lists the transistors with reference to table numbers where the devices are characterized.

Device Type	Table
2N720A	1
2N869A	3
2N930A	5
2N998	8
2N999	8
2N2060A	7
2N2218A	1
2N2219A	1
2N2221A	1
2N2222A	1
2N2330	4
2N2331	4
2N2369A	3
2N2501	3
2N2604	5
2N2605	5
2N2723	8
2N2724	8
2N2725	8
2N2785	8
2N2848	3
2N2896	1
2N2904A	1
2N2905A	1
2N2906A	1
2N2907A	1
2N2913	10
2N2914	10
2N2919	7
2N2920	7
2N2944	4
2N2945	4
2N2945A	4

Device Type	Table
2N2946	4
2N2946A	4
2N2972	10
2N2973	10
2N2975	7
2N2979	7
2N3013	3
2N3014	3
2N3019	1
2N3020	1
2N3043	7
2N3053	1
2N3114	6
2N3250A	1
2N3251A	1
2N3303	3
2N3444	3
2N3467	3
2N3468	3
2N3485A	1
2N3486A	1
2N3494	1
2N3495	6
2N3496	1
2N3497	6
2N3498	6
2N3499	6
2N3500	6
2N3501	6
2N3507	3
2N3509	3
2N3518	7
2N3546	3

Device Type	Table
2N3635	6
2N3636	6
2N3637	6
2N3648	3
2N3712	6
2N3722	3
2N3723	3
2N3724	8
2N3725	3
2N3726	7
2N3734	3
2N3735	3
2N3742	6
2N3743	6
2N3762	3
2N3763	3
2N3764	3
2N3765	3
2N3798	5
2N3799	5
2N3810A	7
2N3811A	7
2N3816A	7
2N3817A	7
2N3838	9
2N3946	1
2N3947	1
2N3960	2
2N4014	3
2N4261	2
2N4404	1
2N4405	1
2N4406	1

Device Type	Table
2N4407	1
2N4854	9
2N4890	1
2N4926	6
2N4927	6
2N4929	6
2N4930	6
2N4931	6
2N4974	8
2N4975	8
2N5146	11
2N5229	4
2N5230	4
2N5231	4
2N5357	6
2N5581	1
2N5582	1
2N5583	2
MD708	7
MD918	10
MD918A	7
MD918AF	7
MD986	9
MD986F	9
MD2218A	10
MD2219A	10
MD2369	10
MD2369A	7
MD2904A	10
MD2905A	10
MD3250	10
MD3251	10
MD3251A	7

Device Type	Table
MD3467	10
MD3725	10
MD4957	10
MD5000	10
MD5000A	7
MD6002	9
MD6100	9
MD7002	10
MD7003	10
MD7021	9
MD8003	10
MM1605	2
MM1748A	3
MM2484	5
MM3005	1
MM3006	1
MM3007	6
MM4545	6
MM4546	6
MM4547	6
MQ930	11
MQ2218	11
MQ2219A	11
MQ2484	11
MQ2904	11
MQ2905A	11
MQ3251	11
MQ3467	11
MQ3725	11
MQ3762	11
MQ3799	11
MQ3799A	11

SILICON SMALL-SIGNAL HERMETIC ANNULAR TRANSISTOR SELECTOR GUIDE (continued)

TO-5
Case 31

TO-18
Case 22

TO-39
Case 79

TABLE 1 – GENERAL-PURPOSE SWITCHING AND AMPLIFIER TRANSISTORS

The transistors in this table are characterized for use as medium-voltage, medium-speed switches and general-purpose, small-signal amplifiers at dc and low to medium frequencies. The transistors are listed first in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing maximum collector current (I_C max) and dc current gain (h_{FE}). High voltage transistors (BV_{CEO} over 90 V) are listed in Table 6.

Type	BV_{CEO} Volts min	I_C mA max	h_{FE} & min/max	$V_{CE(sat)}$ @ Volts max	I_C mA	f_T MHz min	t_{on} ns max	t_{off} ns max	Package
NPN									
2N2896	90	1000	60/120	0.6	150	120	–	–	TO-18
2N3019	80	1000	100/300	0.2	150	100	–	–	TO-5
MM3006	80	1000	50/250	0.4	200	50	120	500	TO-39
2N3020	80	1000	40/120	0.2	150	80	–	–	TO-5
2N720A	80	1000	40/120	5.0	150	50	–	–	TO-18
MM3005	60	1000	50/250	0.35	150	50	120	500	TO-39
2N2219A 2N2222A 2N5582	40	800	100/300	0.3	150	300	35	250	TO-5 TO-18 TO-46
2N2218A 2N2221A 2N5581	40	800	40/120	0.3	150	250	35	250	TO-5 TO-18 TO-46
2N3053	40	700	50/250	1.4	150	100	–	–	TO-5
2N3947	40	200	100/300	0.2	10	300	70	400	TO-18
2N3946	40	200	50/150	0.2	10	250	70	375	TO-18
PNP									
2N4407	80	2000	75/225	0.2	150	150	75	225	TO-39
2N4406	80	2000	25/100	0.2	150	150	75	225	TO-39
2N4405	80	1000	100/300	0.2	150	200	40	200	TO-5
2N4404	80	1000	40/120	0.2	150	200	40	200	TO-5
2N3494	80	100	40/–	0.3	10	200	300	450	TO-5
2N3496	80	100	40/–	0.3	10	200	300	450	TO-18
2N2905A 2N2907A 2N3486A	60	600	100/300	0.4	150	200	45	100	TO-5 TO-18 TO-46
2N2904A 2N2906A 2N3485A	60	600	40/120	0.4	150	200	45	100	TO-5 TO-18 TO-46
2N3251A	60	200	100/300	0.25	10	300	70	200	TO-18
2N3250A	60	200	50/150	0.25	10	250	70	175	TO-18
2N4890	40	700	50/250	1.4	150	100	–	–	TO-5

TO-46
Case 26

TO-72
Case 20

TABLE 2 – CURRENT-MODE SWITCHING TRANSISTORS

The transistors in this table are current-mode switches for use in emitter-coupled (nonsaturated) logic circuitry. The transistors are listed first in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing maximum collector current (I_C max) and dc current gain (h_{FE}).

Type	BV_{CEO} Volts min	I_C mA max	h_{FE} & min/max	I_C mA	C_{ob} pF max	f_T MHz typ	t_{on} ns typ	t_{off} ns typ	Package
NPN									
2N3960	12	50	40/200	10	2.5	2000	5.0	5.0	TO-18
MM1605	10	300	25/200	25	1.0	2500	5.0	5.0	TO-72
PNP									
2N5583	30	500	25/100	100	5.0	1600	0.8	4.0	TO-39
2N4261	15	30	30/150	10	2.5	3000	0.5	2.0	TO-72

SILICON SMALL-SIGNAL HERMETIC ANNULAR TRANSISTOR SELECTOR GUIDE (continued)

TABLE 3 – HIGH-SPEED SATURATED SWITCHING TRANSISTORS

The transistors are optimized for high-speed saturated switching. They are heavily gold doped to provide very short switching times and low capacitances. These devices are listed first in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing maximum collector current (I_C max) and dc current gain (h_{FE}). High voltage transistors (BV_{CEO} over 90 V) are listed in Table 6.

Type	BV_{CEO} Volts min	I_C mA max	h_{FE} min/max	& $V_{CE(sat)}$ Volts max	@ I_C mA	f_T MHz min	t_{on} ns max	t_{off} ns max	Package
NPN									
2N3723	80	800	40/150	0.28	100	300	70	130	TO-5
2N3722	60	800	40/150	0.25	100	300	50	100	TO-5
2N3507	50	3000	30/150	1.0	1500	60	45	90	TO-5
2N3735	50	1500	20/80	0.9	1000	250	48	60	TO-5
2N3725	50	1000	35/–	0.52	500	300	35	60	TO-5
2N4014									TO-18
2N3444	50	1000	20/60	0.6	500	175	50	70	TO-5
2N3734	30	1500	30/120	0.9	1000	250	48	60	TO-5
2N2848	30	800	30/–	1.0	500	250	40	40	TO-5
2N3509	20	500	100/300	0.25	10	500	12	18	TO-46
2N2501	20	500	50/150	0.2	10	350	20	25	TO-18
2N3014	20	500	30/120	0.18	30	350	16	25	TO-52
2N2369A	15	500	40/120	0.2	10	500	12	18	TO-18
2N3013	15	500	30/120	0.18	30	350	15	25	TO-52
2N3648	15	500	30/120	0.4	150	450	16	18	TO-46
2N3303	12	1000	30/120	0.33	300	450	15	25	Case 94
MM1748A	6.0	100	30/90	0.3	10	800	15	15	TO-52
PNP									
2N3763	60	1500	20/80	0.9	1000	150	43	105	TO-5
2N3765									TO-46
2N3468	50	1000	25/75	0.6	500	150	40	90	TO-5
2N3762	40	1500	30/120	0.9	1000	180	43	105	TO-46
2N3764									TO-5
2N3467	40	1000	40/120	0.5	500	175	40	90	TO-5
2N869A	18	200	40/120	0.15	10	400	50	80	TO-18
2N3546	12	200	30/120	0.15	10	700	40	30	TO-18

TO-5
Case 31

TO-18
Case 22

TO-46
Case 26

TABLE 4 – CHOPPER TRANSISTORS

Transistors designed for chopper applications have low offset currents, low "on" voltage, high "off" resistance, and fast switching times. These devices are listed first in decreasing order of breakdown voltage (BV_{CEO}), then in order of decreasing maximum collector current (I_C max) and dc current gain (h_{FE}).

Type	BV_{ECO} Volts min	I_C mA max	h_{FE} min	BV_{EBO} Volts min	h_{FE} (inv)	$V_{EC(off)}$ mVdc max	f_T MHz typ	$r_{ec(on)}$ Ohms max	Package
NPN									
2N2330	20	500	50	7.0	–	3.0	250	–	TO-5
2N2331	20	500	50	7.0	–	3.0	250	–	TO-18
PNP									
2N2946A	35	100	50	40	20	0.8	14	8.0	TO-46
2N2946	35	100	30	40	3.0	0.8	14	45	TO-46
2N5231	30	100	50	50	15	0.8	14	10	TO-46
2N2945A	20	100	70	25	30	0.5	16	6.0	TO-46
2N5230	20	100	50	30	15	0.5	14	8.0	TO-46
2N2945	20	100	40	25	4.0	0.5	14	35	TO-46
2N2944	10	100	80	15	6.0	0.3	16	20	TO-46
2N5229	10	100	50	15	15	0.5	14	6.0	TO-46

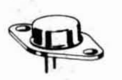
TO-52
Case 27

Case 94

SILICON SMALL-SIGNAL HERMETIC ANNULAR TRANSISTOR SELECTOR GUIDE (continued)

TO-5
Case 31

TO-18
Case 22



TO-37
Case 39

TO-39
Case 79

TO-46
Case 26

TABLE 5 – LOW-NOISE AMPLIFIER TRANSISTORS

These transistors are characterized for low-noise amplification at low frequencies. The transistors are listed first in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing maximum collector current (I_C max) and dc current gain (h_{FE}).

Type	BV_{CEO} Volts min	I_C mA max	h_{FE} min/max	& I_C mA	C_{ob} pF max	NF dB max	f_T MHz typ	Package
NPN								
MM2484	60	50	100/500	0.01	6.0	3.0	70	TO-18
2N930A	45	30	100/300	0.01	6.0	3.0	70	TO-18
PNP								
2N3799	60	50	300/900	0.5	4.0	2.5	150	TO-18
2N3798	60	50	150/450	0.5	4.0	3.5	150	TO-18
2N2605	45	30	100/300	0.01	6.0	3.0	60	TO-46
2N2604	45	30	40/120	0.01	6.0	4.0	60	TO-46

TABLE 6 – HIGH-VOLTAGE TRANSISTORS

These high-voltage transistors are designed for general-purpose amplifiers, dc to ac converters, relay drivers, motor controls and for other applications requiring high-voltage direct line operation capability. These transistors are listed first in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing maximum collector current (I_C max) and dc current gain (h_{FE}).

Type	BV_{CEO} Volts min	I_C mA max	h_{FE} min/max	& $V_{CE(sat)}$ Volts max	& $V_{BE(sat)}$ Volts max	@ I_C mA	f_T MHz typ	Package
NPN								
2N3742	300	50	20/200	5.0	1.2	30	60	TO-5
2N4927	250	50	20/200	2.0	1.5	30	80	TO-5
2N4926	200	50	20/200	2.0	1.5	30	80	TO-5
2N3501	150	300	100/300	0.4	1.2	150	180	TO-5
2N3500	150	300	40/120	0.4	1.2	150	180	TO-5
2N3712	150	200	30/150	2.0	0.9	30	100	TO-5
2N3114	150	200	30/120	1.0	0.9	30	60	TO-5
MM3007	100	1000	30/250	0.45	–	150	120	TO-39
2N3499	100	500	100/300	0.4	1.2	150	180	TO-5
2N3498	100	500	40/120	0.4	1.2	150	180	TO-5
PNP								
MM4547	400	2000	20/–	1.5	–	500	35	TO-37
2N5357	300	2500	25/100	1.0	1.3	500	55	TO-37
MM4546	300	2000	20/–	1.2	–	500	45	TO-37
2N3743	300	50	25/250	8.0	1.2	30	40	TO-5
2N4931	250	500	20/200	5.0	1.0	10	40	TO-39
MM4545	200	2000	20/–	1.0	–	500	45	TO-37
2N4930	200	500	20/200	5.0	1.0	10	40	TO-39
2N3637	175	1000	100/300	0.5	0.9	50	230	TO-5
2N3636	175	1000	50/150	0.5	0.9	50	180	TO-5
2N4929	150	500	25/200	0.5	1.0	10	100	TO-39
2N3635	140	1000	100/300	0.5	–	–	200	TO-5
2N3497	120	100	40/–	0.35	0.9	10	180	TO-18
2N3495	120	100	40/–	0.35	0.9	10	180	TO-5

SILICON SMALL-SIGNAL HERMETIC ANNULAR TRANSISTOR SELECTOR GUIDE (continued)

TABLE 7 – MATCHED DUAL TRANSISTORS

Matched dual transistors find their widest application as differential amplifiers, where they maintain tight tracking with widely varying temperatures. The transistors are listed first in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing maximum collector current (I_C max) and dc current gain (h_{FE}).

Type	BV_{CEO} Volts min	I_C mA max	h_{FE} & min/max	$\frac{h_{FE1}}{h_{FE2}}$ & min	$V_{BE1} - V_{BE2}$ mV max	@ I_C mA	f_T MHz typ	Package
NPN								
2N3518	60	500	50/200	0.9	3.0	1.0	200	TO-89
2N2060A	60	500	30/90	0.9	3.0	0.1	200	Case 32C
2N2920	60	30	300/–	0.9	3.0	1.0	70	Case 32C
2N2979	60	30	150/600	0.9	3.0	0.01	70	Case 32C
2N2919	60	30	150/–	0.9	3.0	1.0	200	Case 32C
2N2975	45	30	150/600	0.9	3.0	0.01	70	TO-71
2N3043	45	30	100/300	0.9	5.0	0.01	70	TO-89
MD2369A	15	500	40/140	0.9	5.0	3.0	600	Case 32C
MD708A	15	200	40/200	0.9	5.0	10	450	Case 32C
MD918A MD918AF	15	50	50/–	0.9	5.0	1.0	700	Case 32C TO-89
PNP								
2N3811A 2N3817A	60	50	300/900	0.95	1.5	0.1	120	Case 32C TO-89
2N3810A 2N3816A	60	50	150/450	0.95	1.5	0.1	120	Case 32C TO-89
2N3726	45	300	120/–	0.9	5.0	0.1	200	Case 32C
MD3251A	40	50	100/300	0.9	3.0	0.1	375	Case 32C
MD5000A	15	50	20/–	0.9	5.0	4.0	700	Case 32C

Case 32C also listed as RO131C

TO-12
Case 34A

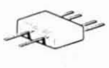
TO-71
Case 35

TABLE 8 – DARLINGTON AMPLIFIER TRANSISTORS

Darlington amplifiers are compound-connected dual transistors used in applications requiring very high current gain and input impedance. The transistors are listed first in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing maximum collector current (I_C max) and dc current gain (h_{FE}).

Type	BV_{CEO} Volts min	I_C mA max	h_{FE} & min/max	$V_{CE(sat)}$ @ Volts max	I_C mA	C_{ob} pF max	f_T MHz typ	Package
NPN								
2N999	60	500	7000/70000	–	100	20	200	TO-72
2N998	60	500	1600/8000	–	10	30	200	TO-72
2N2724	60	40	7000/50000	1.0	10	10	150	TO-72
2N2723	60	40	2000/10000	1.0	10	10	150	TO-72
2N2725	45	30	2000/10000	1.0	0.1	10	150	TO-72
2N2785	40	200	1200/–	1.0	10	30	150	TO-72
PNP								
2N4974	30	1000	15000/–	2.0	500	8.0	200	TO-12
2N4975	30	1000	5000/–	2.0	500	8.0	200	TO-12

TO-72
Case 20



TO-89
Case 33

TABLE 9 – COMPLEMENTARY TRANSISTOR PAIRS

Each of these space-saving complementary transistor pair contains one NPN and one PNP transistor with similar specifications. These devices are listed first in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing maximum collector current (I_C max) and dc current gain (h_{FE}).

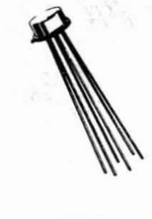
Type	BV_{CEO} Volts min	I_C mA max	h_{FE} & min/max	$V_{CE(sat)}$ & Volts max	I_C mA	t_{off} ns	f_T MHz typ	Package
MD6100	45	50	150/–	0.25	1.0	–	60	Case 32C
2N3838 2N4854	40	600	100/300	0.4	150	250	250	TO-89 Case 32C
MD7021	40	30	50/–	0.35	10	–	230	Case 32C
MD6002	30	300	100/300	0.4	150	250	250	Case 32C
MD986 MD986F	15	200	25/–	0.3	10	–	230	Case 32C TO-89

Case 32C also listed as RO131C

Case 32C

TABLE 10 – DUAL TRANSISTORS

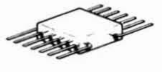
Dual transistors contain two similar general-purpose switching and amplifying transistors. They are space-saving direct replacements for two single devices. These devices are listed first in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing maximum collector current (I_C max) and dc current gain (h_{FE}).



TO-71
Case 35

Type	BV_{CEO} Volts min	I_C mA max	h_{FE} & min/max	$V_{CE(sat)}$ @ Volts max	I_C mA	C_{ob} pF max	f_T MHz typ	Package
NPN								
MD8003	60	30	100/–	–	1.0	3.0	70	Case 32C
2N2914	45	30	300/–	0.35	1.0	6.0	70	Case 32C
2N2973								TO-71
2N2913	45	30	150/–	0.35	1.0	6.0	70	Case 32C
2N2972								TO-71
MD3725	40	1000	30/–	0.52	500	10	300	Case 32C
MD2219A	40	600	100/300	0.3	150	8.0	260	Case 32C
MD2218A	40	600	40/120	0.4	150	8.0	240	Case 32C
MD7002	40	30	40/–	–	0.1	6.0	220	Case 32C
MD2369	15	500	40/140	0.25	10	4.0	600	Case 32C
MD708	15	200	40/200	0.2	10	5.0	450	Case 32C
MD918	15	50	50/–	0.2	10	1.7	700	Case 32C
PNP								
MD2905A	60	600	100/300	0.4	150	8.0	250	Case 32C
MD2904A	60	600	40/120	0.4	150	8.0	250	Case 32C
MD3251	40	50	100/300	–	0.1	6.0	275	Case 32C
MD3250	40	50	50/150	–	0.1	6.0	225	Case 32C
MD7003	40	30	40/–	–	0.01	6.0	230	Case 32C
MD3467	40	1000	20/–	0.5	500	20	200	Case 32C
MD4957	30	30	20/150	–	2.0	0.8	1200	Case 32C
MD5000	15	50	20/–	0.4	10	1.7	650	Case 32C

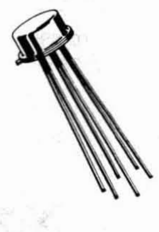
Case 32C also listed as RO131C



TO-86
Case 83

TABLE 11 – QUAD TRANSISTORS

Each quad transistor contains four similar transistors that can be used to reduce space requirements. These transistors are listed first in order of decreasing breakdown voltage (BV_{CEO}), then in order of decreasing maximum collector current (I_C max) and dc current gain (h_{FE}).



Case 32C

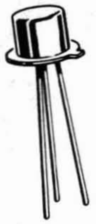
Type	BV_{CEO} Volts min	I_C mA max	h_{FE} & min/max	$V_{CE(sat)}$ @ Volts max	I_C mA	t_{on} ns max	t_{off} ns max	f_T MHz typ	Package
NPN									
MQ2484	60	30	250/–	0.35	1.0	–	–	70	TO-86
MQ930	45	30	150/–	0.35	1.0	–	–	70	TO-86
MQ3725	40	1000	30/–	0.52	500	45	75	300	TO-86
MQ2219A	40	600	100/300	0.3	150	60	350	270	TO-86
MQ2218	30	600	40/120	0.4	150	60	350	220	TO-86
PNP									
MQ2905A	60	600	100/300	0.4	150	45	130	225	TO-86
MQ3799	60	50	300/900	0.2	0.1	–	–	130	TO-86
MQ3799A*	60	50	300/900	0.2	0.1	–	–	130	TO-86
MQ3762 2N5146	40	1500	20/–	1.0	1000	40	120	200	TO-86
MQ3467	40	1000	20/–	0.5	500	40	120	200	TO-86
MQ2904	40	600	40/120	0.4	150	45	130	225	TO-86
MQ3251	40	50	100/300	0.25	10	–	–	350	TO-86

*Matched Quad

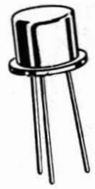
FIELD-EFFECT TRANSISTOR SELECTOR GUIDE

DEVICE DIMENSIONS

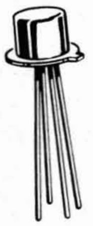
All dimensions are in inches.



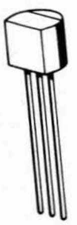
CASE 22
(TO-18)



CASE 79
(TO-39)



CASE 20
(TO-72)



CASE 29
(TO-92)

For lead configurations see Semiconductor Data Book

Motorola offers a line of field-effect transistors encompassing the latest technology and covering the entire gamut of potential applications. Included is a wide variety of junction FETs and MOSFETs, with N- or P-channel polarity. These FETs include devices optimized for operation from dc to UHF in switching and amplifying applications.

Moreover, an exclusive silicon-nitride passivation process now being employed on all Motorola MOSFETs has greatly improved MOSFET threshold stability with aging and temperature change. This process also reduces susceptibility to damage from static-charge buildup during handling because of its increased voltage breakdown capability. All Motorola single-gate MOSFETs have transient gate breakdown voltages of greater than ±150 Vdc peak (typical).

The selection tables in this guide are designed to permit a rapid selection of specific field-effect transistors for a variety of applications.

Five tables cover the major application categories:

RF Amplifiers and Mixers	Table 1
General-Purpose Amplifiers	Table 2
General-Purpose Switches	Table 3
Choppers	Table 4
Matched Pairs	Table 5

The information in the tables is necessarily brief to simplify selection. Complete specifications for these devices are given in the data sheet section of the Motorola Semiconductor Data Book and in individual data sheets.

INDEX to MOTOROLA FIELD-EFFECT TRANSISTORS

The following table lists the Motorola preferred field-effect transistors with reference to selection tables. Package identification is included in this table only.

Device Type	Table	Device Type	Table	Device Type	Table	Device Type	Table
2N3796†	2	2N5270	2	2N5557	2	MFE2097#	2
2N3797†	2	2N5358	2	2N5558	2	MFE2098#	2
2N3821	2	2N5359	2	3N124	2,3	MFE2133#	4
2N3822	2	2N5360	2	3N125	2,3	MFE3001	2
2N3823	1	2N5361	2	3N126	2,3	MFE3002	4
2N3824	3	2N5362	2	3N140	1	MFE3003	4
2N4091†	4	2N5363	2	3N155	3,4	MFE3004	1
2N4092†	4	2N5364	2	3N155A	3,4	MFE3005	1
2N4093†	4	2N5457‡	2	3N156	3,4	MFE3006	1
2N4220	2,3	2N5458‡	2	3N156A	3,4	MFE3007	1
2N4220A	2,3	2N5459‡	2	3N157	2	MFE4007	2
2N4221	2,3	2N5460‡	2	3N157A	2	MFE4008	2
2N4221A	2,3	2N5461‡	2	3N158	2	MFE4009	2
2N4222	2,3	2N5462‡	2	3N158A	2	MFE4010	2
2N4222A	2,3	2N5463‡	2	MFE2000	1	MFE4011	2
2N4223	1	2N5464‡	2	MFE2001	1	MFE4012	2
2N4224	1	2N5465‡	2	MFE2004†	4	MMF1	5
2N4351	3	2N5471	2	MFE2005†	4	MMF2	5
2N4352	3	2N5472	2	MFE2006†	4	MMF3	5
2N4391†	4	2N5473	2	MFE2007†	4	MMF4	5
2N4392†	4	2N5474	2	MFE2008†	4	MMF5	5
2N4393†	4	2N5475	2	MFE2009†	4	MMF6	5
2N4416	1	2N5476	2	MFE2010†	4	MPF102‡	1,2
2N5265	2	2N5484‡	1,2	MFE2011†	4	MPF108‡	1
2N5266	2	2N5485‡	1,2	MFE2012†	4	MPF109‡	2
2N5267	2	2N5486‡	1,2	MFE2093	2,3	MPF161‡	2
2N5268	2	2N5555‡	3,4	MFE2094	2,3		
2N5269	2	2N5556	2	MFE2095	2,3		

All TO-72 packages, except: †TO-18, ‡TO-92, and #TO-39.

TABLE 1 RF AMPLIFIERS AND MIXERS

High performance single and dual gate devices specifically designed for RF applications at operating frequencies up to 400 MHz. The transistors are listed first in order of decreasing specified test frequency; then in order of decreasing power gain (G_{ps}) and noise figure (NF).

Type Number	Test Frequency MHz	G_{ps}* dB min	NF dB max	Comments
N-CHANNEL J FETs (Type A)				
2N4416	400	10	4.0	
2N5486	400	10	4.0	I_{DSS} = 4.0 to 10 mAdc
2N5485	400	10	4.0	I_{DSS} = 8.0 to 20 mAdc
MFE2000	400	10	4.0	I_{DSS} = 4.0 to 10 mAdc
MFE2001	400	10	4.0	I_{DSS} = 8.0 to 20 mAdc
2N3823	200	–	2.5	
2N4223	200	10	5.0	I_{GSS} = 0.25 nAdc (max)
2N4224	200	–	–	I_{GSS} = 0.50 nAdc (max)
2N5484	100	16	3.0	
MPF102	100	–	–	
MPF108	100	–	3.0	Box Sort, Color Coded 2:1 I_{DSS} Ratios
N-CHANNEL MOS FETs (Type B)				
MFE3005	400	10	4.5	
MFE3007	200	18	4.0	Dual Gate
3N140	200	16	4.5	Dual Gate
MFE3004	200	16	4.5	
MFE3006	100	20	4.5	Dual Gate

*For test circuits pertaining to power gain figure, see data sheet.

TABLE 2 GENERAL-PURPOSE AMPLIFIERS

This table includes a wide selection of N- and P-channel field-effect transistors designed for small-signal amplification at low and moderate frequencies (to 30 MHz). The transistors are listed in order of increasing Gate-Source Breakdown Voltage [$V_{(BR)GSS}$], then in order of decreasing Zero-Gate Voltage Drain Current (I_{DSS}) and Forward Transfer Admittance (y_{fs}).

Type Number	$V_{(BR)GSS}$ Volts min	I_{DSS} mA min/max	$\lvert Y_{fs}\rvert$ µmhos min/max	Comments
N-CHANNEL J FETs (Type A)				
2N5486	25	8.0/20	4000/8000	Formerly MPF107
2N5459		4.0/16	2000/6000	Formerly MFP105
2N5485		4.0/10	3500/7000	Formerly MPF106
2N5458		2.0/9.0	1500/5500	Formerly MPF104
MPF102		2.0/20	2000/7500	
2N5457		1.0/5.0	1000/5000	Formerly MPF103
2N5484		1.0/5.0	3000/6000	
MPF109		0.5/24	800/6000	2:1 I_{DSS} Ranges
2N4222	30	5.0/15	2500/6000	
2N4222A		5.0/15	2500/6000	Low Noise
2N5558		4.0/10	1500/6500	Low Noise
2N4221		2.0/6.0	2000/5000	
2N4221A		2.0/6.0	2000/5000	Low Noise
2N5557		2.0/5.0	1500/6500	Low Noise
2N4220		0.5/3.0	1000/4000	
2N4220A		0.5/3.0	1000/4000	Low Noise
2N5556		0.5/2.5	1500/6500	Low Noise
2N5364	40	9.0/18	2700/6500	2:1 I_{DSS} Ratios, Designers Data Sheet
2N5363		7.0/14	2500/6000	2:1 I_{DSS} Ratios, Designers Data Sheet
2N5362		4.0/8.0	2000/5500	2:1 I_{DSS} Ratios, Designers Data Sheet
2N5361		2.5/5.0	1500/4500	2:1 I_{DSS} Ratios, Designers Data Sheet
2N5360		1.5/3.0	1400/3200	2:1 I_{DSS} Ratios, Designers Data Sheet
2N5359		0.8/1.6	1200/3600	2:1 I_{DSS} Ratios, Designers Data Sheet
2N5358		0.5/1.0	1000/3000	2:1 I_{DSS} Ratios, Designers Data Sheet
MFE2098	50	40/100	14000/25000	
MFE2097		15/50	10000/20000	
3N126		3.0/9.0	1200/3600	Tetrode Connected
2N3822		2.0/10	3000/6500	
3N125		1.5/4.5	800/2400	Tetrode Connected
MFE2095		1.0/3.0	400/800	
2N3821		0.5/2.5	1500/4500	
MFE2094		0.4/1.4	350/700	
3N124		0.2/2.0	500/2000	Tetrode Connected
MFE2093		0.1/0.7	250/500	

Note: See Index Table for package identification.

TABLE 2 continued

Type Number	$V_{(BR)GSS}$ Volts min	I_{DSS} mA min/max	$\|Y_{fs}\|$ µmhos min/max	Comments
N-CHANNEL MOS FETs (Type B)				
2N3797	±30	2.0/6.0	1500/3000	I_{GSS} = 1.0 pAdc (max)
MFE3001	±30	0.5/6.0	700/3500	
2N3796	±30	0.5/3.0	900/1800	I_{GSS} = 1.0 pAdc (max)
P-CHANNEL J FETs (Type A)				
MFE4012	40	7.0/14	2500/5000	2:1 I_{DSS} Ratio, Designers Data Sheet
2N5462		4.0/16	2000/6000	Formerly MPF153
MFE4011		4.0/8.0	2200/4500	2:1 I_{DSS} Ratio, Designers Data Sheet
MFE4010		2.5/5.0	2000/4000	2:1 I_{DSS} Ratio, Designers Data Sheet
2N5461		2.0/9.0	1500/5000	Formerly MPF152
MFE4009		1.5/3.0	1500/3500	2:1 I_{DSS} Ratio, Designers Data Sheet
2N5460		1.0/5.0	1000/4000	Formerly MPF151
2N5476		0.8/2.0	260/650	
MFE4008		0.8/1.6	1000/3000	2:1 I_{DSS} Ratio, Designers Data Sheet
MPF161		0.5/14	800/6000	2:1 I_{DSS} Ratio,
MFE4007		0.5/1.0	900/2700	2:1 I_{DSS} Ratio, Designers Data Sheet
2N5475		0.4/1.0	200/500	2.5:1 I_{DSS} Ranges
2N5474		0.2/0.5	160/400	2.5:1 I_{DSS} Ranges
2N5473		0.1/0.25	120/300	2.5:1 I_{DSS} Ranges
2N5472		0.05/0.12	90/225	2.5:1 I_{DSS} Ranges
2N5471		0.02/0.06	60/180	2.5:1 I_{DSS} Ranges
2N5270	60	7.0/14	2500/5000	2:1 I_{DSS} Ratio, Designers Data Sheet
2N5465		4.0/16	2000/6000	Formerly MPF156
2N5269		4.0/8.0	2200/4500	2:1 I_{DSS} Ratio, Designers Data Sheet
2N5268		2.5/5.0	2000/4000	2:1 I_{DSS} Ratio, Designers Data Sheet
2N5464		2.0/9.0	1500/5000	Formerly MPF 155
2N5267		1.5/3.0	1500/3500	2:1 I_{DSS} Ratio, Designers Data Sheet
2N5463		1.0/5.0	1000/4000	Formerly MPF154
2N5266		0.8/1.6	1000/3000	2:1 I_{DSS} Ratio, Designers Data Sheet
2N5265		0.5/1.0	900/2700	2:1 I_{DSS} Ratio, Designers Data Sheet
P-CHANNEL MOS FETs (Type C)				
3N157	±35	*–/0.25	1000/4000	Designers Data Sheet
3N158	±35	*–/0.25		Designers Data Sheet
3N157A	±50	*–/1.0		Designers Data Sheet
3N158A	±50	*–/1.0		Designers Data Sheet

*nAdc

TABLE 3 GENERAL-PURPOSE SWITCHES

The devices in this table have low feedback capacitances (C_{rss}) and relatively low drain-source resistance, [$r_{ds(on)}$], making them suitable for medium-speed switching applications. The transistors are listed first in order of decreasing Gate-Source Breakdown Voltage [$V_{(BR)GSS}$], then in order of increasing $r_{ds(on)}$, decreasing gate cutoff voltage [$V_{GS(off)}$ or $V_{GS(th)}$] and decreasing I_{DSS}.

Type Number	$V_{(BR)GSS}$ Volts min	$r_{ds(on)}$ Ohms max	$V_{GS(off)}$ $V_{GS(th)}$* Volts max	I_{DSS} $I_{D(on)}$* mA min	Comments
N-CHANNEL J FETs (Type A)		All have reverse capacitance (C_{rss}) of 3.0 pF Maximum			
2N3824	50	250	8.0	–	
3N126		500	6.5	3.0	Tetrode Connected
3N125		750	4.0	1.5	Tetrode Connected
3N124		1000	2.5	0.2	Tetrode Connected
MFE2095		1300	5.5	1.0	
MFE2094		1600	4.5	0.4	
MFE2093		2500	2.5	0.1	
2N4222	30	300	8.0	5.0	
2N4222A		300	8.0	5.0	Low Noise
2N4221		400	6.0	2.0	
2N4221A		400	6.0	2.0	Low Noise
2N4220		500	4.0	0.5	
2N4220A		500	4.0	0.5	Low Noise
2N5555	25	150	–	15	High Speed $t_{(on)}$ = 10 ns max
P-CHANNEL MOS FETs					
3N156A	±35	300	5.0*	5.0*	Designers Data Sheet
3N155A		300	3.2*	5.0*	Designers Data Sheet
3N156		600	5.0*	5.0*	Designers Data Sheet
3N155		600	3.2*	5.0*	Designers Data Sheet
2N4351†	±30	300	5.0*	3.0*	Complement to 2N4352
2N4352	±30	600	5.0*	3.0*	Complement to 2N4351

†Indicates N-Channel

Note: See Index Table for package identification.

TABLE 4 CHOPPERS

Because FETs have no offset voltage they are particularly well suited for chopper applications. Devices in this table are designed for low $r_{ds(on)}$, low C_{rss} and fast switching time. The FETs are listed first in order of decreasing $V_{(BR)GSS}$, increasing $r_{ds(on)}$, then in order of increasing C_{rss} and I_{DSS}.

Type Number	$V_{(BR)GSS}$ Volts min	$r_{ds(on)}$ Ohms max	C_{rss} pF max	I_{DSS} mA min	Comments
N-CHANNEL J FETs (Type A)					
2N4391	40	30	3.5	50	
2N4091	│	30	5.0	30	
2N4092	│	50	5.0	15	
2N4392	│	60	3.5	25	
2N4093	│	80	5.0	8.0	
2N4393	↓	100	3.5	5.0	
MFE2006	30	30	5.0	30	
MFE2005	│	50	5.0	15	
MFE2133	│	60	5.0	25	
MFE2004	↓	80	5.0	8.0	
MFE2012	25	10	20	100	
MFE2011	│	15	20	40	
MFE2009	│	20	15	50	
MFE2010	│	25	20	15	
MFE2008	│	30	15	20	
MFE2007	│	40	15	8.0	
2N5555	↓	150	1.2	15	High Speed, $t_{(on)}$ = 10 ns max
N-CHANNEL MOS FETs (Type C)					
MFE3002	±30	100	1.0	10†	Complement to MFE3003
P-CHANNEL MOS FETs (Type C)					
3N155A	±35	300	1.3	0.25†	Designers Data Sheet
3N156A	│	300	1.3	0.25†	Designers Data Sheet
3N155	│	600	1.3	1.0†	Designers Data Sheet
3N156	↓	600	1.3	1.0†	Designers Data Sheet
MFE3003	±30	200	1.0	10†	Complement to MFE3002

†nA max

TABLE 5 MATCHED PAIRS

Each type number in this table represents a pair of devices carefully matched for critical applications such as differential-amplifier service. Each pair is packaged in a metal clip to maintain pair identity.

GENERAL CHARACTERISTICS (per device)

I_{DSS} mA min/max	$\lvert y_{fs}\rvert$ µmhos min	$\lvert y_{os}\rvert$ µmhos max	C_{rss} pF max	NF dB max	$V_{(BR)GSS}$ Volts min
0.5/10	1500	50	2.0	2.5	30

MATCHING CHARACTERISTICS

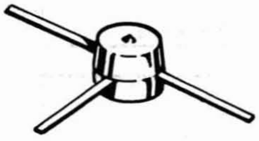
Type Number	$\frac{\Delta\lvert V_{GS1}-V_{GS2}\rvert}{\Delta T}$ max µV/°C	$\lvert V_{GS1}-V_{GS2}\rvert$ mV max	$\lvert I_{G1}-I_{G2}\rvert$ nA max	$\frac{\lvert y_{fs1}\rvert}{\lvert y_{fs2}\rvert}$ min
MMF1	10	5.0	10	0.98
MMF2	10	│	│	0.98
MMF3	25	│	│	0.95
MMF4	25	│	│	│
MMF5	50	│	│	│
MMF6	50	↓	↓	↓

Note: See Index Table for package identification.

MICRO-T TRANSISTORS AND DIODES

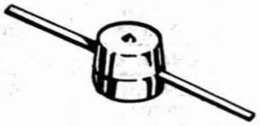
The Micro-T package is a tiny (0.085 inch diameter) injection-molded plastic package for applications requiring extremely high component mounting density. Micro-T transistors and diodes are also useful in hybrid circuits – being easier to mount than unencapsulated semiconductor chips, without special equipment and special operator training.

The following tables list the major characteristics of Micro-T transistors and diodes for amplifying, switching and demodulating applications over a spectrum ranging from dc to ultra-high frequencies. For more detailed information, refer to the individual device listings.



Case 28*

*For Pin Configuration See Case Outlines



Case 166

TABLE I – GENERAL-PURPOSE AMPLIFIER AND SWITCHING TRANSISTORS

Case 28 (1)

Type	V_{CEO} Volts Max	Collector Test Current for Optimum h_{FE} I_C in mA	h_{FE} Min/Max	$V_{CE(sat)}$ Volts Max	@ I_C mA	f_T MHz Min	@ I_C mA	Switching Times ns (Typ) t_d	t_r	t_s	t_f	@ $I_C/I_{B1}/I_{B2}$ mA
NPN												
MMT3904	40	10	100/300	0.2	10	300	10	24	13	125	11	10/1.0/1.0
MMT3903	40	10	50/150	0.2	10	250	10	24	13	125	11	10/1.0/1.0
MMT2222	30	150	100/300	0.4	150	200	20	t_{on} = 25, t_{off} = 250				150/15 /15
PNP												
MMT2907	40	150	100/300	0.4	150	200	50	t_{on} = 25, t_{off} = 250				150/15 /15
MMT3906	40	10	100/300	0.25	10	250	10	25	18	140	15	10/1.0/1.0
MMT3905	40	10	50/150	0.25	10	200	10	25	18	140	15	10/1.0/1.0

TABLE II – HIGH SPEED SATURATED SWITCHING TRANSISTORS

Case 28 (1)

Type	V_{CEO} Volts Max	Collector Test Current for Optimum h_{FE} I_C in mA	h_{FE} Min/Max	$V_{CE(sat)}$ Volts Max	@ I_C mA	f_T MHz Min	@ I_C mA	Switching Times ns Max t_d	t_r	t_s	t_f	@ I_C/I_B mA
NPN												
MMT2369	15	10	40/120	0.25	10	500	10	t_{on} = 12, t_{off} = 18				10/3.0
PNP												
MMT3546	12	10	30/-	0.15	10	700	10	10	15	20	15	50/5.0

TABLE III – HIGH-SPEED NON-SATURATED SWITCHING TRANSISTORS

Case 28 (1)

Type	V_{CEO} Volts Max	Collector Test Current for Optimum h_{FE} I_C in mA	h_{FE} Min/Max	$V_{CE(sat)}$ Volts Max	@ I_C mA	f_T MHz Min	@ I_C mA	Switching Times ns Typ t_d	t_r	t_s	t_f	@ I_C mA
NPN												
MMT3960A	8.0	10	30/200	0.2	10	1600	30	1.0	0.75	1.1	0.85	20

TABLE IV – LOW NOISE AMPLIFIER TRANSISTORS

Case 28 (1)

Type	V_{CEO} Volts Max	Collector Test Current for Optimum h_{FE} I_C in mA	h_{FE} Min/Max	f_T MHz Min	@ I_C μA	NF dB Max	@ I_C μA	and f MHz
NPN								
MMT2484	60	1.0	250/-	60	500	3.0	10	10 Hz to 10 kHz
MMT930	45	1.0	150/-	60	500	-	-	-
PNP								
MMT3799	60	0.1	300/900	40	500	2.5	100	10 Hz to 15.7 kHz
MMT3798	60	0.1	150/450	40	500	3.5	100	10 Hz to 15.7 kHz

TABLE V – RF AMPLIFIER AND OSCILLATOR TRANSISTORS

Case 28 (1)

Type	V_{CEO} Volts Max	Collector Test Current for Optimum h_{FE} I_C in mA	h_{FE} Min	NF dB Max	@ I_C mA	and f MHz	f_T MHz Min	@ I_C mA	Feedback Capacitance @V_{CB} = 10 Vdc pF Max
NPN									
MMT2857	15	3.0	30	3.8*	1.5	450	1000	4.0	1.0
MMT918	15	3.0	20	6.0	1.0	60	600	10	1.7

*Typical

TABLE VI – N-CHANNEL FIELD-EFFECT TRANSISTORS

Type	$V_{(BR)GSS}$ Volts Min	I_{DSS} mA Min/Max	C_{iss} pF Typ	$Re(y_{is})$ μmhos Typ	NF Typ dB	@ f MHz	Case
MMT3823	-30	5.0/20	4.0	500	2.0	100	28(5)

TABLE VII – SWITCHING DIODES

Type	$V_{(BR)}$ Volts Min	@ $I_{(BR)}$ μA	I_R μA Max	@ V_R Volts	V_F Volts Min/Max	@ I_F mA	C @ V_R = 0 pF Max	t_{rr} ns Max	Case	Description
MMD6050	70	100	0.1	50	0.55/0.7	1.0	2.0	5.0	166	Single
MMD6100	70	100	0.1	50	0.55/0.7	1.0	2.0	5.0	28(2)	Common-Cathode
MMD6150	70	100	0.1	50	0.55/0.7	1.0	2.0	5.0	28(3)	Common-Anode
MMD7000	70	100	0.1	50	0.55/0.7	1.0	2.0	5.0	28(4)	Series

OPTOELECTRONICS

These optoelectronic devices are designed for use in computer, industrial, and consumer equipment. The most popular are the discrete phototransistors listed below. Also available are custom phototransistor arrays using these discrete devices, and monolithic arrays for applications requiring very high density and exceptional alignment.

Phototransistors

These phototransistors are high-quality passivated Annular devices providing a high order of stability and reliability. They are sensitive throughout the visible and near-infrared spectral range with peak sensitivity at a typical wavelength of 0.8 micrometers. Much faster than the conventional photocells or mechanical contacts, these phototransistors have a maximum rise time of 2.5 microseconds, and a maximum fall time of 4.0 microseconds when pulsed with a gallium arsenide light-emitting diode. The devices fall in two major categories, dependent on applications: (1) high-density mounting (subminiature size) and (2) low-density mounting (miniature size).

High-Density Applications

These devices are subminiature NPN silicon phototransistors designed for use in card and tape readers, pattern and character recognition, shaft encoders, or any design requiring radiation sensitivity, stable characteristics and high-density mounting in arrays. The hermetically sealed subminiature "pill" package used for the MRD200, MRD210, MRD250, and MRD600 device types provides high reliability and high stability for these applications. The unique, clear-plastic Micro-T package in both three and two leaded configurations (MRD100 and MRD150) combines reliability, medium sensitivity, and small size for high-density mounting in an economical package.

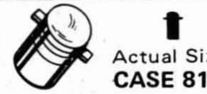
ELECTRICAL CHARACTERISTICS @ V_{CC} = 20 Volts, T_A = 25°C

Case Number	Device Type	S_{RCEO} Collector-Emitter Radiation Sensitivity @ H* = 5.0 mW/cm^2 mA/mW/cm^2 (min)	I_L Light Current @ H* = 5.0 mW/cm^2 mA (min)	I_{CEO} Dark Current @ H* = 0 μA (max)

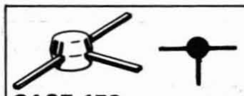
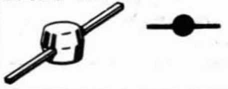
For use with circuit boards less than 1/16" thick.

Actual Size **CASE 81** Hemispheric Lens	MRD200 MRD210	0.25 0.05	1.25 0.25	0.025 0.025
Actual Size **CASE 81A-02** Low Profile Lens	MRD600	0.04 Note 2	0.8 Note 2	0.025 Note 3

For use with circuit boards at least 1/16" thick.

 Actual Size **CASE 81A** Low Profile Lens	MRD250	0.1	0.5	0.025

For use with circuit boards less than 1/16" thick.

 **CASE 172** Actual Size	MRD100 Note 1	0.04	0.2	0.1
CASE 173 	MRD150	0.04	0.2	0.1

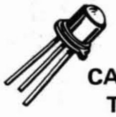
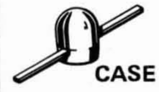
NOTES:
1. Base connection provided
2. MRD600 conditions: V_{CC} = 5 Volts, H = 20 mW/cm^2, R_L = 100 Ω
3. MRD600 conditions: V_{CC} = 30 Volts, H = 0, R_L = 1 MΩ

*4. H is radiation flux density emitted from a tungsten source at 2870 K

Low-Density Applications

These devices are high-sensitivity NPN silicon phototransistors designed for use in industrial inspection, processing and control,counters, sorters, switching and logic circuits or any design requiring radiation sensitivity, stable characteristics, and moderate mounting density in arrays or single device applications. The TO-18 type hermetically sealed package (MRD300 and MRD310) is recommended for high reliability, high stability, and high sensitivity desired in these applications, while the clear plastic MRD450 provides high, uniform sensitivity in an economical package.

ELECTRICAL CHARACTERISTICS @ V_{CC} = 20 Volts, T_A = 25°C

Case Number	Device Type	S_{RCEO} Collector-Emitter Radiation Sensitivity @ H* = 5.0 mW/cm^2 mA/mW/cm^2 (min)	I_L Light Current @ H* = 5.0 mW/cm^2 mA (min)	I_{CEO} Dark Current @ H* = 0 μA (max)
 CASE 82 TO-18	MRD300	0.8	4.0	0.025
	MRD310	0.2	1.0	0.025
 CASE 171	MRD450	0.2	1.0	0.1

* NOTE 4: H is radiation flux density emitted from a tungsten source at 2870 K.

RF SELECTOR GUIDE

	POWER OUT IN WATTS	To 0.1	0.1-0.25	0.25-0.5	0.5-1.0	1.0-5.0	5.0-15	15-25	25-50
2 MHz ↕ 76 MHz	NPN	2N4124 2N3903 2N3904 2N4123 MM1941 MPS918	2N2952 2N4072	2N2951 2N2952 2N3295* 2N4073	2N2951 2N3924 2N3948	2N3924 2N3925 2N3926 MM1601	2N3926 2N2927 MM1602 MM1603 MM1557	MM1603 MM1604	MM1604
					2N2949 2N2950 2N3866	2N2950 2N3296* 2N3375 2N3553 2N3961 MM1557	2N2947 2N2948 2N3297* 2N3375 2N3632 MM1558 MM8004	2N3950 MM1558 MM1559	2N3950 MM1559
	PNP	2N3905 2N3906 2N4125 2N4126							
			2N5160	2N5160	2N5160	2N5161	2N5161 2N5162	2N5162	2N5162
76 MHz ↕ 250 MHz	NPN	MM1941 MPS918	2N4072	2N4073	2N3924 2N3948	2N3924 2N3925 MM1601	2N3926 2N3927 MM1602	MM1603	
					2N3866	2N3375 2N3553 2N3961 MM1549 MM1557	2N3375 2N3632 2N3733 MM1550 MM1558	MM1551 MM1559 MM1558	MM1559
	PNP				2N5160	2N5161	2N5161 2N5162	2N5162	2N5162
	VARACTOR MULTIPLIER								1N4387
250 MHz ↕ 470 MHz	NPN	MM1941 MPS918	2N4072	2N4073	2N3948				
					2N3866 MM1549	2N3375 2N3553 2N3961 MM1549 MM1550	2N3375 2N3733 MM1551 MM1550	MM1551	
	PNP				2N5160	2N5161	2N5161	2N5162	
	VARACTOR MULTIPLIER							1N4388	1N4387
470 MHz ↓ 1 GHz	NPN			2N3866 MM1500† MM1501†	2N3866				
	VARACTOR MULTIPLIER						1N5151 1N5152A 1N5153A	1N4388 1N5149	1N5150A MV1805C
1 GHz ↕ 2 GHz	NPN	2N3544†							
			MM1500† MM1501†						
	VARACTOR MULTIPLIER				1N5154 1N5155A		1N5149 1N5151 1N5152A 1N5153A	1N5150A MV1809C1	MV1805C
2 GHz ↕ 6.4 GHz	VARACTOR MULTIPLIER					1N5154 1N5155A	1N5151 1N5152A 1N5153A		
	ONE-STEP VARACTOR MULTIPLIER			MV1817B1	MV1816B1				
6.4 GHz ↕ 10 GHz	VARACTOR MULTIPLIER				1N5156 1N5157	1N5154 1N5155A			
	ONE-STEP VARACTOR MULTIPLIER			MV1817B1					
10 GHz UP	VARACTOR MULTIPLIER				1N5156 1N5157	MV1817B1			

†Power Oscillator

* SSB Linear Amplifier

▨ 10-15 V CW, FM, SSB

░ 15-28 V CW, FM, SSB
10-15 V AM

RF POWER SEMICONDUCTOR SPECIFICATIONS

TRANSISTORS

TYPE	POLARITY	P_O (WATTS)	TEST FREQUENCY (MHz)	V_{CC} (Vdc)	Ge (dB)	BV_{CES} (Vdc)	PACKAGE
2N2947	NPN	15	50	25	7	60	TO-3
2N2948	NPN	15	30	25	7	60	TO-3
2N2949	NPN	3.5	50	25	10	60	TO-107
2N2950	NPN	3.5	50	25	10	60	TO-102
2N2951	NPN	0.6	50	13.6	7.8	60	TO-5
2N2952	NPN	0.6	50	13.6	7.8	60	TO-18
2N3295	NPN	0.3 PEP*	30	15	14	60	TO-5
2N3296	NPN	3 PEP*	30	30	16	60	TO-102
2N3297	NPN	12 PEP*	30	30	10	60	TO-3
2N3375	NPN	7.5	100	28	8.7	65	TO-60
		3.0	400	28	4.8		
2N3544	NPN	0.01†	1000	12	–	25	TO-18
2N3553	NPN	2.5	175	28	10	65	TO-39
2N3632	NPN	13.5	175	28	5.9	65	TO-60
2N3733	NPN	10	400	28	4	65	TO-60
2N3866	NPN	1.0	400	28	10	55	TO-39
2N3903	NPN	–	–	–	–	60	TO-92
2N3904	NPN	–	–	–	–	60	TO-92
2N3905	PNP	–	–	–	–	60	TO-92
2N3906	PNP	–	–	–	–	60	TO-92
2N3924	NPN	4	175	13.6	6	36	TO-39
2N3925	NPN	5	175	13.6	5.8	36	TO-102
2N3926	NPN	7	175	13.6	5.4	36	TO-60
2N3927	NPN	12	175	13.6	4.7	36	TO-60
2N3948	NPN	1.0	400	13.6	6	36	TO-39
2N3950	NPN	50	50	28	8	65	TO-60
2N3961	NPN	4	175	28	9	65	TO-102
2N4072	NPN	0.25	175	13.6	10	40	TO-18
2N4073	NPN	0.5	175	13.6	10	40	TO-5
2N4123	NPN	–	–	–	–	40	TO-92
2N4124	NPN	–	–	–	–	30	TO-92
2N4125	PNP	–	–	–	–	30	TO-92
2N4126	PNP	–	–	–	–	25	TO-92
2N5160	PNP	1.0	400	28	8.0	60	TO-39
2N5161	PNP	7.5	175	28	8.75	60	TO-60
2N5162	PNP	30	175	28	6.0	60	TO-60
MM1500	NPN	0.25†	1500	20	–	30	TO-107
MM1501	NPN	0.15†	1500	20	–	30	TO-107
MM1551	NPN	20	400	28	4.6	60	Case 145
MM1559	NPN	40	175	28	7.6	65	Case 145
MM1549	NPN	2.5	400	28	6.2	60	Case 144
MM1550	NPN	7.5	400	28	5.7	60	Case 144
MM1557	NPN	7.0	175	28	8.4	65	Case 144
MM1558	NPN	20	175	28	8.2	65	Case 145
MM1601	NPN	3	175	13.6	8.2	36	Case 144
MM1602	NPN	10	175	13.6	5.2	36	Case 145
MM1603	NPN	25	175	13.6	4.4	36	Case 145
MM1941	NPN	0.1	175	13.6	7	30	TO-18
MM8004	NPN	3.5	27	12.5	10	60	TO-39

† Oscillator Power Output.

* Single Sideband Two Tone Test.

POWER VARACTOR SELECTOR GUIDE

This guide lists a broad line of step-recovery varactors that provide high-power output and high efficiency over a wide range of microwave frequencies, from 35 W at 500 MHz to 1 W at 12 GHz. The varactors are available in many package variations for maximum versatility of mounting in all types of equipment.

Also available are efficient one-step multipliers for local-oscillator and phase-locking applications where multiplications to 25 are desired.

The selector guide includes the information necessary to choose the best power varactor for an application.

With the output frequency and power in mind, a specific varactor or varactor chain can be selected from Figure 1, Typical Doubling Performance, or Figure 2, Typical Tripling Performance. For one-step, high-order multiplication, the 1N5155, MV1816, and MV1817 are recommended.

TABLE I — Basic Electrical Characteristics of Power Varactors

This table provides the fundamental electrical characteristics of power varactors. The varactors are listed by the basic type number in order of decreasing output frequency and power output. JEDEC-registered devices follow the basic types from which they are derived. A complete type number must include package style, i.e., MV1806A, package variations for the varactors are given in Table II. Premium varactors with tighter control of capacitance and lower thermal resistance are designated by the "1" suffix.

Basic Type Numbers See Table II for Package Variations		Maximum P_D @ $T_C = 75^oC$ †@ $T_A = 75^oC$ Watts	ELECTRICAL CHARACTERISTICS							
			100% Functional Test				θ_{JC} C/W Max	BV_R $I_R = 10\ \mu A$ Volts Min	R_S $V_R = 6.0$ V f = 50 MHz Ohms Typ	C_T $V_R = 6.0$ V f = 1.0 MHz pF	
	JEDEC Variations		f_{out} MHz	P_{out} Min Watts	f_{in} MHz	P_{in} Watts				Min	Max
MV1812		3.3	10000	1.0	5000	2.6	38	20	1.0	0.5	1.0
	1N5156	3.3	10000	1.0	5000	2.6	38	20	1.0	0.5	1.0
	1N5157	3.3	10000	1.0	5000	2.6	38	20	1.0	0.5	1.0
MV1817-1		5.0	6400	0.25	800	1.0	25	35	0.8	0.9	1.1
MV1817		3.6	6400	0.20	800	1.0	35	35	0.8	0.8	1.2
MV1810-1		6.2	6000	2.0	2000	5.0	20	35	0.9	1.71	2.09
	1N5155A	6.2	6000	2.0	2000	5.0	20	35	0.9	1.71	2.09
MV1810		3.5	6000	2.0	2000	5.0	35	35	0.9	1.0	3.0
	1N5154	3.5	6000	2.0	2000	5.0	35	35	0.9	1.0	3.0
	1N5155	3.5	6000	2.0	2000	5.0	35	35	0.9	1.0	3.0
MV1811-1		8.2	4000	7.2	2000	12	15	35	0.5	4.5	5.5
MV1811		6.2	4000	5.0	2000	10	20	35	0.5	4.0	6.0
MV1816-1		8.2	2400	0.75	300	3.0	15	75	0.6	2.7	3.3
MV1816		5.3	2400	0.6	300	3.0	23	75	0.6	2.4	3.6
MV1809-1		14	2000	14.5	1000	25	9.0	75	0.25	10.8	13.2
MV1809		9.0	2000	10.4	1000	20	14	75	0.25	9.6	14.4
MV1808-1		8.4	2000	7.2	1000	12	15	75	0.5	5.4	6.6
	1N5152A	8.4	2000	7.2	1000	12	15	75	0.5	5.4	6.6
	1N5153A	8.4	2000	7.2	1000	12	15	75	0.5	5.4	6.6
MV1808		5.5	2000	6.0	1000	12	23	75	0.5	5.0	7.5
	1N5151	5.5	2000	6.0	1000	12	23	75	0.5	5.0	7.5
	1N5152	5.5	2000	6.0	1000	12	23	75	0.5	5.0	7.5
	1N5153	5.5	2000	6.0	1000	12	23	75	0.5	5.0	7.5
MV1807-1		21	1000	25.1	500	37	6.0	80	0.25	10.8	13.2
	1N5050A	21	1000	25.1	500	37	6.0	80	0.25	10.8	13.2
MV1807		14†	1000	24	500	37	9.0	80	0.25	5.0	20
	1N5050	14†	1000	24	500	37	9.0	80	0.25	5.0	20
MV1806		10†	1000	11	500	20	9.0	80	0.25	5.0	20
	1N5149	10†	1000	11	500	20	9.0	80	0.25	5.0	20
	1N4388	10	1000	11	500	20	9.0	100	0.25	–	20
MV1805		18†	750	26	250	40	7.0	80	0.2	20	30
MV1804		20	450	15	150	30	5.0	150	0.7	–	35
	1N4387	20	450	15	150	30	5.0	150	0.7	–	35

Typical case capacitance for A, B, and C packages are 0.25 pF, 0.15 pF, and 0.47 pF respectively.

FIGURE 1 – Typical Doubling Performance

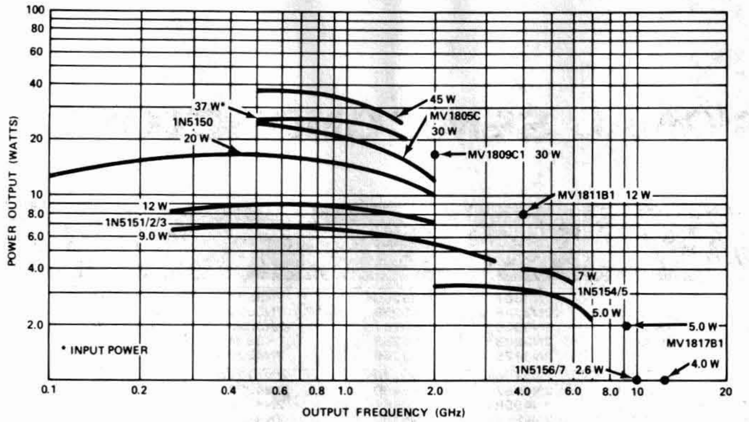


FIGURE 2 – Typical Tripling Performance

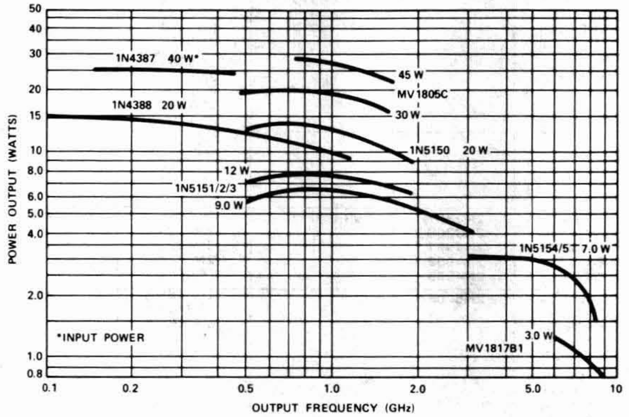
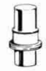
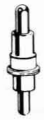
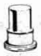
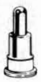
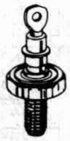
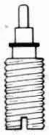
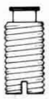
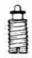
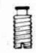
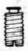


TABLE II – Package Configurations and Descriptions

MOTOROLA TYPE NO.	Ⓐ (Pill)	Ⓑ (Pill w Prongs)	Ⓒ (Cartridge)	Ⓓ	Ⓔ	Ⓕ	Ⓖ	Ⓙ	Ⓚ	Ⓛ	Ⓜ	Ⓝ	Ⓟ
													
CASE	48	46	47	45 (B)*	(B)	(C)	(C)	(C)	(C)	(C)	(B)	(B)	(A)
MV1804			●			●	●	1N4387	●	●			
MV1805			●			●	●	●	●	●			
MV1806			1N5149			●	●	1N4388	●	●			
MV1807 MV1807-1			1N5150 1N5150A			● ●	● ●	● ●	● ●	● ●			
MV1808 MV1808-1	1N5151 ●	1N5152 1N5152A	1N5153 1N5153A	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● ●
MV1809 MV1809-1			● ●			● ●	● ●	● ●	● ●	● ●			
MV1810 MV1810-1	1N5154 ●	1N5155 1N5155A		● ●	● ●						● ●	● ●	● ●
MV1811 MV1811-1	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● ●
MV1812	1N5156	1N5157		●	●						●	●	●
MV1816 MV1816-1	● ●	● ●		● ●	● ●						● ●	● ●	● ●
MV1817 MV1817-1	● ●	● ●		● ●	● ●						● ●	● ●	● ●

*Cases A, B, C are basic package types. D-P types are all special versions of A, B, C. Thus (A), (B), or (C) shown under the D-P column headings identifies basic package types.

Key to columnar designations opposite type numbers: "●" indicates availability; specific type number (i.e., "1N5149") indicates availability of JEDEC type. Available on special order.

When ordering, follow type number by alphabetical.identification of package type required (i.e., "MV1805C").

SMALL-SIGNAL SEMICONDUCTORS

FREQUENCY	PNP Ge	NPN Si	PNP Si	P-CHANNEL JFET	N-CHANNEL JFET	N-CHANNEL MOSFET	INTEGRATED CIRCUIT	DUAL TRANSISTOR
2 MHz	2N700 2N1141A 2N1142A 2N1143 2N1195	2N918 2N2857 2N3287 2N3288 2N3289	2N3307 2N3308 2N3905 2N3906 2N4125	2N5265 2N5266 2N5267 2N5268 2N5269	2N3821 2N3822 2N3823 2N3824 2N4220A	MFE3004 MFE3005 MFE3006	MC1550	MD918B MD918BF MD4957 MD5000B
	2N2415 2N2416 2N2929 2N2996 2N2997	2N3290 2N3839 2N3903 2N3904 2N4123	2N4126 2N4957 2N4958 2N4959 2N5208	2N5270 2N5460 2N5461 2N5462 2N5463	2N4221A 2N4222A 2N4223 2N4224 2N4416			
	2N2998 2N3127 2N3279 2N3280 2N3281	2N4124 MPS918 MM8000 MM8001 MM8002		2N5464 2N5465 MPF161 MFE4007 MFE4008	2N5358 2N5359 2N5360 2N5361 2N5362			
	2N3282 2N3783 2N3784 2N3785 AF239	MM8003 MMT918 2N5222 2N3127 MM1605		MFE4009 MFE4010 MFE4011 MFE4012	2N5363 2N5364 2N5457 2N5458 2N5459			
	MM5000 MM5001 MM5002 MM5043 MM5044	MM1606 MM1607			2N5484 2N5485 2N5486 3N124 3N125			
76 MHz	2N2273				3N126 MFE2000 MFE2001 MPF102			
76 MHz	2N700 2N1141A 2N1142A 2N1143 2N1195	2N918 2N2857 2N3287 2N3288 2N3289	2N3307 2N3308 2N4957 2N4958 2N4959	MFE2002	2N3823 2N4223 2N4224 2N4416 2N5484	MFE3004 MFE3005 MFE3006	MC1550	MD918B MD918BF MD4957 MD5000B
	2N2415 2N2416 2N2929 2N2996 2N2997	2N3290 2N3839 MPS918 MM8000 MM8001	2N5208		2N5485 2N5486 MFE2000 MFE2001 MPF102			
	2N2998 2N3127 2N3279 2N3280 2N3281	MM8002 MM8003 MMT918 2N5222 2N3127						
	2N3282 2N3783 2N3784 2N3785 AF239							
250 MHz	MM5000 MM5001 MM5002 MM5043 MM5044							
250 MHz	2N1141A 2N1142A 2N1143 2N1195 2N2415	2N918 2N2857 2N3287 2N3288 2N3289	2N3307 2N3308 2N4957 2N4958 2N4959		2N4416 2N5484 2N5485 2N5486	MFE3004 MFE3005 MFE3006		MD918B MD918BF MD4957 MD5000B
	2N2416 2N2929 2N2996 2N2997 2N2998	2N3290 2N3839 MPS918 MMT918 MM1605	2N5208					
	2N3127 2N3279 2N3280 2N3281 2N3282	MM1606 MM1607						
	2N3783 2N3784 2N3785 AF239 MM5000							
500 MHz	MM5001 MM5002 MM5043 MM5044							
500 MHz	2N2415 2N2416 2N2997 2N2998 2N3783	2N2857 2N3839	2N4957 2N4958 2N4959					MD4957
	2N3784 2N3785 AF239 MM5000 MM5001							
UP	MM5002 MM5043 MM5044							

SMALL-SIGNAL SPECIFICATIONS

TYPE	DEVICE	POLARITY	Ge (dB) (min)	NF (dB) (max)	TEST FREQUENCY (MHz)	PACKAGE
2N700A	GE	PNP	22	10	100	TO-17
2N918	SI	NPN	15	3 (typ)	200	TO-72
2N1141A	GE	PNP	–	5.5 (typ)	200	TO-5
2N1142A	GE	PNP	–	6.0 (typ)	200	TO-5
2N1143	GE	PNP	–	6.5 (typ)	200	TO-5
2N1195	GE	PNP	–	6.0 (typ)	200	TO-5
2N2415	GE	PNP	–	3	200	TO-72
2N2416	GE	PNP	–	4	200	TO-72
2N2857	SI	NPN	12.5	4.5	450	TO-72
2N2929	GE	PNP	16 (typ)	5.5 (typ)	200	TO-5
2N2996	GE	PNP	–	5	200	TO-72
2N2997	GE	PNP	–	4.5	200	TO-72
2N2998	GE	PNP	–	8	1000	TO-72
2N3127	GE	PNP	17	5	200	TO-72
2N3279	GE	PNP	17	3.5	200	TO-72
2N3280	GE	PNP	17	3.5	200	TO-72
2N3281	GE	PNP	16	5	200	TO-72
2N3282	GE	PNP	16	5	200	TO-72
2N3287	SI	NPN	17	6	200	TO-72
2N3288	SI	NPN	17	6	200	TO-72
2N3289	SI	NPN	17	7	200	TO-72
2N3290	SI	NPN	17	7	200	TO-72
2N3307	SI	PNP	17	4.5	200	TO-72
2N3308	SI	PNP	17	6	200	TO-72
2N3783	GE	PNP	20	2.2	200	TO-72
2N3784	GE	PNP	20	2.5	200	TO-72
2N3785	GE	PNP	18	2.9	200	TO-72
2N3821	JFET	N-CHANNEL	–	–	–	TO-72
2N3822	JFET	N-CHANNEL	–	–	–	TO-72
2N3823	JFET	N-CHANNEL	–	2.5	100	TO-72
2N3824	JFET	N-CHANNEL	–	–	–	TO-72
2N3839	SI	NPN	12.5	3.9	450	TO-72
2N3903	SI	NPN	–	–	–	TO-92
2N3904	SI	NPN	–	–	–	TO-92
2N3905	SI	PNP	–	–	–	TO-92
2N3906	SI	PNP	–	–	–	TO-92
2N4123	SI	NPN	–	–	–	TO-92
2N4124	SI	NPN	–	–	–	TO-92
2N4125	SI	PNP	–	–	–	TO-92
2N4126	SI	PNP	–	–	–	TO-92
2N4220A	JFET	N-CHANNEL	–	–	–	TO-72
2N4221A	JFET	N-CHANNEL	–	–	–	TO-72
2N4222A	JFET	N-CHANNEL	–	–	–	TO-72
2N4223	JFET	N-CHANNEL	10	5	200	TO-72
2N4224	JFET	N-CHANNEL	–	–	–	TO-72
2N4416	JFET	N-CHANNEL	10	4	400	TO-72
2N4957	SI	PNP	17	3 5.0 (typ)	450 1000	TO-72
2N4958	SI	PNP	16	3.3	450	TO-72
2N4959	SI	PNP	15	3.8	450	TO-72
2N5208	SI	PNP	22	3	100	TO-92
2N5265	JFET	P-CHANNEL	–	–	–	TO-72
2N5266	JFET	P-CHANNEL	–	–	–	TO-72
2N5267	JFET	P-CHANNEL	–	–	–	TO-72
2N5268	JFET	P-CHANNEL	–	–	–	TO-72
2N5269	JFET	P-CHANNEL	–	–	–	TO-72
2N5270	JFET	P-CHANNEL	–	–	–	TO-72
2N5358	JFET	N-CHANNEL	–	–	–	TO-72
2N5359	JFET	N-CHANNEL	–	–	–	TO-72
2N5360	JFET	N-CHANNEL	–	–	–	TO-72
2N5361	JFET	N-CHANNEL	–	–	–	TO-72
2N5362	JFET	N-CHANNEL	–	–	–	TO-72
2N5363	JFET	N-CHANNEL	–	–	–	TO-72
2N5364	JFET	N-CHANNEL	–	–	–	TO-72
2N5457	JFET	N-CHANNEL	–	–	–	TO-92
2N5458	JFET	N-CHANNEL	–	–	–	TO-92
2N5459	JFET	N-CHANNEL	–	–	–	TO-92
2N5460	JFET	P-CHANNEL	–	–	–	TO-92
2N5461	JFET	P-CHANNEL	–	–	–	TO-92
2N5462	JFET	P-CHANNEL	–	–	–	TO-92
2N5463	JFET	P-CHANNEL	–	–	–	TO-92
2N5464	JFET	P-CHANNEL	–	–	–	TO-92
2N5465	JFET	P-CHANNEL	–	–	–	TO-92
2N5484	JFET	N-CHANNEL	16	3.0	100	TO-92
2N5485	JFET	N-CHANNEL	18	2.0	100	TO-92
2N5486	JFET	N-CHANNEL	10	4.0	400	TO-92
3N124	JFET	N-CHANNEL	–	–	–	TO-72
3N125	JFET	N-CHANNEL	–	–	–	TO-72
3N126	JFET	N-CHANNEL	–	–	–	TO-72
AF239	GE	PNP	11.2	–	800	TO-72
MC1550	IC	–	21 (typ)	–	100	Case 71
MFE2000	JFET	N-CHANNEL	10	4	400	TO-72
MFE2001	JFET	N-CHANNEL	10	4	400	TO-72
MFE2002	JFET	P-CHANNEL	–	2.5	100	TO-72
MFE3004	MOSFET	N-CHANNEL	10	4.5	400	TO-72
MFE3005	MOSFET	N-CHANNEL	10	4.5	400	TO-72
MFE3006	DUAL GATE MOSFET	N-CHANNEL	20	4.5	100	TO-72
MFE4007	JFET	P-CHANNEL	–	–	–	TO-72
MFE4008	JFET	P-CHANNEL	–	–	–	TO-72
MFE4009	JFET	P-CHANNEL	–	–	–	TO-72
MFE4010	JFET	P-CHANNEL	–	–	–	TO-72
MFE4011	JFET	P-CHANNEL	–	–	–	TO-72
MFE4012	JFET	P-CHANNEL	–	–	–	TO-72
MM5000	GE	PNP	24	1.6	200	TO-72
MM5001	GE	PNP	22	2.0	200	TO-72
MM5002	GE	PNP	20	2.2	200	TO-72
MPF102	JFET	N-CHANNEL	–	2.5 (typ)	100	TO-92
MPF161	JFET	P-CHANNEL	–	–	–	TO-92
MPS918	SI	NPN	15	–	200	TO-92
MM1605	SI	NPN	2.0 GHz*	–	–	TO-72
MM1606	SI	NPN	2.0 GHz*	–	–	TO-72
MM1607	SI	NPN	1.7 GHz*	–	–	TO-72
MM5043	GE	PNP	20 14 (typ)	2.5 3.5 (typ)	450 1000	TO-72
MM5044	GE	PNP	16	3.5	450	TO-72
MM8000	SI	NPN	11.4 (typ)	2.7 (typ)	200	TO-39
MM8001	SI	NPN	11.4 (typ)	2.7 (typ)	200	TO-39
MM8002	SI	NPN	11.4 (typ)	2.9 (typ)	200	TO-39
MM8003	SI	NPN	11.4 (typ)	2.7 (typ)	200	Case 144
MMT918	SI	NPN	23 (typ)	– 6	200 60	Case 28
2N5222	SI	NPN	–	–	–	TO-92
MD918B	SI	NPN	–	6	60	Case 32
MD918BF	SI	NPN	–	6	60	Case 33
MD4957	SI	PNP	18 (typ) 13 (typ)	2.6 (typ) 5.0 (typ)	450 1000	Case 32C
MD5000B	SI	NPN	15	6†	200	Case 32
2N2273	GE	PNP	10	–	30	
2N3127	SI	NPN	17	5	200	

†60 MHz GE – Germanium SI – Silicon *f_T

EPICAP TUNING DIODE SELECTOR GUIDE

LINE HIGHLIGHTS		• LOW CAPACITANCE • MICROWAVE OPERATION • MICROWAVE PACKAGE • HIGH Q			• HIGH Q • CAPACITANCE TOLERANCE – 10% AND 5.0%			• HIGH Q GUARANTEED AT 4.0 V AND 60 V • CONTROLLED TR			• THE PREMIUM GLASS LINE • VERY HIGH Q • GUARANTEED HIGH TR • CAPACITANCE TOLERANCE – 10%, 5.0% AND 2.0%		
		MAXIMUM WORKING VOLTAGE			60 VOLTS								
		Case 45			Case 51 DO-7			Case 51 DO-7			Case 51 DO-7		
		Type	Tuning Ratio C_4/C_{60} pF min/typ	Q @ 4.0 V 100 MHz min	Type ③	Tuning Ratio C_4/C_{60} pF min/typ	Q @ 4.0 V 50 MHz min	Type	Tuning Ratio C_4/C_{60} pF min/max	Q @ 4.0 V 50 MHz min	Type ④	Tuning Ratio C_2/C_{30} pF min/max	Q @ 4.0 V 50 MHz min
C_T NOMINAL CAPACITANCE pF ±10% @ V_R = 4.0 V f = 1.0 MHz	1.0	MV1858D ①	2.1/2.3	350									
	2.2	MV1860D ②	2.5/2.7	350									
	3.3	MV1862D	2.6/2.8	300									
	4.7	MV1863D	2.6/2.8	300									
	6.8	MV1864D	2.7/2.9	300	1N5139	2.7/2.9	350				1N5461A	2.7/3.1	600
	8.2	MV1865D	2.7/2.9	300							1N5462A	2.8/3.1	600
	10	MV1866D	2.8/3.0	250	1N5140	2.8/3.0	300	MV1866	2.8/3.2	300	1N5463A	2.8/3.1	550
	12	MV1868D	2.8/3.0	200	1N5141	2.8/3.0	300	MV1868	2.8/3.2	300	1N5464A	2.8/3.1	550
	15	MV1870D	2.8/3.0	200	1N5142	2.8/3.0	250	MV1870	2.8/3.2	250	1N5465A	2.8/3.1	550
	18				1N5143	2.8/3.0	250	MV1871	3.2/3.6	200	1N5466A	2.9/3.1	500
	20										1N5467A	2.9/3.1	500
	22				1N5144	3.2/3.4	200	MV1872	3.2/3.6	200	1N5468A	2.9/3.2	500
	27				1N5145	3.2/3.4	200	MV1874	3.2/3.6	200	1N5469A	2.9/3.2	500
	33				1N5146	3.2/3.4	200	MV1876	3.2/3.6	200	1N5470A	2.9/3.2	500
	39				1N5147	3.2/3.4	200	MV1877	3.2/3.6	200	1N5471A	2.9/3.2	450
	47				1N5148	3.2/3.4	200	MV1878	3.2/3.6	200	1N5472A	2.9/3.2	400
	56										1N5473A	2.9/3.3	300
	68										1N5474A	2.9/3.3	250
	82										1N5475A	2.9/3.3	225
	100										1N5476A	2.9/3.3	200
	120												
	150												
	180												
	200												
	220												
	250												
	270												
	330												

① C_T = ±30%   ② C_T = ±20%   ③ Add Suffix "A" for ±5.0% C_T tolerance   ④ Substitute "B" Suffix for ±5.0% C_T, "C" Suffix for ±2.0% C_T ⑤ Tuning Ratio is C_2/C_{15}

EPICAP TUNING DIODE SELECTOR GUIDE (continued)

<table>
<tr><td colspan="3">• HIGH Q
• CAPACITANCE TOLERANCE – 10%, 5.0% AND 2.0%
• CONTROLLED TR</td><td colspan="3">• PLASTIC PACKAGE
• LOW COST, HIGH VOLUME</td><td colspan="3">• GENERAL PURPOSE</td><td colspan="3">• GENERAL PURPOSE</td><td colspan="3">• HIGH CAPACITANCE
• GENERAL PURPOSE</td></tr>
<tr><td colspan="9">30 VOLTS</td><td colspan="6">20 VOLTS</td></tr>
<tr><td colspan="3">
Case 51
DO-7</td><td colspan="3">
Case 182</td><td colspan="3">
Case 51
DO-7</td><td colspan="3">
Case 51
DO-7</td><td colspan="3">
Case 146
DO-14</td></tr>
<tr><td>Type ④</td><td>Tuning Ratio C_2/C_{30} pF min/max</td><td>Q @ 4.0 V 50 MHz min</td><td>Type</td><td>Tuning Ratio C_2/C_{30} pF min/max</td><td>Q @ 4.0 V 50 MHz min</td><td>Type</td><td>Tuning Ratio C_4/C_{25} pF min/typ</td><td>Q @ 4.0 V 50 MHz min</td><td>Type</td><td>Tuning Ratio C_2/C_{20} pF min/typ</td><td>Q @ 4.0 V 50 MHz min</td><td>Type</td><td>Tuning Ratio C_2/C_{20} pF typ</td><td>Q @ 4.0 V 20 MHz min</td></tr>
<tr><td>1N5441A</td><td>2.5/3.1</td><td>450</td><td>MV2101</td><td>2.5/3.2</td><td>450</td><td></td><td></td><td></td><td>MV1620</td><td>2.0/2.2</td><td>300</td><td></td><td></td><td></td></tr>
<tr><td>1N5442A</td><td>2.5/3.1</td><td>450</td><td>MV2102</td><td>2.5/3.2</td><td>450</td><td></td><td></td><td></td><td>MV1622</td><td>2.0/2.2</td><td>300</td><td></td><td></td><td></td></tr>
<tr><td>1N5443A</td><td>2.6/3.1</td><td>400</td><td>MV2103</td><td>2.5/3.2</td><td>400</td><td></td><td></td><td></td><td>MV1624</td><td>2.0/2.3</td><td>300</td><td></td><td></td><td></td></tr>
<tr><td>1N5444A</td><td>2.6/3.1</td><td>400</td><td>MV2104</td><td>2.5/3.2</td><td>400</td><td></td><td></td><td></td><td>MV1626</td><td>2.0/2.3</td><td>300</td><td></td><td></td><td></td></tr>
<tr><td>1N5445A</td><td>2.6/3.1</td><td>400</td><td>MV2105</td><td>2.5/3.2</td><td>400</td><td>MV830</td><td>1.8/2.00</td><td>30</td><td>MV1628</td><td>2.0/2.3</td><td>250</td><td></td><td></td><td></td></tr>
<tr><td>1N5446A</td><td>2.6/3.1</td><td>350</td><td>MV2106</td><td>2.5/3.2</td><td>350</td><td>MV831</td><td>1.8/2.00</td><td>25</td><td>MV1630</td><td>2.0/2.3</td><td>250</td><td></td><td></td><td></td></tr>
<tr><td>1N5447A</td><td>2.6/3.1</td><td>350</td><td></td><td></td><td></td><td></td><td></td><td></td><td>MV1632</td><td>2.0/2.3</td><td>250</td><td></td><td></td><td></td></tr>
<tr><td>1N5448A</td><td>2.6/3.2</td><td>350</td><td>MV2107</td><td>2.5/3.2</td><td>350</td><td>MV832</td><td>1.8/2.10</td><td>25</td><td>MV1634</td><td>2.0/2.3</td><td>250</td><td></td><td></td><td></td></tr>
<tr><td>1N5449A</td><td>2.6/3.2</td><td>350</td><td>MV2108</td><td>2.5/3.2</td><td>300</td><td>MV833</td><td>1.8/2.10</td><td>25</td><td>MV1636</td><td>2.0/2.3</td><td>200</td><td></td><td></td><td></td></tr>
<tr><td>1N5450A</td><td>2.6/3.2</td><td>350</td><td>MV2109</td><td>2.5/3.2</td><td>200</td><td>MV834</td><td>1.9/2.12</td><td>20</td><td>MV1638</td><td>2.0/2.4</td><td>200</td><td></td><td></td><td></td></tr>
<tr><td>1N5451A</td><td>2.6/3.2</td><td>300</td><td>MV2110</td><td>2.5/3.2</td><td>150</td><td>MV835</td><td>1.9/2.12</td><td>20</td><td>MV1640</td><td>2.0/2.4</td><td>200</td><td></td><td></td><td></td></tr>
<tr><td>1N5452A</td><td>2.6/3.2</td><td>250</td><td>MV2111</td><td>2.5/3.2</td><td>150</td><td>MV836</td><td>1.9/2.15</td><td>15</td><td>MV1642</td><td>2.0/2.4</td><td>200</td><td></td><td></td><td></td></tr>
<tr><td>1N5453A</td><td>2.6/3.3</td><td>200</td><td>MV2112</td><td>2.6/3.3</td><td>150</td><td>MV837</td><td>1.9/2.15</td><td>15</td><td>MV1644</td><td>2.0/2.4</td><td>150</td><td></td><td></td><td></td></tr>
<tr><td>1N5454A</td><td>2.7/3.3</td><td>175</td><td>MV2113</td><td>2.6/3.3</td><td>150</td><td>MV838</td><td>2.0/2.18</td><td>15</td><td>MV1646</td><td>2.0/2.4</td><td>150</td><td></td><td></td><td></td></tr>
<tr><td>1N5455A</td><td>2.7/3.3</td><td>175</td><td>MV2114</td><td>2.6/3.3</td><td>100</td><td>MV839</td><td>2.0/2.18</td><td>10</td><td>MV1648</td><td>2.0/2.4</td><td>150</td><td></td><td></td><td></td></tr>
<tr><td>1N5456A</td><td>2.7/3.3</td><td>175</td><td>MV2115</td><td>2.6/3.3</td><td>100</td><td>MV840</td><td>2.0/2.18</td><td>10</td><td>MV1650</td><td>2.0/2.4</td><td>150</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>MV1652</td><td>2.6</td><td>250</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>MV1654</td><td>2.6</td><td>250</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>MV1656</td><td>2.6</td><td>200</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>MV1658</td><td>2.6</td><td>200</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>MV1660</td><td>2.6</td><td>150</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>MV1662 ⑤</td><td>2.3</td><td>150</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>MV1664 ⑤</td><td>2.3</td><td>100</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>MV1666 ⑤</td><td>2.3</td><td>100</td></tr>
</table>

HYPER-ABRUPT JUNCTION TUNING DIODES

Hyper-Abrupt Junction Tuning Diodes have a greater capacitance change per bias voltage change than abrupt junction diodes. A capacitance change of greater than TEN TIMES for a bias change from 2 to 10 volts is achieved. Available in standard glass packages.

Type Number	C_T, DIODE CAPACITANCE		TR, TUNING RATIO		Q, FIGURE OF MERIT
	V_R = 1.0 Vdc f = 1.0 MHz pF (typ)	V_R = 2.0 Vdc f = 1.0 MHz pF nom ±20%	C_1/C_{10} f = 1.0 MHz min	C_2/C_{10} f = 1.0 MHz min	V_R = 2.0 Vdc f = 1.0 MHz min
MV1401	550	–	14	–	200
MV1403	275	175	–	10	200
MV1404	190	120	–	10	200
MV1405	390	250	–	10	200

1N... JEDEC REGISTERED DEVICE SPECIFICATIONS

DIODES
- Reference
- Zener
- Signal

RECTIFIERS
- Fast Recovery

POWER VARACTORS
- Tuning Diodes

ASSEMBLIES

1N-NUMBERED DEVICES for MILITARY APPLICATIONS

The following tables list devices that comply with military specifications.

SILICON ZENER DIODES ±5% SERIES

MIL-S-19500/127
†JAN 1N746A .. thru .. JAN 1N759A

MIL-S-19500/117
†JAN 1N962B .. thru .. JAN 1N992B

***MIL-S-19500/114**

†JAN 1N2804B.. thru ..JAN 1N2811B
†JAN 1N2813B ....
†JAN 1N2814B ....
†JAN 1N2816B ....
†JAN 1N2818B.. thru ..JAN 1N2820B
†JAN 1N2822B.. thru ..JAN 1N2827B
†JAN 1N2829B ....
†JAN 1N2831B.. thru ..JAN 1N2838B
†JAN 1N2840B.. thru ..JAN 1N2846B

***MIL-S-19500/124**

†JAN 1N2970B.. thru ..JAN 1N2977B
†JAN 1N2979B ....
†JAN 1N2980B ....
†JAN 1N2982B ....
†JAN 1N2984B.. thru ..JAN 1N2986B
†JAN 1N2988B.. thru ..JAN 1N2993B
†JAN 1N2995B ....
†JAN 1N2997B ....
†JAN 1N2999B.. thru ..JAN 1N3005B
†JAN 1N3007B.. thru ..JAN 1N3009B
†JAN 1N3011B ....
†JAN 1N3012B ....
†JAN 1N3014B ....
†JAN 1N3015B ....

MIL-S-19500/115
†JAN 1N3016B.. thru ..JAN 1N3051B

MIL-S-19500/115
†JAN 1N3821A.. thru ..JAN 1N3828A

****MIL-S-19500/272**
JAN 1N3993A .. thru .. JAN 1N4000A

MIL-S-19500/127
†JAN 1N4370A.. thru ..JAN 1N4372A

*Reverse Polarities (Suffix RB) are available.
**Reverse Polarities (Suffix RA) are available.

TC REFERENCE DIODES

MIL-S-19500

JAN 1N429	/299
†JAN 1N821	/159
†JAN 1N823	/159
†JAN 1N825	/159
†JAN 1N827	/159
†JAN 1N829	/159
†JAN 1N935B	/156
†JAN 1N937B	/156
†JAN 1N938B	/156
†JAN 1N939B	/156
†JAN 1N941B	/157
†JAN 1N943B	/157
†JAN 1N944B	/157
†JAN 1N3154	/158
†JAN 1N3155	/158
†JAN 1N3156	/158
†JAN 1N3157	/158

DIODE ASSEMBLIES

MIL-S-19500

JAN 1N1530A	/320
JAN 1N1742A	/298

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†Recommended TX Devices.

1N91 thru 1N93

$V_R = 100 - 300$ V
$I_O = 1.0$ A

CASE 52
(DO-13)

Low-current germanium rectifiers for applications requiring extremely low forward voltage drop, low power dissipation,and high rectification efficiency, such as biasing and battery charging circuits.

MAXIMUM RATINGS*

Rating	Symbol	1N91	1N92	1N93	Unit
Peak Repetitive Reverse Voltage (Rated I_O, $T_A \leq 55^\circ C$, see Figure 2)	$V_{RM(rep)}$	100	200	300	Volts
DC Blocking Voltage $T_A \leq 80^\circ C$	V_R	100	200	300	Volts
$T_A \geq 80^\circ C$		Derate V_R 6.7%/°C above 80°C			
Average Rectified Forward Current (Single Phase, Resistive Load, 60 Hz)	I_O				Amp
$T_A = 55^\circ C$, 100% V_{RM}		1.0			
$T_A = 75^\circ C$, 50% V_{RM}		0.25			
Non-Repetitive Peak Surge Current (Surge Applied at Rated Load Conditions, see Figure 4)	$I_{FM(surge)}$	30			Amp
Operating Junction Temperature Range	T_J	-65 to +95			°C
Storage Temperature Range	T_{stg}	-65 to +125			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}		°C/W
1 inch Leads		100	
1/4 inch Leads		70	

ELECTRICAL CHARACTERISTICS

Characteristics	Symbol	Max	Unit
Peak Forward Voltage Drop (I_F = 150 mAdc, $T_A = 25^\circ C$, see Figure 1)	V_F	0.45	Volts
DC Reverse Current (Rated V_R, $T_A = 25^\circ C$, see Figure 3)	I_R	0.22	mA

* These ratings and characteristics as specified may surpass those specified in the original JEDEC registration for these device types.

1N91 thru 1N93 (continued)

FIGURE 1 — FORWARD CHARACTERISTICS

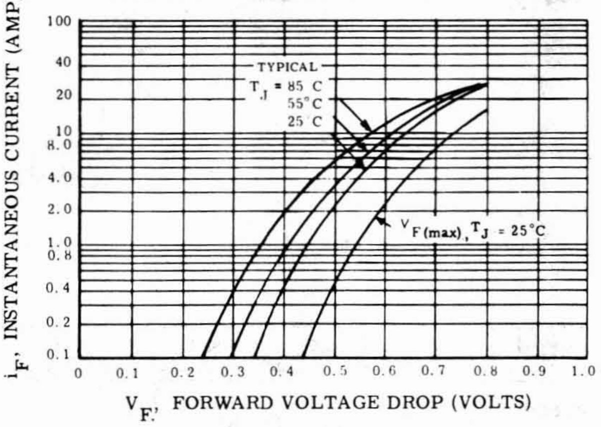


FIGURE 2 — MAXIMUM CURRENT RATINGS

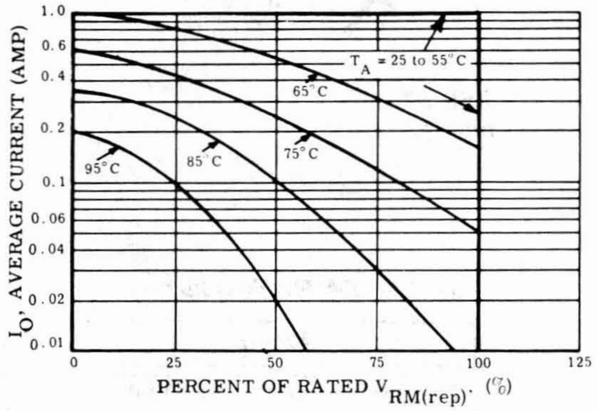


FIGURE 3 — TYPICAL REVERSE CHARACTERISTICS

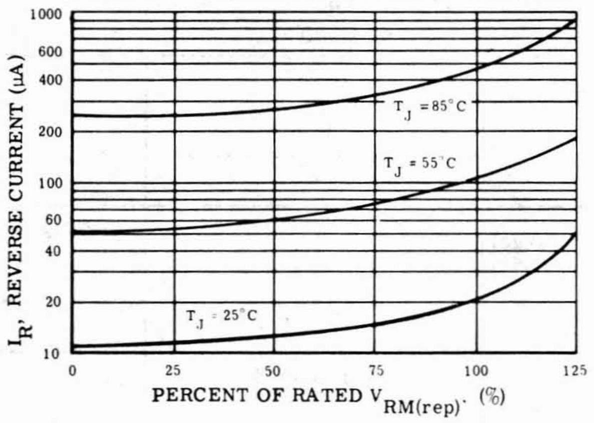
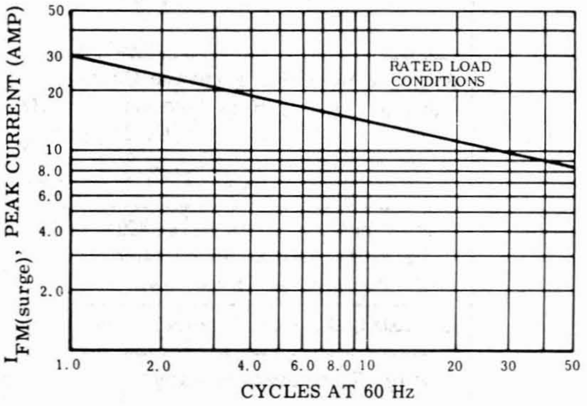


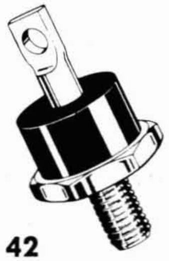
FIGURE 4 — MAXIMUM SURGE CURRENT



1N248B,C thru 1N250B,C

V_R to 600 V
I_O = 20 A

1N1191 thru 1N1198
1N1195A thru 1N1198A
1N3213,1N3214



CASE 42
(DO-5)

Medium current silicon rectifiers. Unique double-case construction consists of hermetically sealed inner metallic case surrounded by molded external case; provides highest degree of ruggedness and reliability. Type numbers shown have cathode connected to case, but reverse-polarity units can be obtained by adding suffix "R" to standard type number, e.g. 1N248BR.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Peak Repetitive Reverse Voltage and DC Blocking Voltage	$V_{RM\,(rep)}$ V_R		Volts
1N248B, 1N1191		50	
1N248C		55	
1N249B, 1N1192		100	
1N249C		110	
1N1193		150	
1N250B, 1N1194		200	
1N250C		220	
1N1195, 1N1195A		300	
1N1196, 1N1196A		400	
1N1197, 1N1197A, 1N3213		500	
1N1198, 1N1198A, 1N3214		600	
RMS Reverse Voltage	V_r		Volts
1N248B, 1N1191		35	
1N248C		38.5	
1N249B, 1N1192		70	
1N249C		77	
1N1193		105	
1N250B, 1N1194		140	
1N250C		154	
1N1195, 1N1195A		210	
1N1196, 1N1196A		280	
1N1197, 1N1197A, 1N3213		350	
1N1198, 1N1198A, 1N3214		420	
Average 1/2-Wave Rectified Forward Current (Resistive Load, 60 Hz, T_C = 150°C)	I_O	20	Amp
Peak Repetitive Forward Current (T_C = 150°C)	$I_{FM\,(rep)}$	90	Amp
Peak Surge Current (T_C = 150°C, superimposed on Rated Current at Rated Voltage, 1/2-Cycle, 1/120 sec)	$I_{FM\,(surge)}$	350	Amp

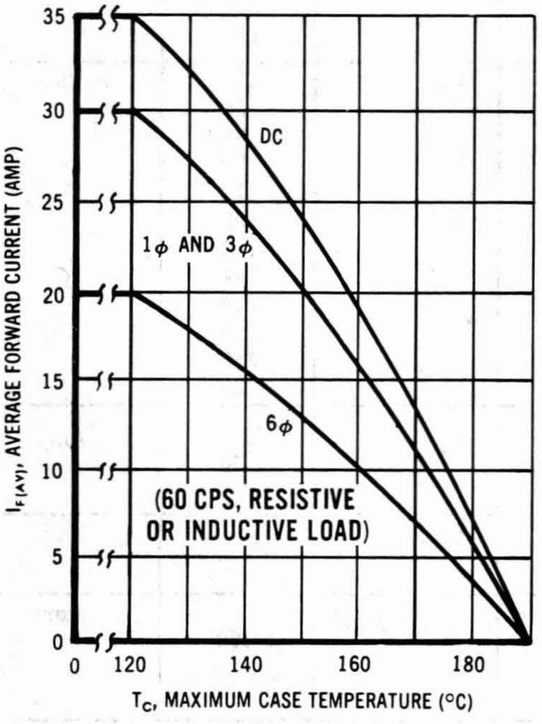
THERMAL CHARACTERISTICS

Maximum Operating and Storage Temperature: −65 to + 190°C
Maximum Thermal Impedance, Junction to Case: θ_{JC} = 1.50°C/W DC

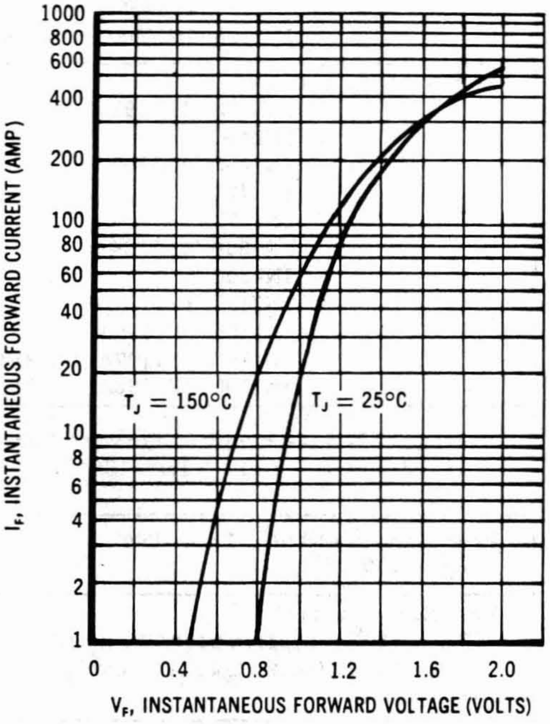
ELECTRICAL CHARACTERISTICS

Characteristics	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop ($I_{O\,(max)}$, rated V_r, 60 cps, T_C = 150°C)	$V_{F(AV)}$	0.6	Volts
Instantaneous Forward Voltage Drop (I_F = 100 Amps, T_J = 25°C)	V_F	1.5	Volts
Full Cycle Average Reverse Current ($I_{O\,(max)}$, rated V_r, 60 cps, T_C = 150°C)	$I_{R(AV)}$		mA
1N248B thru 1N250B, 1N1191 thru 1N1198		5.0	
1N248C		3.8	
1N249C		3.6	
1N250C		3.4	
1N1195A		3.2	
1N1196A		2.5	
1N1197A		2.2	
1N1198A		1.5	
1N3213 and 1N3214		10.0	
DC Reverse Current (Rated V_R, T_C = 25°C)	I_R	1.0	mA

MAXIMUM AVERAGE FORWARD CURRENT RATING versus MAXIMUM CASE TEMPERATURE

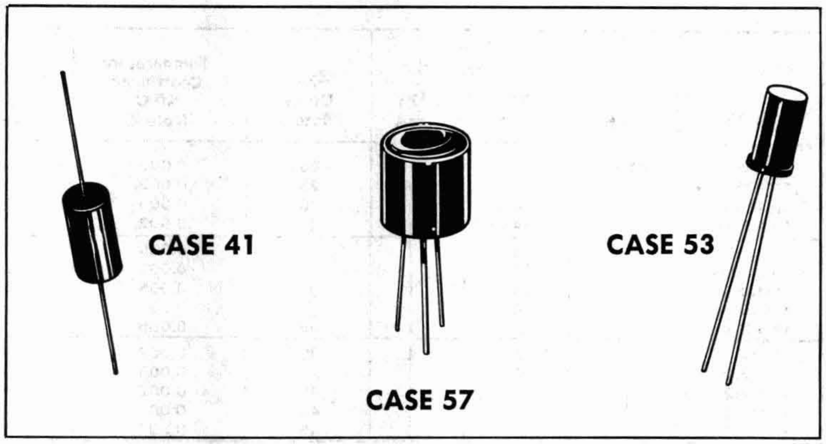


TYPICAL FORWARD CHARACTERISTICS



1N429
(6.2V)
1N1530 series
(8.4V)
1N1735 series
(6.2V thru 49.6V)
1N4057 series
(12.4 thru 200V)

Temperature compensated zener reference diodes designed for reference sources utilizing an oxide-passivated junction for long-term voltage stability, high uniformity and reliable operation.



MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Operating Junction Temperature Range	T_J	-55 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C
Power Dissipation*	P_D	See Tables 1 & 2*	W

*The devices are designed for operation at the specified I_{ZT}. Operation above or below this current is not recommended, since the temperature coefficient is no longer valid. See Note 2 and Figure 4.

MECHANICAL CHARACTERISTICS

Case:	Void free, transfer molded plastic package
Polarity:	Indicated by diode symbol except 1N429, 1N1530, 1N1530A where cathode indicated by polarity dot of contrasting color
Weight:	Varies according to device 0.5 grams (min) 12 grams (max)
Finish:	All external surfaces corrosion resistant and leads readily solderable.

1N429/1N1530/1N1735/1N4057 (continued)

TABLE 1 – ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

TYPE	CASE	Zener Voltage ±5% V_Z @ Volts	I_{ZT} mA	Z_{ZT} Ohms (Note 3)	Temperature Coefficient %/°C (Note 2)	ΔV_Z @ I_{ZT} (+25 to +100°C) Volts (Note 2)	ΔV_Z (–55 to + 25°C) Volts (Note 2)	P_D* T_A = 25°C W
1N4057	41-8	12.4	10	25	0.005	0.047	0.050	1.5
1N4057A		12.4		25	0.002	0.019	0.020	
1N4058		14.6		30	0.005	0.055	0.058	
1N4058A		14.6			0.002	0.022	0.023	
1N4059		16.8			0.005	0.063	0.067	
1N4059A		16.8			0.002	0.025	0.027	
1N4060		18.5			0.005	0.069	0.074	
1N4060A		18.5		↓	0.002	0.028	0.030	
1N4061		21		35	0.005	0.079	0.084	
1N4061A		21		35	0.002	0.032	0.034	
1N4062		23		40	0.005	0.086	0.092	
1N4062A		23		40	0.002	0.035	0.037	
1N4063		27		45	0.005	0.101	0.108	
1N4063A		27		45	0.002	0.041	0.043	
1N4064		30		50	0.005	0.113	0.120	
1N4064A		30		50	0.002	0.045	0.048	
1N4065		33		55	0.005	0.124	0.132	
1N4065A		33	↓	55	0.002	0.050	0.053	
1N4066		37	7.5	80	0.005	0.139	0.148	
1N4066A		37		80	0.002	0.056	0.059	
1N4067		43		90	0.005	0.161	0.172	
1N4067A		43		90	0.002	0.065	0.069	
1N4068		47		100	0.005	0.176	0.188	
1N4068A	↓	47		100	0.002	0.071	0.075	↓
1N4069	41-9	51		110	0.005	0.191	0.204	2.0
1N4069A		51		110	0.002	0.077	0.082	
1N4070		56		120	0.005	0.210	0.224	
1N4070A		56		120	0.002	0.084	0.090	
1N4071		62		135	0.005	0.232	0.248	
1N4071A		62	↓	135	0.002	0.093	0.099	
1N4072		68	5.0	230	0.005	0.255	0.272	
1N4072A		68		230	0.002	0.102	0.109	
1N4073		75		250	0.005	0.281	0.300	
1N4073A		75		250	0.002	0.113	0.120	
1N4074		82		270	0.005	0.307	0.328	
1N4074A		82		270	0.002	0.123	0.131	
1N4075		87		290	0.005	0.326	0.348	
1N4075A		87		290	0.002	0.131	0.139	
1N4076		91		310	0.005	0.341	0.364	
1N4076A		91		310	0.002	0.137	0.146	
1N4077		100		340	0.005	0,375	0.400	
1N4077A		100	↓	340	0.002	0.150	0.160	
1N4078		105	2.5	700	0.005	0.394	0.420	
1N4078A		105		700	0.002	0.158	0.168	
1N4079		110		740	0.005	0.413	0.440	
1N4079A		110		740	0.002	0.165	0.176	
1N4080		120		800	0.005	0.450	0.480	
1N4080A	↓	120		800	0.002	0.180	0.192	↓
1N4081	41-10	130		840	0.005	0.488	0.520	2.5
1N4081A		130		840	0.002	0.195	0.208	
1N4082		140		960	0.005	0.525	0.560	
1N4082A		140		960	0.002	0.210	0.224	
1N4083		150		1020	0.005	0.563	0.600	
1N4083A		150		1020	0.002	0.225	0.240	
1N4084		175		1150	0.005	0.656	0.700	
1N4084A		175		1150	0.002	0.263	0.280	
1N4085		200		1350	0.005	0.750	0.800	
1N4085A	↓	200	↓	1350	0.002	0.300	0.320	↓

*Derate linearly from 25°C to 175°C.

TABLE 2 – ELECTRICAL CHARACTERISTICS (I_{ZT} = 7.5 mA, T_A = 25°C unless otherwise noted)

Type Number	Zener Voltage $V_Z \pm 5\%$ (Volts)	Max Voltage Change @ −55, +25, +100°C ΔV_Z (Volts) (Note 2)	Max Dynamic Impedance (Note 3) Z_{ZT} (Ohms)	Temperature Coefficient (Note 2) (%/°C)	Power* Dissipation P_D (mW)	Case Number	Figure Number
1N429 ①	6.2	0.050	20	0.01	200	53	1
1N1735	6.2	0.050	20	0.01	200	41-6	2
1N1530** 1N1530A** ②	8.4	0.014 0.007	15	0.002 0.001	250	57	3
1N1736 1N1736A	12.4	0.100 0.050	40	0.01 0.005	400	41-3	2
1N1737 1N1737A	18.6	0.150 0.075	60	0.01 0.005	600	41-5	2
1N1738 1N1738A	24.8	0.200 0.100	80	0.01 0.005	800	41-5	2
1N1739 1N1739A	31.0	0.250 0.125	100	0.01 0.005	1000	41-4	2
1N1740 1N1740A	37.2	0.300 0.150	120	0.01 0.005	1200	41-4	2
1N1741 1N1741A	43.4	0.350 0.175	140	0.01 0.005	1400	41-4	2
1N1742 1N1742A ③	49.6	0.400 0.200	180	0.01 0.005	1600	41-4	2

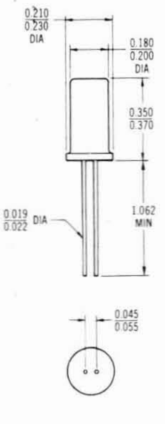
*Derate linearly from 25°C to 175°C

**I_{ZT} = 10 mA

① Available to MIL-S-19500/299 Specifications.

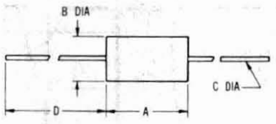
② Available to MIL-S-19500/320 Specifications.

③ Available to MIL-S-19500/298 Specifications.



0.210
0.230
DIA
0.180
0.200
DIA
0.350
0.370
0.019
0.022 DIA
1.062
MIN
0.045
0.055

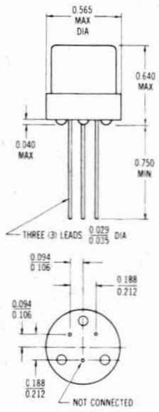
FIGURE 1
CASE 53



B DIA
C DIA
D
A

PKG.	OUTLINE DIMENSIONS (INCHES)			
	A MAX	B MAX	C ± 0.002	D MIN
41-1	1.00	0.500	0.032	1.25
41-2	0.500	0.375	0.032	1.25
41-3	1.030	0.378	0.032	1.25
41-4	1.220	0.641	0.032	1.75
41-5	0.655	0.641	0.032	1.25
41-6	0.520	0.275	0.022	1.25
41-7	1.000	0.375	0.032	1.25
41-8	0.520	0.260	0.032	1.00
41-9	0.780	0.260	0.032	1.00
41-10	1.155	0.323	0.032	1.00

FIGURE 2
CASE 41



0.565
MAX
DIA
0.640
MAX
0.040
MAX
0.750
MIN
THREE (3) LEADS 0.029/0.035 DIA
0.094
0.106
0.188
0.212
0.094
0.106
0.188
0.212
NOT CONNECTED

FIGURE 3
CASE 57

TEMPERATURE-COMPENSATED REFERENCE DIODES

Temperature compensated reference diodes are made possible by taking advantage of the differing thermal characteristics of forward and reverse biased silicon PN junctions. A forward biased junction has a negative temperature coefficient of approximately 2.0 millivolts/°C. Reverse biased junctions above 5.0 volts have a positive temperature coefficient and therefore it is possible by judicious selection of combinations of forward and reverse biased junctions to obtain a device which shows a very low temperature coefficient due to cancellation. Because of the differing impedance versus temperature characteristics of the junctions involved, optimum temperature stability is obtained by operating in the zener current range at which the temperature coefficient is a minimum (Figure 4)

Further information, including a method of effective impedance cancellation in a bridge circuit for ultra-stable reference supplies, is contained in the Zener Diode Handbook. The handbook, containing valuable theory, design, and application information, is available from your distributor.

NOTE 1 – Voltage-Current Characteristics

Figure 4 shows the voltage-current characteristics of a typical temperature compensated unit at three different temperatures. The exploded view illustrates the cross-over area (optimum temperature stability point), the non-linearity of the temperature-voltage relationship, and the maximum voltage variation (ΔV_Z) for the three temperatures shown.

Because of device impedance, the reference voltage will vary with changes in zener current. These variations can be minimized by driving the device from a constant current source.

NOTE 2 – Voltage Variation (ΔV_Z) and Temperature Coefficient

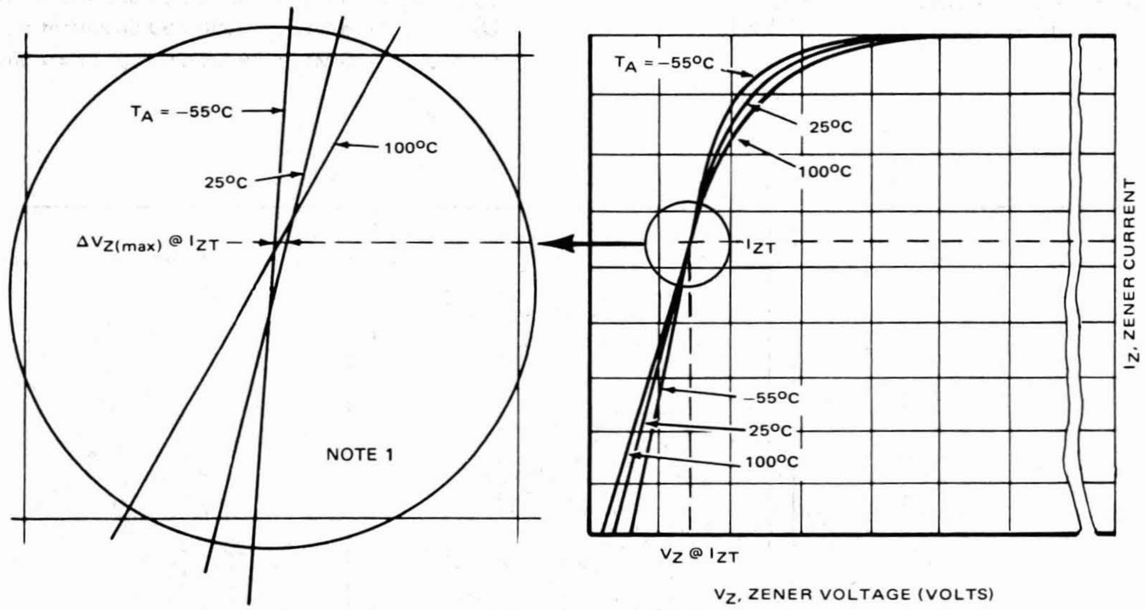
All reference diodes are characterized by the "box" method. This method provides for a guaranteed maximum voltage variation (ΔV_Z in mV) over a specified temperature range at the specified I_{ZT} verified by tests at several points within the range. (Maximum voltage variations over the specified temperature ranges are given in Tables 1 and 2.) The design engineer now has a number (without any calculations) telling him the stability of the voltage over the temperature range of interest thus giving him the maximum flexibility as well as economy in selecting the temperature stability required. The referenced military specifications use this approach to characterize these devices.

Since reference diodes have a non-linear voltage-temperature relationship (illustrated in exploded view, Figure 4) the temperature coefficients in %/°C are tabulated primarily for reference purposes and are guaranteed only at the end points of the temperature range.

NOTE 3 – Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60 Hz ac voltage which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. A cathode-ray tube curve trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

FIGURE 4 – TYPICAL OPERATING CHARACTERISTICS



1N702 thru 1N745

¼ W
2 — 200 V

CASE 51
(DO-7)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N5221 series.

Maximum rating-junction and storage temperature range -65 to +175°C, derated 1.67 mW/°C.

1N746 thru 1N759 1N746A thru 1N759A
1N4370 thru 1N4372 1N4370A thru 1N4372A

400 mW
2.4 — 12 V

CASE 51
(DO-7)

Hermetically sealed, all-glass case with all external surfaces corrosion resistant. Cathode end, indicated by color band, will be positive with respect to anode end when operated in the zener region.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C
D C Power Dissipation: 400 Milliwatts at 50°C Ambient (Derate 3.2 mW/°C Above 50°C Ambient)

TOLERANCE DESIGNATIONS

The type numbers shown have tolerance designations as follows:

1N4370 series: ±10%, suffix A for ±5% units.
1N746 series: ±10%, suffix A for ±5% units.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

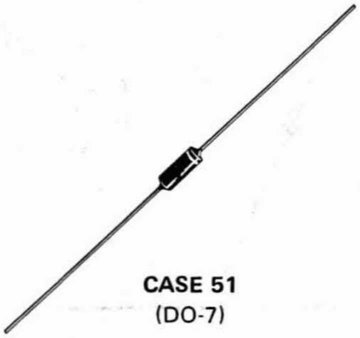
TYPE NUMBER	NOMINAL ZENER VOLTAGE V_Z @ I_{ZT} VOLTS	TEST CURRENT I_{ZT} mA	MAXIMUM ZENER IMPEDANCE Z_{ZT} @ I_{ZT} Ohms	MAXIMUM DC ZENER CURRENT I_{ZM} mA	MAXIMUM REVERSE LEAKAGE CURRENT T_A = 25°C I_R @ V_R = 1 V μA	T_A = 150°C I_R @ V_R = 1 V μA
1N4370	2.4	20	30	150	100	200
1N4371	2.7	20	30	135	75	150
1N4372	3.0	20	29	120	50	100
1N746	3.3	20	28	110	10	30
1N747	3.6	20	24	100	10	30
1N748	3.9	20	23	95	10	30
1N749	4.3	20	22	85	2	30
1N750	4.7	20	19	75	2	30
1N751	5.1	20	17	70	1	20
1N752	5.6	20	11	65	1	20
1N753	6.2	20	7	60	0.1	20
1N754	6.8	20	5	55	0.1	20
1N755	7.5	20	6	50	0.1	20
1N756	8.2	20	8	45	0.1	20
1N757	9.1	20	10	40	0.1	20
1N758	10.0	20	17	35	0.1	20
1N759	12.0	20	30	30	0.1	20

SPECIAL SELECTIONS AVAILABLE INCLUDE: **(See Selector Guide for details)**
1 — Nominal zener voltages between those shown.
2 — Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  b. Two or more units matched to one another with any specified tolerance.
3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

1N761 thru 1N769

Recommended for applications requiring an exact replacement only. For new designs see 1N5221 series.

1N816/.4M.64FR10
.4M1.36FR5
.4M1.36FR2
.4M2.04FR5
.4M2.04FR2



CASE 51
(DO-7)

Constant-voltage reference diodes designed for stable forward reference sources, transistor amplifier biasing and similar applications. Ramrod construction provides a rugged, glass-enclosed, hermetically sealed structure.

	ELECTRICAL CHARACTERISTICS ($T_A = 25^oC$)			
Type	V_F @ Volts min/max	I_F mA	I_R $V_R = 4.0$ V µA max	R_D @ I_F ohms
.4M.64FR10/1N816	0.58/0.70	1.0	0.1	50
.4M1.36FR5	1.29/1.43	10	↓	20
.4M1.36FR2	1.33/1.39	↓	↓	20
.4M2.04FR5	1.94/2.14	↓	↓	30
.4M2.04FR2	2.00/2.08	↓	↓	30

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all glass

DIMENSIONS: See outline drawing

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band. Cathode negative for forward reference application.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any

1N821, A, 1N823, A (SILICON)
1N825, A, 1N827, A
1N829, A

6.2 V ± 5.0%

Temperature-compensated zener reference diodes utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.

CASE 51
(DO-7)

MAXIMUM RATINGS

Junction Temperature: -55 to +175°C

Storage Temperature: -65 to +175°C

DC Power Dissipation: 400 mW @ T_A = 50°C

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

JEDEC Type No. (Note 1)	Maximum Voltage Change ΔV_Z (Volts) (Note 2)	Test Temperature °C	Temperature Coefficient %/°C (Note 2)	Maximum Dynamic Impedance Z_{ZT} Ohms (Note 3)

V_Z = 6.2 V ±5.0%* @ I_{ZT} = 7.5 mA

1N821	0.096	-55, 0, +25, +75, +100	0.01	15
1N823	0.048		0.005	
1N825	0.019		0.002	
1N827	0.009		0.001	
1N829	0.005		0.0005	
1N821A	0.096		0.01	10
1N823A	0.048		0.005	
1N825A	0.019		0.002	
1N827A	0.009		0.001	
1N829A	0.005		0.0005	

*Tighter-tolerance units available on special request.

CAPACITANCE (C) = 30 to 400 pF @ 90% of V_Z

FORWARD BREAKDOWN VOLTAGE (V_f) = 15 to 400 V

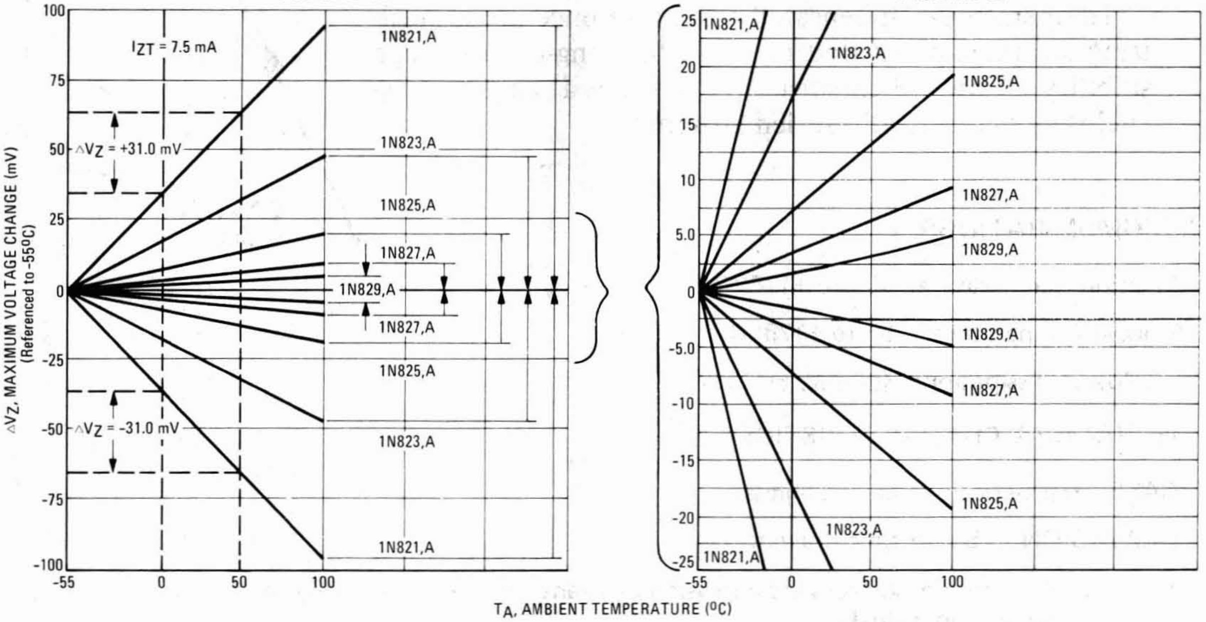
1N821,A / 1N823,A / 1N825,A / 1N827,A / 1N829,A (continued)

MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(with I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N821 thru 1N829

FIGURE 1a FIGURE 1b



ZENER CURRENT versus MAXIMUM VOLTAGE CHANGE

(At Specified Temperatures)

(See Note 5)

MORE THAN 95% OF THE UNITS ARE IN THE RANGES INDICATED BY THE CURVES.

FIGURE 2 – 1N821 SERIES

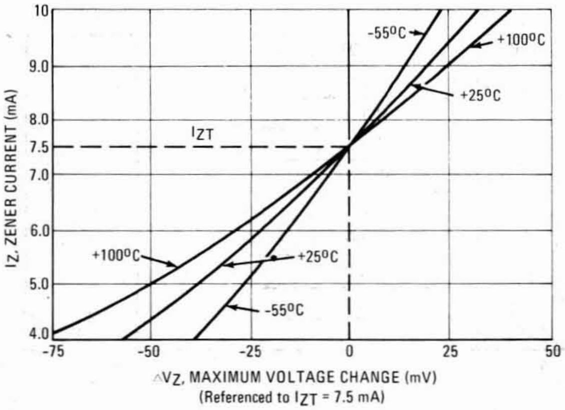
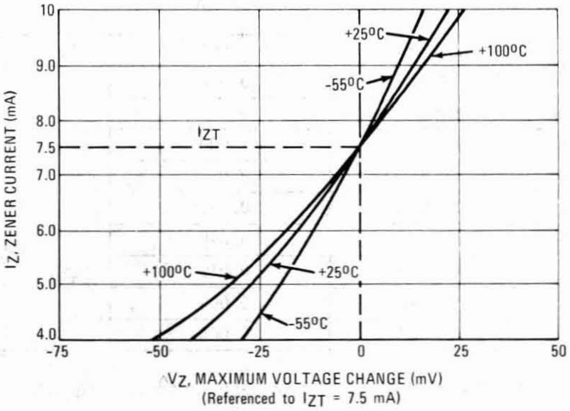


FIGURE 3 – 1N821A SERIES



1N821,A / 1N823,A / 1N825,A / 1N827,A / 1N829,A (continued)

MAXIMUM ZENER IMPEDANCE versus ZENER CURRENT

(See Note 3)

MORE THAN 95% OF THE UNITS ARE IN THE RANGES INDICATED BY THE CURVES.

FIGURE 4 – 1N821 SERIES

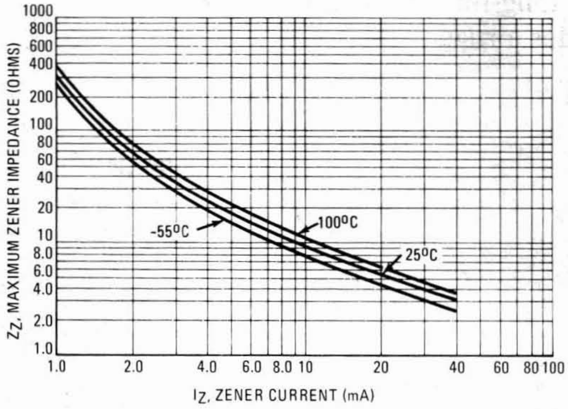


FIGURE 5 – 1N821A SERIES

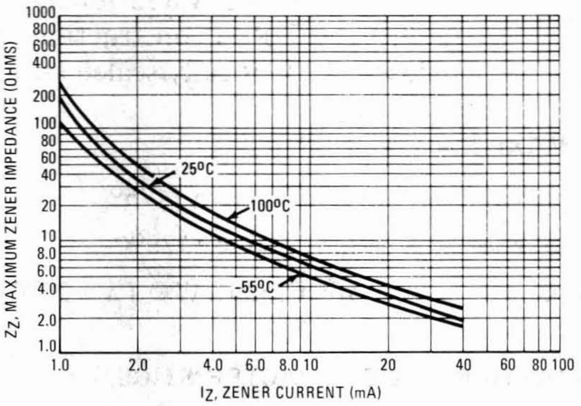
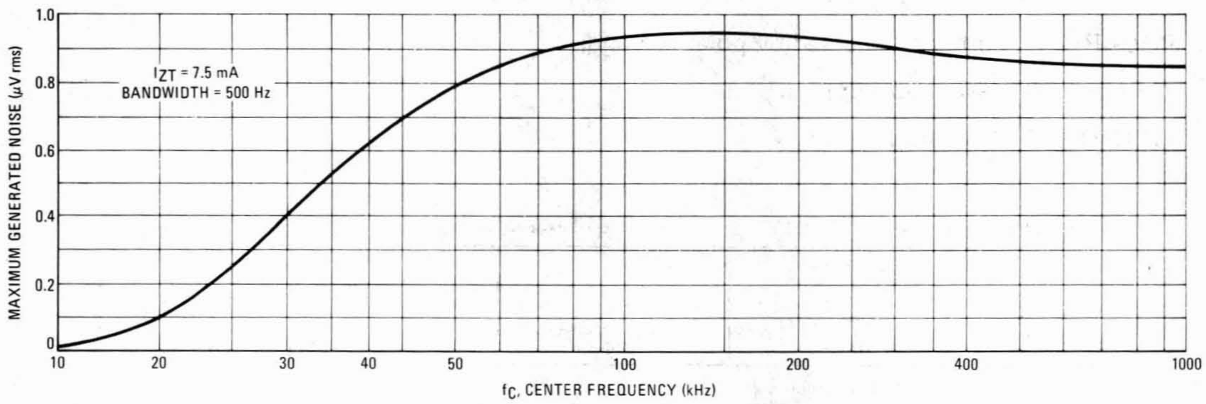


FIGURE 6 – DISTRIBUTION OF MAXIMUM GENERATED NOISE



NOTE 1:

Types 1N821, 1N823, 1N825, 1N827, and 1N829 are available to MIL-S-19500/159 and MEG-A-LIFE II, Levels 1, 2, & 3, specifications.

NOTE 2:

Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. V_Z is measured and recorded at each temperature specified. The ΔV_Z between the highest and lowest values must not exceed the maximum ΔV_Z given. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 3:

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. Curves showing the variation of zener impedance with zener current for each series are given in Figures 4 and 5. A cathode-ray tube curve-trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

NOTE 4:

These graphs can be used to determine the maximum voltage change of any device in the series over any specific temperature range. For example, a temperature change from 0 to +50°C will cause a voltage change no greater than +31 mV or -31 mV for 1N821 or 1N821A, as illustrated by the dashed lines in Figure 1. The boundaries given are maximum values. For greater resolution, an expanded view of the shaded area in Figure 1a is shown in Figure 1b.

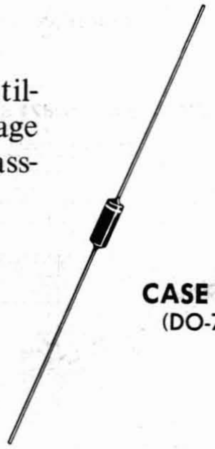
NOTE 5:

The maximum voltage change, ΔV_Z, Figures 2 and 3 is due entirely to the impedance of the device. If both temperature and I_{ZT} are varied, then the total voltage change may be obtained by graphically adding ΔV_Z in Figure 2 or 3 to the ΔV_Z in Figure 1 for the device under consideration. If the device is to be operated at some stable current other than the specified test current, a new set of characteristics may be plotted by superimposing the data in Figure 2 or 3 on Figure 1. For a more detailed explanation see AN-437 (Application Note).

1N935, A, B (SILICON)
thru
1N939, A, B

9.0 V ± 5.0%

Temperature-compensated zener reference diodes utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.



CASE 51
(DO-7)

MAXIMUM RATINGS

Junction Temperature: -55 to +175°C

Storage Temperature: -65 to +175°C

DC Power Dissipation: 500 mW @ T_A = 25°C

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

JEDEC Type No. (Note 1)	Maximum Voltage Change ΔV_Z (Volts) (Note 2)	Test Temperature °C	Temperature Coefficient %/°C (Note 2)	Maximum Dynamic Impedance Z_{ZT} (Ohms) (Note 3)
V_Z = 9.0 V ±5.0%* @ I_{ZT} = 7.5 mA				
1N935	0.067	0, +25, +75	0.01	20
1N936	0.033		0.005	
1N937	0.013		0.002	
1N938	0.006		0.001	
1N939	0.003		0.0005	
1N935A	0.139	-55, 0, +25, +75, +100	0.01	20
1N936A	0.069		0.005	
1N937A	0.027		0.002	
1N938A	0.013		0.001	
1N939A	0.007		0.0005	
1N935B	0.184	-55, 0, +25, +75, +100, +150	0.01	20
1N936B	0.092		0.005	
1N937B	0.037		0.002	
1N938B	0.018		0.001	
1N939B	0.009		0.0005	

*Tighter-tolerance units available on special request.

CAPACITANCE (C) = 20 to 180 pF @ 90% of V_Z

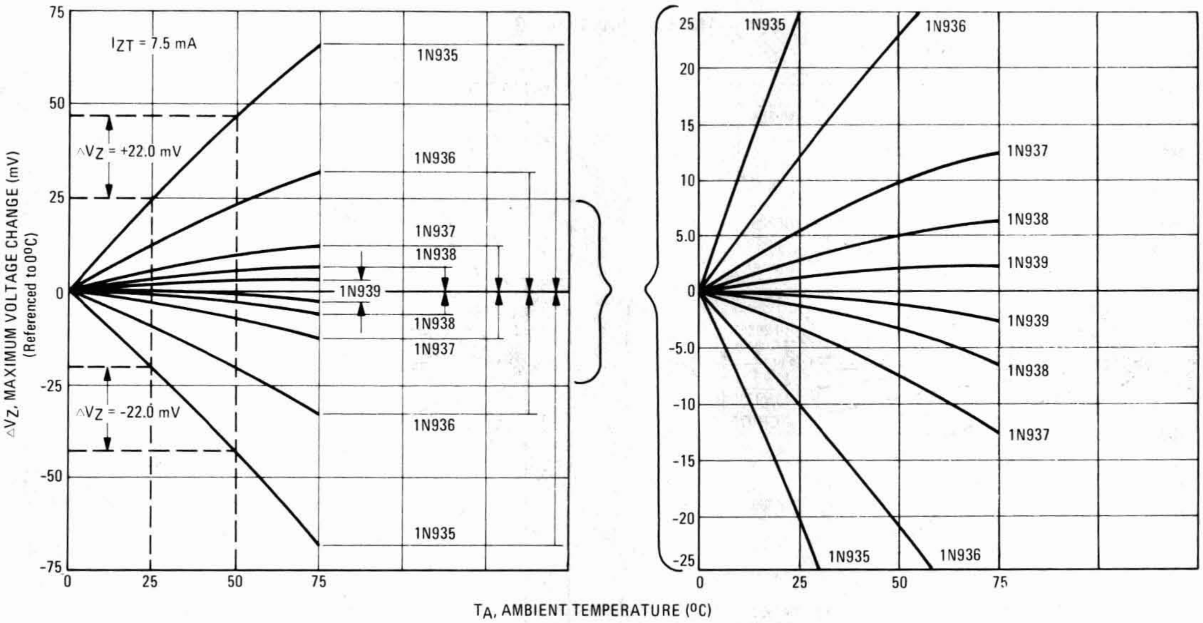
FORWARD BREAKDOWN VOLTAGE (V_f) = 100 to 800 V

MAXIMUM VOLTAGE CHANGE versus TEMPERATURE

(with I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N935 thru 1N939

FIGURE 1a **FIGURE 1b**

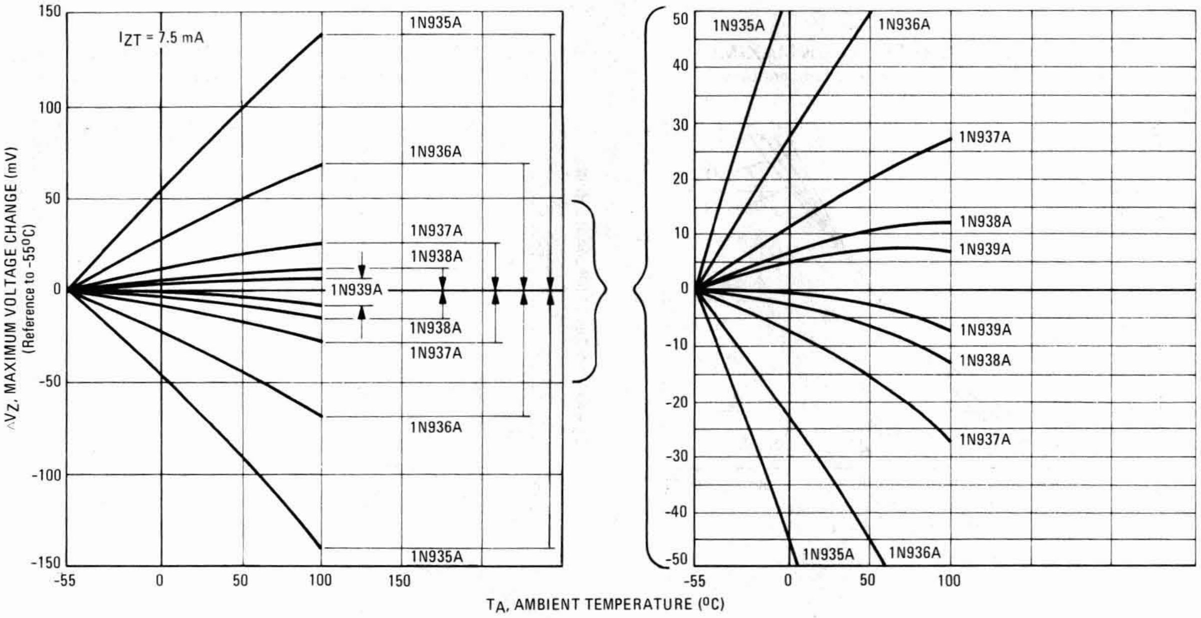


MAXIMUM VOLTAGE CHANGE versus TEMPERATURE

(with I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N935A thru 1N939A

FIGURE 2a **FIGURE 2b**



MAXIMUM VOLTAGE CHANGE versus TEMPERATURE

(with I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N935B thru 1N939B

FIGURE 3a

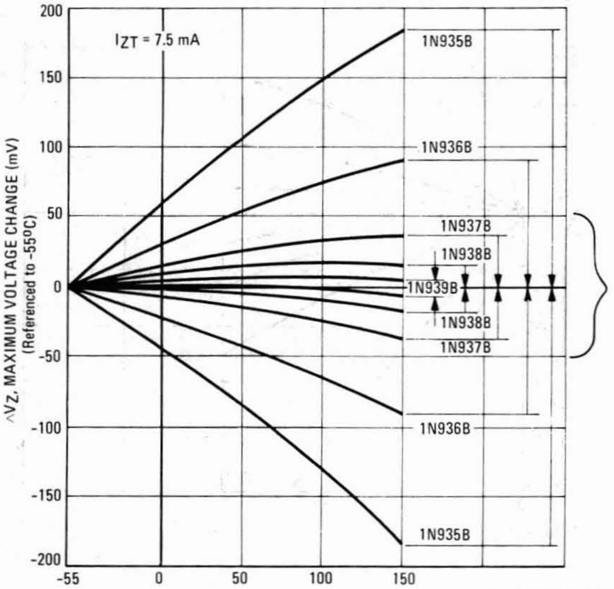
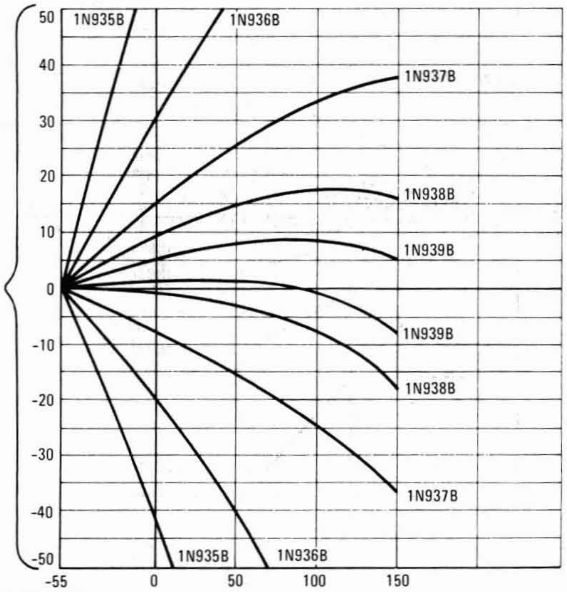


FIGURE 3b



T_A, AMBIENT TEMPERATURE (°C)

FIGURE 4 – ZENER CURRENT versus MAXIMUM VOLTAGE CHANGE (at specified temperatures)
(See Note 5)

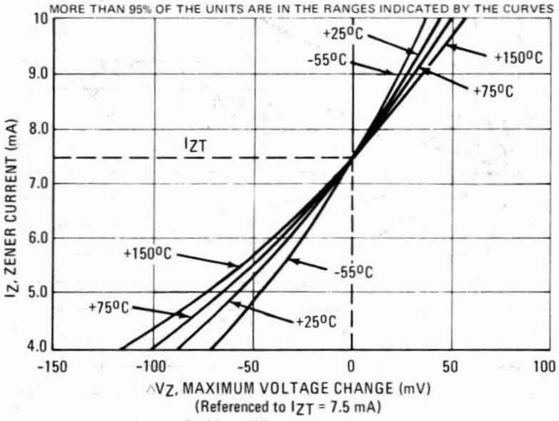


FIGURE 5 – MAXIMUM ZENER IMPEDANCE versus ZENER CURRENT
(See Note 3)

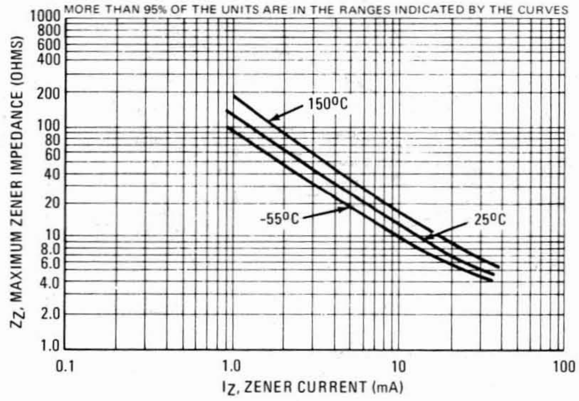
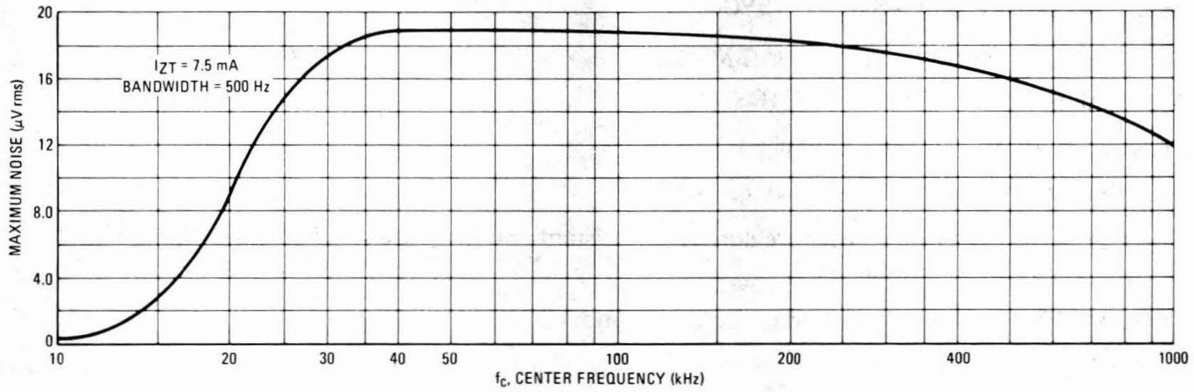


FIGURE 6 – DISTRIBUTION OF MAXIMUM GENERATED NOISE



NOTE 1:

Types 1N935B, 1N937B, and 1N939B are available to MIL-S-19500/156 and MEG-A-LIFE II, Levels 1, 2, & 3, specifications.

NOTE 2:

Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 3:

Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}.

Curves showing the variation of zener impedance with zener current for each series are given in Figure 5. A cathode-ray tube curve-trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

NOTE 4:

These graphs can be used to determine the maximum voltage change of any device in the series over any specific temperature range. For example, a temperature change from +25 to +50°C will cause a voltage change no greater than +22 mV or -22 mV for 1N935, as illustrated by the dashed lines in Figure 1. The boundaries given are maximum values. For greater resolution, expanded views of the shaded areas in Figures 1a, 2a, and 3a are shown in Figures 1b, 2b, and 3b respectively.

NOTE 5:

The maximum voltage change, ΔV_Z, in Figure 4 is due entirely to the impedance of the device. If both temperature and I_{ZT} are varied, then the total voltage change may be obtained by adding ΔV_Z in Figure 4 to the ΔV_Z in Figure 1, 2, or 3 for the device under consideration. If the device is to be operated at some stable current other than the specified test current, a new set of characteristics may be plotted by superimposing the data in Figure 4 on Figure 1, 2, or 3.

11.7 V ± 5.0%

1N941, A, B (SILICON)
thru
1N946, A, B

Temperature-compensated zener reference diodes utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.

CASE 51
(DO-7)

MAXIMUM RATINGS

Junction Temperature: -55 to +175°C

Storage Temperature: -65 to +175°C

DC Power Dissipation: 500 mW @ T_A = 25°C

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any

ELECTRICAL CHARACTERISTICS (TA = 25°C unless otherwise noted)

JEDEC Type No. (Note 1)	Maximum Voltage Change ΔV_Z (Volts) (Note 2)	Test Temperature °C	Temperature Coefficient %/°C (Note 2)	Maximum Impedance Z_{ZT} (Ohms) (Note 3)
V_Z = 11.7 V ±5.0%* @ I_{ZT} = 7.5 mA				
1N941	0.088	0, +25, +75	0.01	30
1N942	0.044		0.005	
1N943	0.018		0.002	
1N944	0.009		0.001	
1N945	0.004		0.0005	
1N946	0.002		0.0002	
1N941A	0.181	-55, 0, +25, +75, +100	0.01	30
1N942A	0.090		0.005	
1N943A	0.036		0.002	
1N944A	0.018		0.001	
1N945A	0.009		0.0005	
1N946A	0.004		0.0002	
1N941B	0.239	-55, 0, +25, +75, +100, +150	0.01	30
1N942B	0.120		0.005	
1N943B	0.047		0.002	
1N944B	0.024		0.001	
1N945B	0.012		0.0005	
1N946B	0.005		0.0002	

*Tighter-tolerance units available on special request.

CAPACITANCE (C) = 14 to 35 pF @ 90% of V_Z

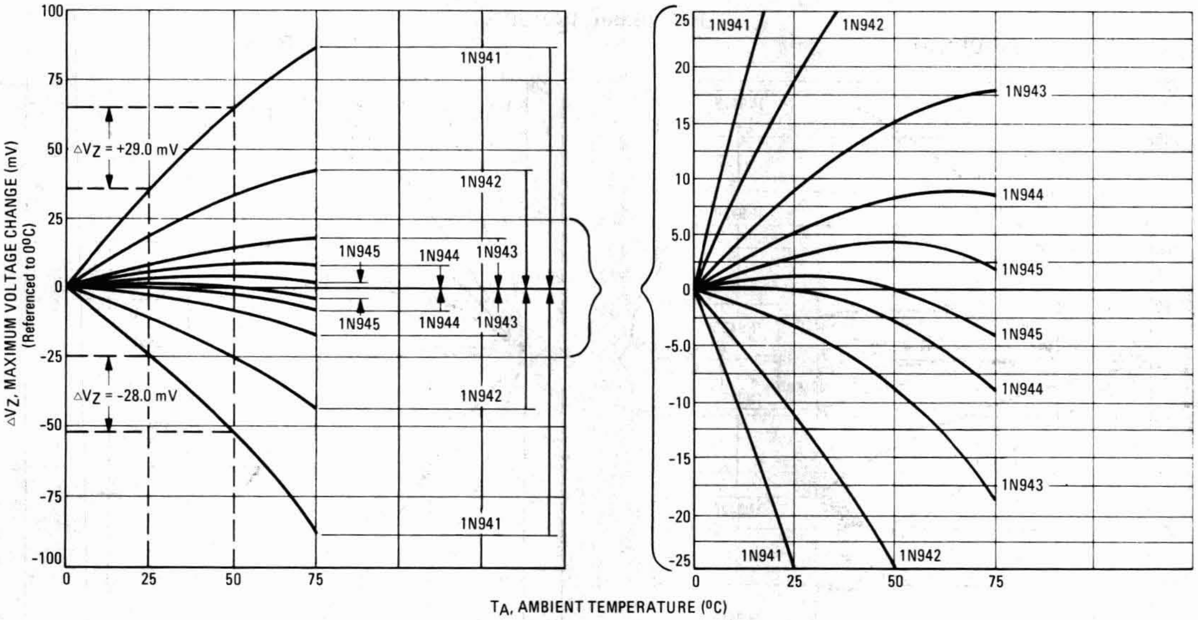
FORWARD BREAKDOWN VOLTAGE (V_f) = 150 to 1200 V

MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(With I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N941 thru 1N945

FIGURE 1a FIGURE 1b

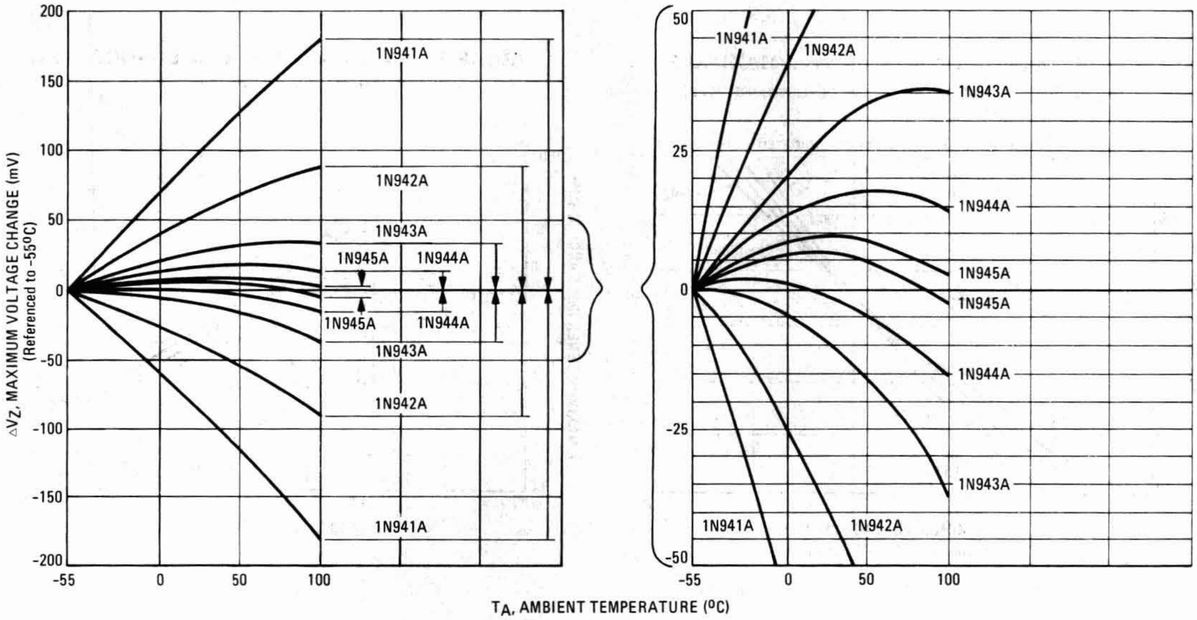


MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(With I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N941A thru 1N945A

FIGURE 2a FIGURE 2b



MAXIMUM VOLTAGE CHANGE versus TEMPERATURE

(with I_{ZT} = 7.5 mA ±0.01 mA) (See Note 4)

1N941B thru 1N945B

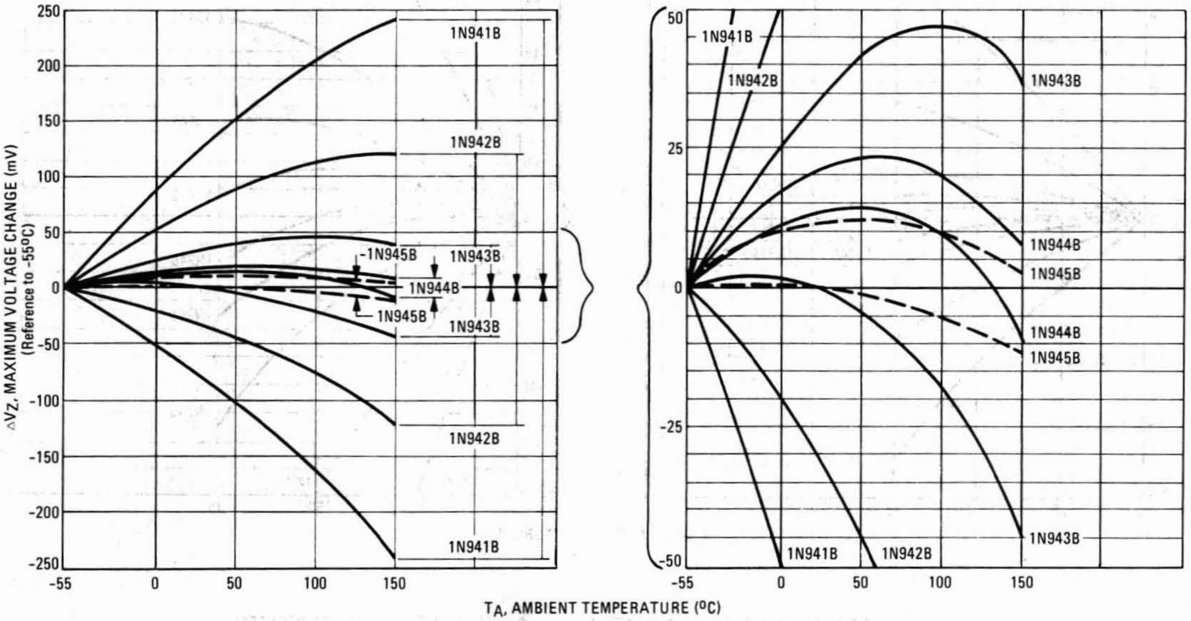


FIGURE 3a

FIGURE 3b

FIGURE 4 – ZENER CURRENT versus MAXIMUM VOLTAGE CHANGE (At specified temperatures)

(See Note 5)

MORE THAN 95% OF THE UNITS ARE IN THE RANGES INDICATED BY THE CURVES

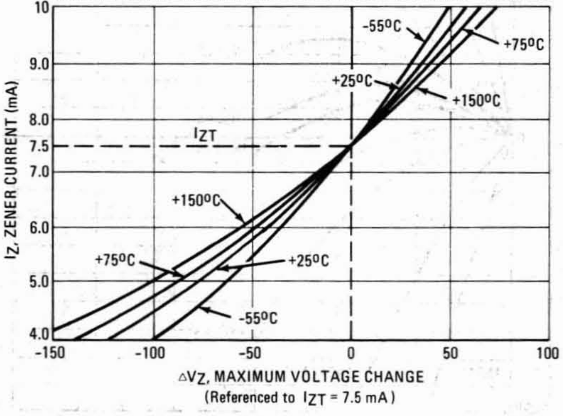


FIGURE 5 – MAXIMUM ZENER IMPEDANCE versus ZENER CURRENT

(See Note 3)

MORE THAN 95% OF THE UNITS ARE IN THE RANGES INDICATED BY THE CURVES

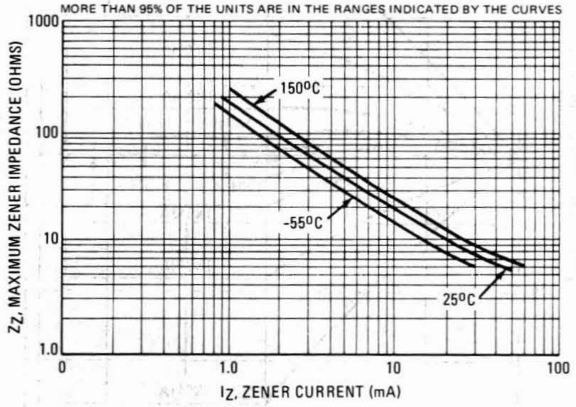
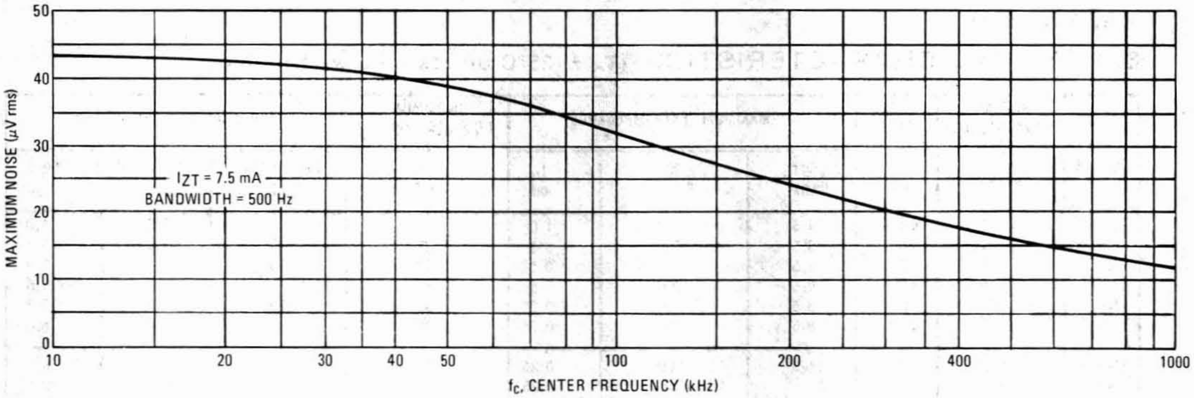


FIGURE 6 – DISTRIBUTION OF MAXIMUM GENERATED NOISE



NOTE 1:

Types 1N941B, 1N943B, and 1N944B are available to MIL-S-19500/157 and MEG-A-LIFE II, Levels 1, 2, & 3, specifications.

NOTE 2:

Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 3:

Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. Curves showing the variation of zener impedance with zener current for each series are given in Figure 5. A cathode-ray tube curve-trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

NOTE 4:

These graphs can be used to determine the maximum voltage change of any device in the series over any specific temperature range. For example, a temperature change from +25 to +50°C will cause a voltage change no greater than +29 mV or −28 mV for 1N941, as illustrated by the dashed lines in Figure 1. The boundaries given are maximum values. For greater resolution, expanded views of the shaded areas in Figures 1a, 2a, and 3a are shown in Figures 1b, 2b, and 3b respectively.

NOTE 5:

The maximum voltage change, ΔV_Z, in Figure 4 is due entirely to the impedance of the device. If both temperature and I_{ZT} are varied, then the total voltage change may be obtained by adding ΔV_Z in Figure 4 to the ΔV_Z in Figure 1, 2, or 3 for the device under consideration. If the device is to be operated at some stable current other than the specified test current, a new set of characteristics may be plotted by superimposing the data in Figure 4 on Figure 1, 2, or 3.

1N957 thru 1N992

400 mW
6.8 – 200 V

CASE 51
(DO-7)

Hermetically sealed, all-glass case with all external surfaces corrosion resistant. Cathode end, indicated by color band, will be positive with respect to anode end when operated in the zener region.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C

D C Power Dissipation: 400 Milliwatts at 50°C Ambient (Derate 3.2 mW/°C Above 50°C Ambient)

TOLERANCE DESIGNATIONS

With no suffix, tolerance is ±20%, for ±10% units, add suffix A, for ±5% units, add suffix B.

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

TYPE NUMBER	NOMINAL ZENER VOLTAGE V_Z VOLTS	TEST CURRENT I_{ZT} mA	MAXIMUM ZENER IMPEDANCE			MAXIMUM DC ZENER CURRENT I_{ZM} mA	REVERSE LEAKAGE CURRENT		
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} Ohms	I_{ZK} mA		I_R MAXIMUM (μA)	TEST VOLTAGE Vdc* V_{R1}	V_{R2}
1N957	6.8	18.5	4.5	700	1.0	47	150	5.2	4.9
1N958	7.5	16.5	5.5	700	0.5	42	75	5.7	5.4
1N959	8.2	15	6.5	700	0.5	38	50	6.2	5.9
1N960	9.1	14	7.5	700	0.5	35	25	6.9	6.6
1N961	10	12.5	8.5	700	0.25	32	10	7.6	7.2
1N962	11	11.5	9.5	700	0.25	28	5	8.4	8.0
1N963	12	10.5	11.5	700	0.25	26	5	9.1	8.6
1N964	13	9.5	13	700	0.25	24	5	9.9	9.4
1N965	15	8.5	16	700	0.25	21	5	11.4	10.8
1N966	16	7.8	17	700	0.25	19	5	12.2	11.5
1N967	18	7.0	21	750	0.25	17	5	13.7	13.0
1N968	20	6.2	25	750	0.25	15	5	15.2	14.4
1N969	22	5.6	29	750	0.25	14	5	16.7	15.8
1N970	24	5.2	33	750	0.25	13	5	18.2	17.3
1N971	27	4.6	41	750	0.25	11	5	20.6	19.4
1N972	30	4.2	49	1000	0.25	10	5	22.8	21.6
1N973	33	3.8	58	1000	0.25	9.2	5	25.1	23.8
1N974	36	3.4	70	1000	0.25	8.5	5	27.4	25.9
1N975	39	3.2	80	1000	0.25	7.8	5	29.7	28.1
1N976	43	3.0	93	1500	0.25	7.0	5	32.7	31.0
1N977	47	2.7	105	1500	0.25	6.4	5	35.8	33.8
1N978	51	2.5	125	1500	0.25	5.9	5	38.8	36.7
1N979	56	2.2	150	2000	0.25	5.4	5	42.6	40.3
1N980	62	2.0	185	2000	0.25	4.9	5	47.1	44.6
1N981	68	1.8	230	2000	0.25	4.5	5	51.7	49.0
1N982	75	1.7	270	2000	0.25	4.0	5	56.0	54.0
1N983	82	1.5	330	3000	0.25	3.7	5	62.2	59.0
1N984	91	1.4	400	3000	0.25	3.3	5	69.2	65.5
1N985	100	1.3	500	3000	0.25	3.0	5	76.0	72.0
1N986	110	1.1	750	4000	0.25	2.7	5	83.6	79.2
1N987	120	1.0	900	4500	0.25	2.5	5	91.2	86.4
1N988	130	0.95	1100	5000	0.25	2.3	5	98.8	93.6
1N989	150	0.85	1500	6000	0.25	2.0	5	114.0	108.0
1N990	160	0.80	1700	6500	0.25	1.9	5	121.6	115.2
1N991	180	0.68	2200	7100	0.25	1.7	5	136.8	129.6
1N992	200	0.65	2500	8000	0.25	1.5	5	152.0	144.0

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

1 – Nominal zener voltages between those shown.
2 – Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  b. Two or more units matched to one another with any specified tolerance.
3 – Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

*V_{R1} – Test Voltage for 5% Tolerance Device
V_{R2} – Test Voltage for 10% Tolerance Device
No Leakage Specified as 20% Tolerance Device

1N1183 thru 1N1190

V_R — to 600 V
I_O = 35 A

CASE 42
(DO-5)

Medium current silicon rectifiers. Unique double-case construction consists of hermetically sealed inner metallic case surrounded by molded external case; provides highest degree of ruggedness and reliability. Type numbers shown have cathode connected to case, but reverse-polarity units can be obtained by adding suffix "R" to standard type number, e.g. 1N1183R.

MAXIMUM RATINGS

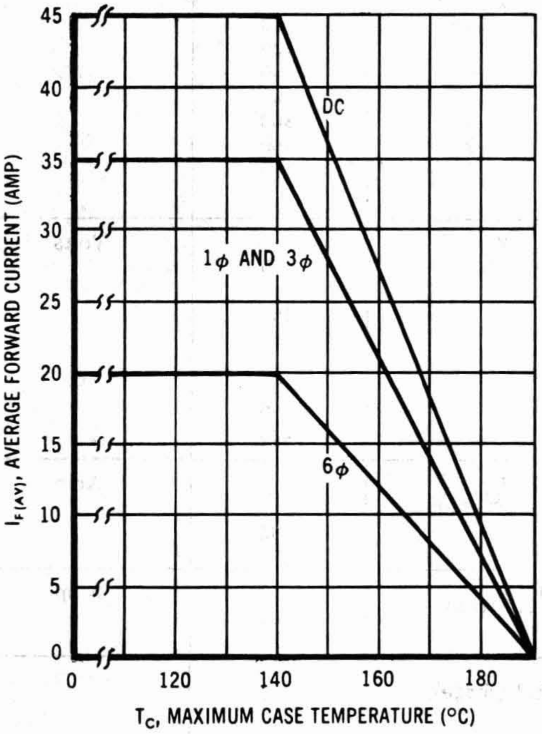
Rating	Symbol	Value	Unit
Peak Repetitive Reverse Voltage and DC Blocking Voltage	$V_{RM\,(rep)}$ V_R		Volts
1N1183		50	
1N1184		100	
1N1185		150	
1N1186		200	
1N1187		300	
1N1188		400	
1N1189		500	
1N1190		600	
RMS Reverse Voltage	V_r		Volts
1N1183		35	
1N1184		70	
1N1185		105	
1N1186		140	
1N1187		210	
1N1188		280	
1N1189		350	
1N1190		420	
Average 1/2-Wave Rectified Forward Current (Resistive Load, 60 Hz, T_C = 140°C)	I_O	35	Amp
Peak Repetitive Forward Current (T_C = 140°C)	$I_{FM\,(rep)}$	150	Amp
Peak Surge Current (T_C = 140°C, superimposed on Rated Current at Rated Voltage)	$I_{FM\,(surge)}$	400	Amp
Operating and Storage Temperature	T_J, T_{stg}	-65 to +190	°C
Thermal Impedance	θ_{JC}	1.0	°C/W, DC steady state

1N1183 thru 1N1190 (continued)

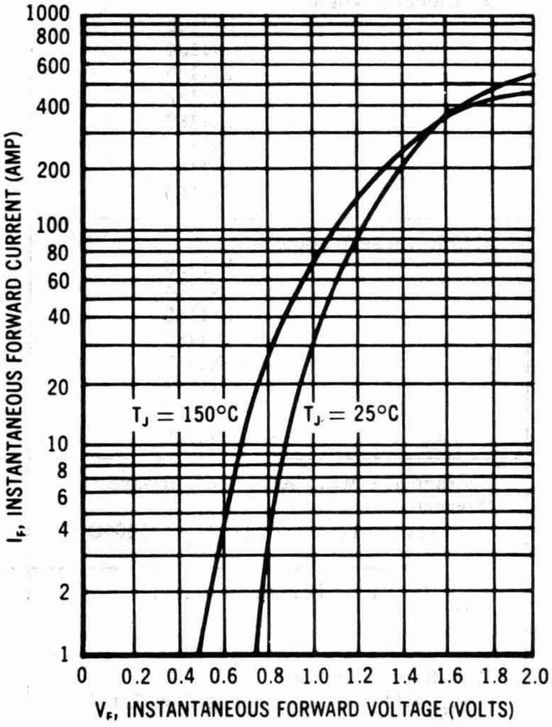
ELECTRICAL CHARACTERISTICS

Characteristics	Symbol	Value	Unit
Max Full Cycle Average Forward Voltage Drop ($I_{O\,(max)}$, rated V_r, 60 Hz, T_C = 140°C)	$V_{F(AV)}$	0.6	Volts
Max Instantaneous Forward Voltage Drop (I_F = 100 Amps, T_J = 25°C)	V_F	1.3	Volts
Max Full Cycle Average Reverse Current ($I_{O\,(max)}$, rated V_r, 60 Hz, T_C = 140°C)	$I_{R(AV)}$	10.0	mA
Max DC Reverse Current (Rated V_R, T_C = 25°)	I_R	1.0	mA

MAXIMUM AVERAGE FORWARD CURRENT RATING versus MAXIMUM CASE TEMPERATURE (60 CPS, RESISTIVE OR INDUCTIVE LOAD)



TYPICAL FORWARD CHARACTERISTICS



1N1191 thru 1N1198
1N1195A thru 1N1198A

For Specifications, See **1N248B** Data.

1N1313 thru 1N1327

150 mW
8.75 — 127.5 V

CASE 53

Very low power zener diodes with standard ±10% tolerances. Available with ±5.0% tolerance by adding suffix "A" to type number.

Standard cathode-to-case polarity.

For new designs and for industry preferred replacement devices, see 1N5221 series.

MAXIMUM RATINGS

Junction and Storage Temperature Range: -65 to +175°C (Derate 1 mW/°C above 25°C).

ELECTRICAL CHARACTERISTICS (TA = 25°C unless otherwise noted)

Type	Nominal Voltage V_Z @ I_{ZT} = 200 μA volts	Max Reverse Current		Test Voltage V_R volts
		T_A = 25°C I_R @ V_R μA	T_A = 100°C I_A @ V_R μA	
1N1313	8.75	0.5	5	6.8
1N1314	10.50	0.5	5	8.2
1N1315	12.75	0.5	5	10
1N1316	15.75	0.5	5	12
1N1317	19.00	0.5	5	15

Type	Nominal Voltage V_Z @ I_{ZT} = 200 μA volts	Max Reverse Current		Test Voltage V_R volts
		T_A = 25 C I_R @ V_R μA	T_A = 100 C I_A @ V_R μA	
1N1318	23.50	0.1	10	18
1N1319	28.50	0.1	10	22
1N1320	34.50	0.1	10	27
1N1321	41.00	0.1	10	33
1N1322	48.50	0.1	10	39

Type	Nominal Voltage V_Z @ I_{ZT} = 200 μA volts	Max Reverse Current		Test Voltage V_R volts
		T_A = 25°C I_R @ V_R μA	T_A = 100°C I_A @ V_R μA	
1N1323	58.00	0.1	10	47
1N1324	71.00	1.0	50	56
1N1325	87.50	1.0	50	68
1N1326	105.0	1.0	50	82
1N1327	127.5	1.0	50	100

1N1351 thru 1N1375

10 W
10 — 100 V

CASE 56
(DO-4)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N2970 series.

1N1507 thru 1N1517

¾ W
3.9 — 27 V

CASE 52
(DO-13)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1.0-watt, 1N4728 series.

1N1518 thru 1N1528

1 W
3.9 — 27 V

CASE 52
(DO-13)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N4728 series.

1N1530, A

For Specifications, See 1N429 Data.

1N1588 thru 1N1598

3.5 W
3.9 — 27 V

CASE 56
(DO-4)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N3993 series.

1N1599 thru 1N1609

10 W
3.9 — 27 V

CASE 56
(DO-4)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N3993 series.

HIGH VOLTAGE SILICON RECTIFIERS MOLDED ASSEMBLIES

1N1730 thru 1N1734
1N2382 thru 1N2385

I_O — to 0.2 A
$V_{RM(rep)}$ — to 10,000 V

CASE 41

Standard single-phase, half-wave, high-voltage silicon rectifier assemblies.

MAXIMUM RATINGS (covering all devices in the table below)

Max. DC Reverse Current @ Rated Peak Reverse Voltage 25°C	10 μA
100°C	100 μA
Max. Surge Current (8 ms)	2.5A
Operating Temperature	-55°C to +150°C

ELECTRICAL CHARACTERISTICS

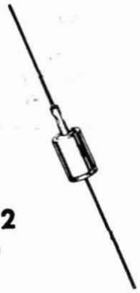
Rectifier Types	V_{RM} (rep)	Avg. Rectified Fwd. Current – mA		Max. RMS Input Voltage	Max. DC Fwd. Voltage @ 100mA @ 25°C	Case Dimensions		Lead Dimensions	
		@25°C	@100°C			L	Dia.	L	Dia.
1N1730	1000	200	100	700	5	.5	.375	1.250	.030
1N1731	1500	200	100	1050	5	.5	.375	1.250	.030
1N1732	2000	200	100	1400	9	1.0	.375	1.250	.030
1N1733	3000	150	75	2100	12	1.0	.375	1.250	.030
1N1734	5000	100	50	3500	18	1.0	.5	1.250	.030
1N2382	4000	150	75	2800	18	1.5	.5	1.250	.030
1N2383	6000	100	50	4200	27	1.5	.5	1.250	.030
1N2384	8000	70	35	5600	27	1.5	.5	1.250	.030
1N2385	10000	70	35	7000	39	2.0	.5	1.250	.030

1N1735 thru 1N1742
1N1736A thru 1N1742A

For Specifications, See 1N429 Data.

1N1765 thru 1N1802

1 W
5.6 — 200 V



CASE 52
(DO-13)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N4728 series.

1N2163 thru 1N2171

9.4 V ± 0.4 V

1N2163A thru 1N2171A

9.4 ± 0.2 V

1N3580, A, B thru 1N3583, A, B

11.7 ± 5.0%

TEMPERATURE-COMPENSATED ZENER REFERENCE DIODES

Highly reliable reference sources utilizing an oxide-passivated junction for long-term voltage stability. Construction consists of welded hermetically sealed metal and glass case.

- Low Dynamic Impedance
- Choice of Three Temperature Ranges
- "Box Method" Specifications Guarantee Maximum Voltage Deviation.

Temperature compensated reference diodes are made by taking advantage of the differing thermal characteristics of forward and reverse biased silicon PN junctions. A forward biased junction has a negative temperature coefficient of approximately 2.0 millivolts/°C. Reverse biased junctions above 5.0 volts have a positive temperature coefficient and therefore it is possible by judicious selection of combinations of forward and reverse biased junctions to obtain a device that shows a very low temperature coefficient due to cancellation. Because of the differing impedance versus temperature characteristics of the junctions involved, optimum temperature stability is obtained by operating in the zener current range at which the temperature coefficient is a minimum.

MAXIMUM RATINGS

Junction Temperature: -55 to +200°C

Storage Temperature: -65 to +200°C

DC Power Dissipation: 750 mW @ T_A = 25°C

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, welded metal glass

DIMENSIONS: See outline drawing.

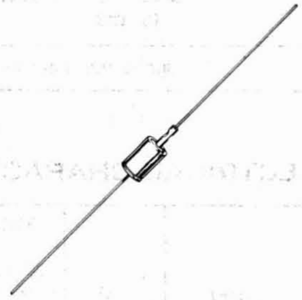
FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

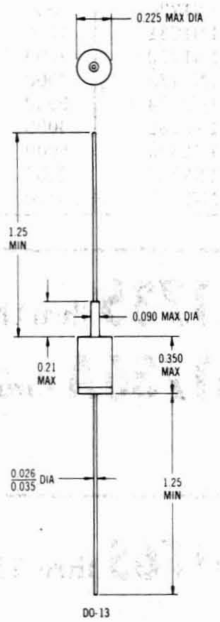
POLARITY: Cathode to case

WEIGHT: 1.5 Grams (approx)

MOUNTING POSITION: Any

TEMPERATURE-COMPENSATED SILICON ZENER REFERENCE DIODES





CASE 52
(DO-13)

1N2163 thru 1N2171, 1N2163A thru 1N2171A, 1N3580, A, B thru 1N3583, A, B (continued)

ELECTRICAL CHARACTERISTICS

V_Z = 9.4 Volts ± 0.4 V (± 0.2 V Suffix "A") @ (I_{ZT} = 10 mA)

Type Number	Max Voltage Change (Note 1) ΔV_Z (Volts)	Test Temperatures °C	Temperature Coefficient (Note 1) %/°C	Max Dynamic Impedance (Note 2) Z_{ZT} (Ohms)
1N2163,A	0.033	0, +25, +70	0.005	15
1N2164,A	0.086	-55, 0, +25, +75, +125	0.005	
1N2165,A	0.115	-55, 0, +25, +75, +125, +185	0.005	
1N2166,A	0.007	0, +25, +70	0.001	15
1N2167,A	0.017	-55, 0, +25, +75, +125	0.001	
1N2168,A	0.023	-55, 0, +25, +75, +125, +185	0.001	
1N2169,A	0.004	0, +25, +70	0.0005	15
1N2170,A	0.009	-55, 0, +25, +75, +125	0.0005	
1N2171,A	0.012	-55, 0, +25, +75, +125, +185	0.0005	

NOTE 1:

Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. V_Z is measured and recorded at each temperature specified. The ΔV_Z between the highest and lowest values must not exceed the maximum ΔV_Z given.

This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

ELECTRICAL CHARACTERISTICS

V_Z = 11.7 Volts ± 5.0% (I_{ZT} = 7.5 mA)

Type Number	Max Voltage Change (Note 1) ΔV_Z (Volts)	Test Temperatures °C	Temperature Coefficient (Note 1) %/°C	Max Dynamic Impedance (Note 2) Z_{ZT} (Ohms)
1N3580	0.088	0, +25, +75	0.01	25
1N3581	0.044		0.005	
1N3582	0.018		0.002	
1N3583	0.009		0.001	
1N3580A	0.181	-55, 0, +25, +75, +100	0.01	25
1N3581A	0.090		0.005	
1N3582A	0.036		0.002	
1N3583A	0.018		0.001	
1N3580B	0.239	-55, 0, +25 +75, +100, +150	0.01	25
1N3581B	0.120		0.005	
1N3582B	0.048		0.002	
1N3583B	0.024		0.001	

NOTE 2:

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. A cathode-ray tube curve-trace test on a sample basis is used to ensure that the zener has a sharp and stable knee region.

1N2382 thru 1N2385

For Specifications, See 1N1730 Data.

1N2498 thru 1N2500

10 W
10 — 12 V

CASE 56
(DO-4)

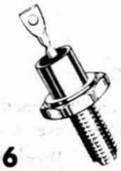
Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N2970 series.

1N2609 thru 1N2617

Obsolete, discontinued types, replace with devices from the 1N4001 series.

1N1803 thru 1N1836

10 W
5.6 — 200 V

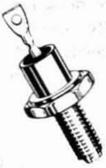


CASE 56
(DO-4)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N3993 series.

1N2008 thru 1N2012

10 W
100 — 150 V

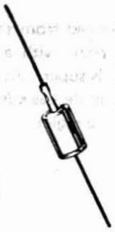


CASE 56
(DO-4)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N2970 series.

1N2032 thru 1N2040

¾ W
4.3 — 12 V

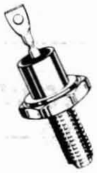


CASE 52
(DO-13)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N4728 series.

1N2041 thru 1N2049

10 W
4.3 — 27 V



CASE 56
(DO-4)

Recommended for applications requiring an exact replacement only. For new designs and for industry preferred replacement devices, see 1N3993 series.

1N2620, A, B (SILICON)
thru
1N2624, A, B

9.3 V ± 5.0%

Temperature-compensated zener reference diodes utilizing an oxide-passivated junction for long-term voltage stability. Construction consists of welded hermetically sealed metal and glass case.

CASE 52
(DO-13)

MAXIMUM RATINGS

Junction Temperature: –55 to +175°C

Storage Temperature: -65 to +175°C

DC Power Dissipation: 750 mW @ T_A = 25°C

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, welded metal and glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode to case

WEIGHT: 1.5 Grams (approx)

MOUNTING POSITION: Any

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

JEDEC Type No.	Maximum Voltage Change ΔV_Z (Volts) (Note 1)	Test Temperature °C	Temperature Coefficient %/°C (Note 1)	Maximum Dynamic Impedance Z_{ZT} (Ohms) (Note 2)
V_Z = 9.3 V ±5.0%* @ I_{ZT} = 10 mA				
1N2620	0.070	0, +25, +75	0.01	15
1N2621	0.035		0.005	
1N2622	0.014		0.002	
1N2623	0.007		0.001	
1N2624	0.003		0.0005	
1N2620A	0.144	-55, 0, +25, +75, +100	0.01	15
1N2621A	0.072		0.005	
1N2622A	0.029		0.002	
1N2623A	0.014		0.001	
1N2624A	0.007		0.0005	
1N2620B	0.191	-55, 0, +25, +75, +100, +150	0.01	15
1N2621B	0.095		0.005	
1N2622B	0.038		0.002	
1N2623B	0.019		0.001	
1N2624B	0.010		0.0005	

*Tighter-tolerance units available on special request.

CAPACITANCE (C) = 75 to 200 pF @ 90% of V_Z

FORWARD BREAKDOWN VOLTAGE (V_f) = 100 to 800 V

MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(With I_{ZT} = 10 mA ±0.01 mA) (See Note 3)

1N2620 thru 1N2624

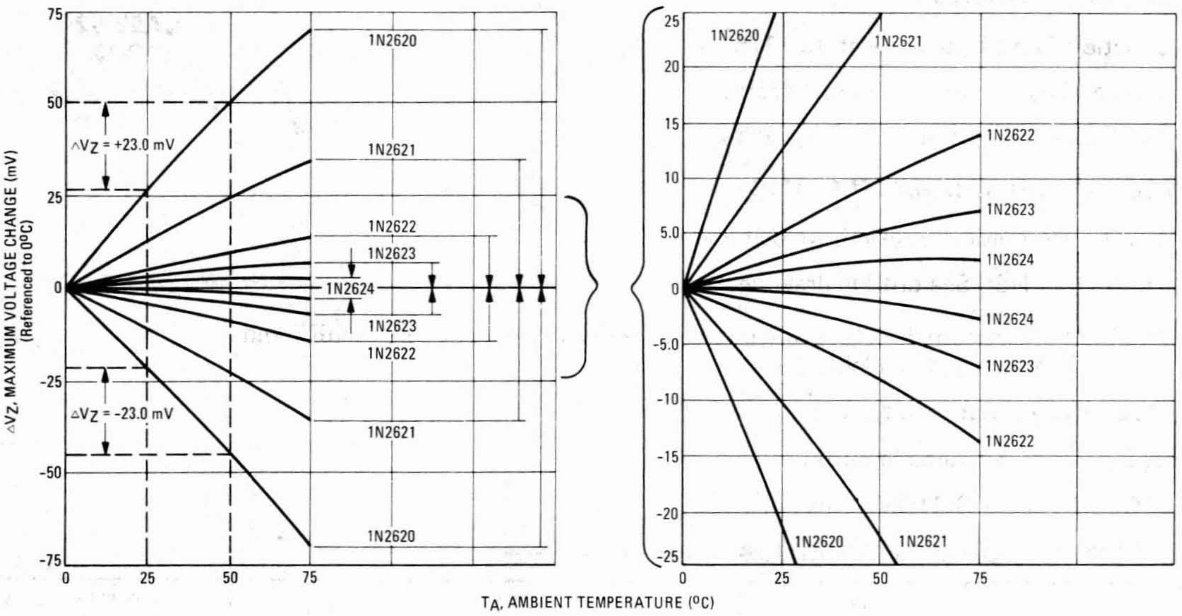


FIGURE 1a

FIGURE 1b

MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(With I_{ZT} = 10 mA ±0.01 mA) (See Note 3)

1N2620A thru 1N2624A

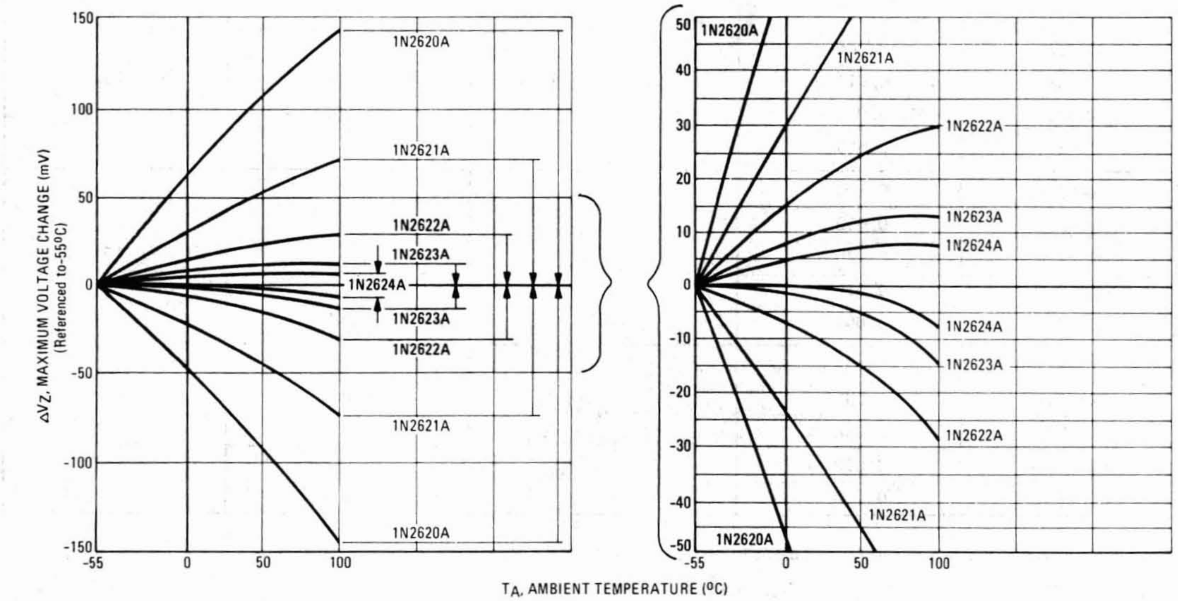


FIGURE 2a

FIGURE 2b

MAXIMUM VOLTAGE CHANGE versus TEMPERATURE

(with I_{ZT} = 10 mA ±0.01 mA) (See Note 4)

1N2620B thru 1N2624B

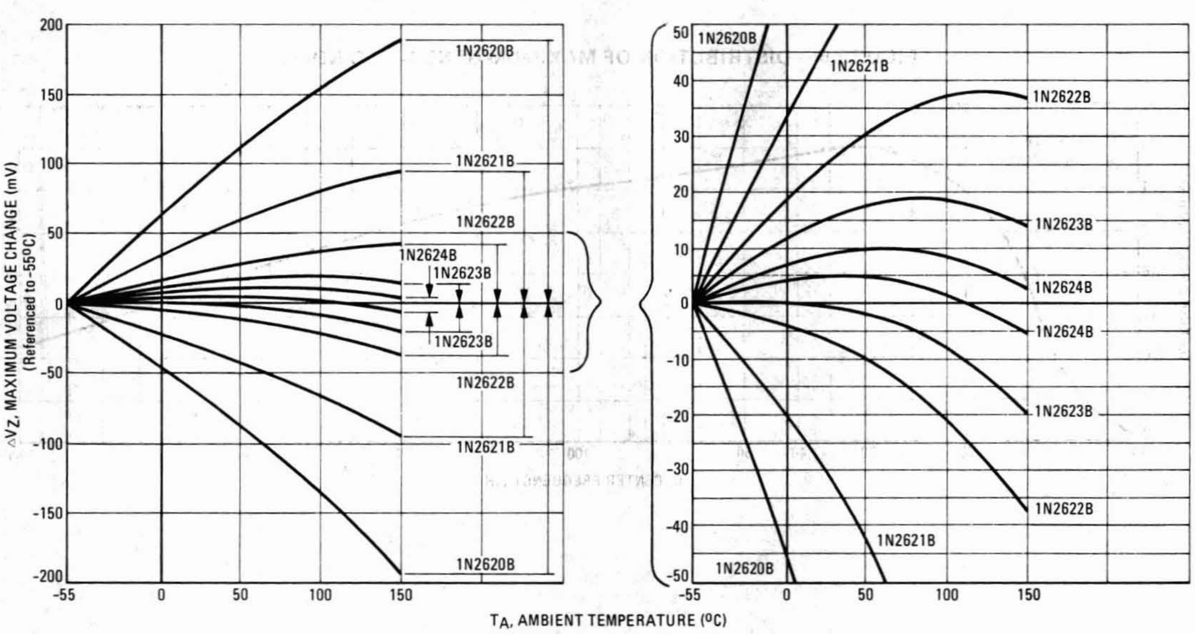


FIGURE 3a

FIGURE 3b

FIGURE 4 – ZENER CURRENT versus MAXIMUM VOLTAGE CHANGE (at specified temperatures)

(See Note 4)

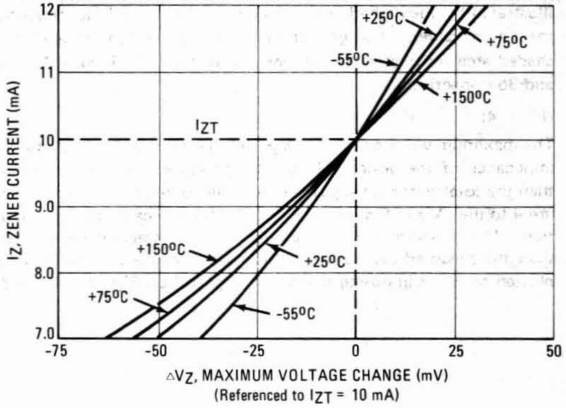


FIGURE 5 – MAXIMUM ZENER IMPEDANCE versus ZENER CURRENT

(See Note 2)

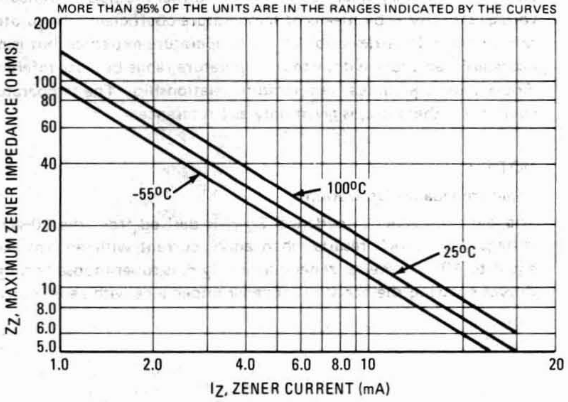
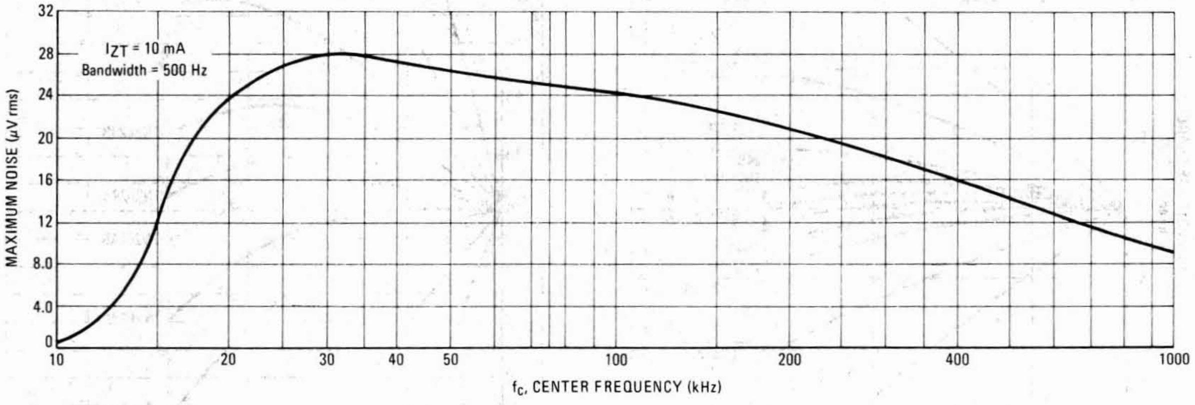


FIGURE 6 – DISTRIBUTION OF MAXIMUM GENERATED NOISE



NOTE 1:

Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 2:

Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. Curves showing the variation of zener impedance with zener current for each series are given in Figure 5. A cathode-ray tube curve-trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

NOTE 3:

These graphs can be used to determine the maximum voltage change of any device in the series over any specific temperature range. For example, a temperature change from +25 to +50°C will cause a voltage change no greater than +23 mV or −23 mV for 1N2620, as illustrated by the dashed lines in Figure 1. The boundaries given are maximum values. For greater resolution, expanded views of the shaded areas in Figures 1a, 2a, and 3a are shown in Figures 1b, 2b, and 3b respectively.

NOTE 4:

The maximum voltage change, ΔV_Z, in Figure 4 is due entirely to the impedance of the device. If both temperature and I_{ZT} are varied, then the total voltage change may be obtained by adding ΔV_Z in Figure 4 to the ΔV_Z in Figure 1, 2, or 3 for the device under consideration. If the device is to be operated at some stable current other than the specified test current, a new set of characteristics may be plotted by superimposing the data in Figure 4 on Figure 1, 2, or 3.

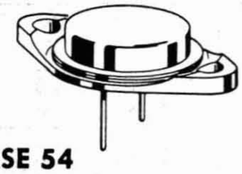
50 W
3.9 — 200 V

1N2804 thru 1N2846 (Case 54)
6.8V thru 200V

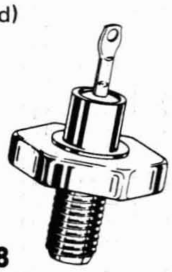
1N4557 thru 1N4564 (Case 54)
3.9V thru 7.5V

1N3305 thru 1N3350 (Case 58)
6.8V thru 200V

1N4549 thru 1N4556 (Case 58)
3.9V thru 7.5V


CASE 54
(TO-3 Modified)

Units are available with anode-to-case and cathode-to-case connections (standard and reverse polarity). For reverse polarity, add suffix "R" to type number.


CASE 58
(stud package)

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C.
D C Power Dissipation: 50 Watts. (Derate 0.5 W/°C above 75°C).

TOLERANCE DESIGNATION

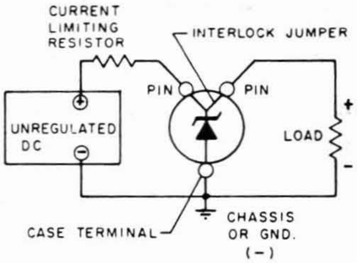
The type numbers shown have a standard tolerance of ±20% on the nominal zener voltage. Add suffix "A" for ±10% units or "B" for ±5% units. (2% and 1% tolerance also available. *(See Selector Guide for details)*

CASE 54 APPLICATIONS INFORMATION

If these units are used with a socket, the unregulated line should be connected to one pin through a suitable current limiting resistor and the load should be connected to the other pin. The load will now be disconnected from the line if the unit is removed from the socket.

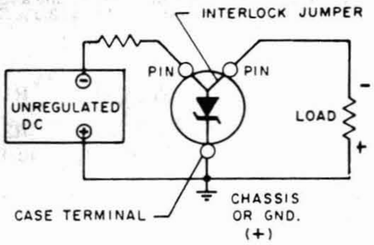
Typical circuit connections for anode-to-case and cathode-to-case polarities (standard and reverse polarities, respectively) are shown below

CIRCUIT CONNECTIONS


CURRENT LIMITING RESISTOR
INTERLOCK JUMPER
PIN
PIN
+
UNREGULATED DC
+
−
LOAD
−
CASE TERMINAL
CHASSIS OR GND.
(−)

STANDARD POLARITY
(ANODE TO CASE)

REVERSE POLARITY
(CATHODE TO CASE)
(RED DOT ON CASE AND "R" SUFFIX ON TYPE NO.)


INTERLOCK JUMPER
PIN
PIN
−
UNREGULATED DC
−
+
LOAD
+
CASE TERMINAL
CHASSIS OR GND.
(+)

1N2804 thru 1N2846 (continued)

ELECTRICAL CHARACTERISTICS

(Tc = 30°C unless otherwise specified) V_F = 1.5 V max @ 10 A on all types.

50 Watt CASE 54	50 Watt CASE 58	Nominal Zener Voltage @ I_{ZT} (V_Z) Volts	Test Current (I_{ZT}) mA	Max Zener Impedance		Max DC Zener Current 75°C Case Temp (I_{ZM}) mA	REVERSE * LEAKAGE CURRENT			Typical Zener Voltage Temp. Coeff. %/°C
				Z_{ZT} @ I_{ZT} ohms	Z_{ZK} @ I_{ZK} = 5mA ohms		I_R MAX (μA)	V_{R1}	V_{R2}	
1N4557	1N4549	3.9	3200	0.16	400	11900	150	0.5	0.5	-.025
1N4558	1N4550	4.3	2900	0.16	500	10650	150	0.5	0.5	-.025
1N4559	1N4551	4.7	2650	0.12	600	9700	100	1.0	1.0	.010
1N4560	1N4552	5.1	2450	0.12	650	8900	20	1.0	1.0	.015
1N4561	1N4553	5.6	2250	0.12	900	8100	20	1.0	1.0	.030
1N4562	1N4554	6.2	2000	0.14	1000	7300	20	2.0	2.0	.040
1N2804	1N3305	6.8	1850	0.2	70	6600	150	4.5	4.3	.040
1N4563	1N4555	6.8	1850	0.16	200	6650	10	2.0	2.0	.045
1N2805	1N3306	7.5	1700	0.3	70	5900	75	5.0	4.7	.045
1N4564	1N4556	7.5	1650	0.24	100	6050	10	3.0	3.0	.053
1N2806	1N3307	8.2	1500	0.4	70	5200	50	5.4	5.2	.048
1N2807	1N3308	9.1	1370	0.5	70	4800	25	6.1	5.7	.051
1N2808	1N3309	10	1200	0.6	80	4300	10	6.7	6.3	.055
1N2809	1N3310	11	1100	0.8	80	3900	5	8.4	8.0	.060
1N2810	1N3311	12	1000	1.0	80	3600	5	9.1	8.6	.065
1N2811	1N3312	13	960	1.1	80	3300	5	9.9	9.4	.065
1N2812	1N3313	14	890	1.2	80	3000	5	10.6	10.1	.070
1N2813	1N3314	15	830	1.4	80	2800	5	11.4	10.8	.070
1N2814	1N3315	16	780	1.6	80	2650	5	12.2	11.5	.070
1N2815	1N3316	17	740	1.8	80	2500	5	13.0	12.2	.075
1N2816	1N3317	18	700	2.0	80	2300	5	13.7	13.0	.075
1N2817	1N3318	19	660	2.2	80	2200	5	14.4	13.7	.075
1N2818	1N3319	20	630	2.4	80	2100	5	15.2	14.4	.075
1N2819	1N3320	22	570	2.5	80	1900	5	16.7	15.8	.080
1N2820	1N3321	24	520	2.6	80	1750	5	18.2	17.3	.080
1N2821	1N3322	25	500	2.7	90	1550	5	19.0	18.0	.080
1N2822	1N3323	27	460	2.8	90	1500	5	20.6	19.4	.085
1N2823	1N3324	30	420	3.0	90	1400	5	22.8	21.6	.085
1N2824	1N3325	33	380	3.2	90	1300	5	25.1	23.8	.085
1N2825	1N3326	36	350	3.5	90	1150	5	27.4	25.9	.085
1N2826	1N3327	39	320	4.0	90	1050	5	29.7	28.1	.090
1N2827	1N3328	43	290	4.5	90	975	5	32.7	31.0	.090
1N2828	1N3329	45	280	4.5	100	930	5	34.2	32.4	.090
1N2829	1N3330	47	270	5.0	100	880	5	35.8	33.8	.090
1N2830	1N3331	50	250	5.0	100	830	5	38.0	36.0	.090
1N2831	1N3332	51	245	5.2	100	810	5	38.8	36.7	.090
-	1N3333	52	240	5.5	100	790	5	39.5	37.4	.090
1N2832	1N3334	56	220	6	110	740	5	42.6	40.3	.090
1N2833	1N3335	62	200	7	120	660	5	47.1	44.6	.090
1N2834	1N3336	68	180	8	140	600	5	51.7	49.0	.090
1N2835	1N3337	75	170	9	150	540	5	56.0	54.0	.090
1N2836	1N3338	82	150	11	160	490	5	62.2	59.0	.090
1N2837	1N3339	91	140	15	180	420	5	69.2	65.5	.090
1N2838	1N3340	100	120	20	200	400	5	76.0	72.0	.090
1N2839	1N3341	105	120	25	210	380	5	79.8	75.6	.095
1N2840	1N3342	110	110	30	220	365	5	83.6	79.2	.095
1N2841	1N3343	120	100	40	240	335	5	91.2	86.4	.095
1N2842	1N3344	130	95	50	275	310	5	98.8	93.6	.095
-	1N3345	140	90	60	325	290	5	106.4	100.8	.095
1N2843	1N3346	150	85	75	400	270	5	114.0	108.0	.095
1N2844	1N3347	160	80	80	450	250	5	121.6	115.2	.095
-	1N3348	175	70	85	500	230	5	133.0	126.0	.095
1N2845	1N3349	180	68	90	525	220	5	136.8	129.6	.095
1N2846	1N3350	200	65	100	600	200	5	152.0	144.0	.100

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

1 — Nominal zener voltages between those shown.
2 — Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  b. Two or more units matched to one another with any specified tolerance.
3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

*V_{R1} – Test Voltage for 5% Tolerance Device
V_{R2} – Test Voltage for 10% Tolerance Device
No Leakage Specified as 20% Tolerance Device

FIGURE 1 — TEMPERATURE CHARACTERISTICS

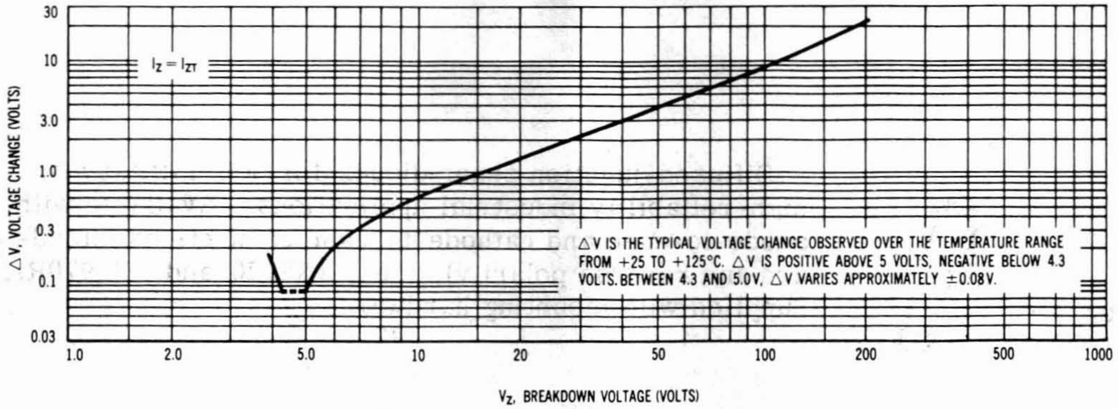


FIGURE 2 — POWER-TEMPERATURE DERATING CURVE

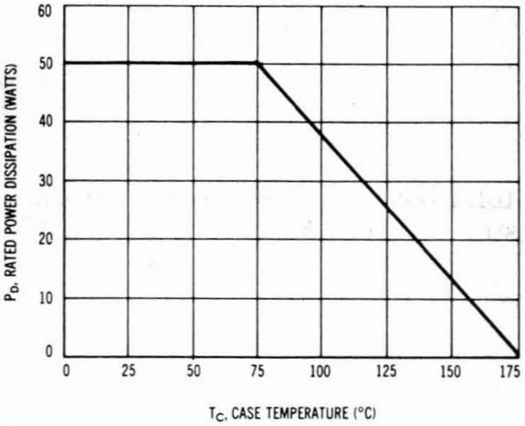


FIGURE 3 — LEAKAGE CURRENT

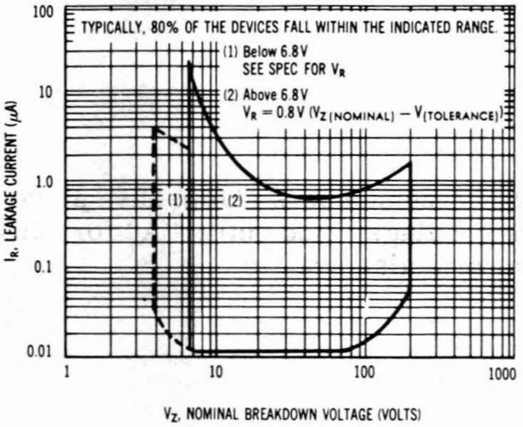
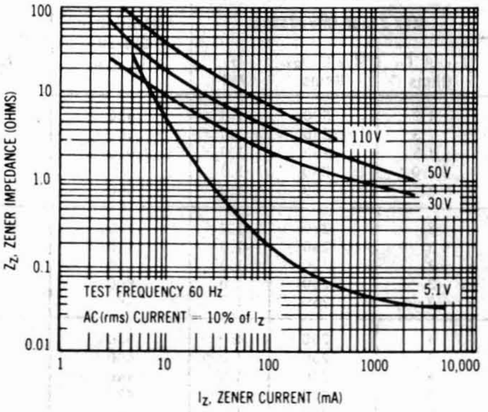
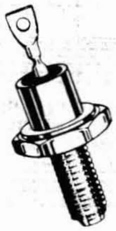


FIGURE 4 — ZENER IMPEDANCE versus ZENER CURRENT



1N2970 thru 1N3015

10 W
6.8 — 200 V


CASE 56
(DO-4)

Diffused-junction zener diodes for both military and high-reliability industrial applications. Available with anode-to-case and cathode-to-case connections (standard and reverse polarity), i.e., 1N2970 and 1N2970R. Supplied with mounting hardware.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C.
D C Power Dissipation: 10 Watts. (Derate 83.3 mW/°C above 55°C).

The type numbers shown have a standard tolerance of ±20% on the nominal zener voltage. Add suffix "A" for ±10% units or "B" for ±5% units. (2% and 1% tolerance also available.)

ELECTRICAL CHARACTERISTICS

(Tc = 30°C unless otherwise noted) V_F = 1.5 V max @ I_F = 2 amp on all types.

Type No.	Nominal Zener Voltage V_Z @ I_{ZT} Volts	Test Current I_{ZT} mA	Max Zener Impedance			Max DC Zener Current I_{ZM} mA	Max. Reverse Current *		
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} Ohms	I_{ZK} mA		I_R Max (μA)	V_{R1}	V_{R2}
1N2970	6.8	370	1.2	500	1.0	1,320	150	5.2	4.9
1N2971	7.5	335	1.3	250	1.0	1,180	75	5.7	5.4
1N2972	8.2	305	1.5	250	1.0	1,040	50	6.2	5.9
1N2973	9.1	275	2.0	250	1.0	960	25	6.9	6.6
1N2974	10	250	3	250	1.0	860	10	7.6	7.2
1N2975	11	230	3	250	1.0	780	5	8.4	8.0
1N2976	12	210	3	250	1.0	720	5	9.1	8.6
1N2977	13	190	3	250	1.0	660	5	9.9	9.4
1N2978	14	180	3	250	1.0	600	5	10.6	10.1
1N2979	15	170	3	250	1.0	560	5	11.4	10.8
1N2980	16	155	4	250	1.0	530	5	12.2	11.5
1N2982	18	140	4	250	1.0	460	5	13.7	13.0
1N2983	19	130	4	250	1.0	440	5	14.4	13.7
1N2984	20	125	4	250	1.0	420	5	15.2	14.4
1N2985	22	115	5	250	1.0	380	5	16.7	15.8
1N2986	24	105	5	250	1.0	350	5	18.2	17.3
1N2988	27	95	7	250	1.0	300	5	20.6	19.4
1N2989	30	85	8	300	1.0	280	5	22.8	21.6
1N2990	33	75	9	300	1.0	260	5	25.1	23.8
1N2991	36	70	10	300	1.0	230	5	27.4	25.9

*V_{R1} – Test Voltage for 5% Tolerance Device. V_{R2} – Test Voltage for 10% Tolerance Device. No Leakage Specified as 20% Tolerance Device.

1N2970 thru 1N3015 (continued)

ELECTRICAL CHARACTERISTICS

(Tc = 30°C unless otherwise noted) V_F = 1.5 V max @ I_F = 2 amp on all types.

Type No.	Nominal Zener Voltage V_Z @ I_{ZT} Volts	Test Current I_{ZT} mA	Max Zener Impedance			Max DC Zener Current I_{ZM} mA	Max. Reverse Current *		
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} Ohms	I_{ZK} mA		I_R Max (μA)	V_{R1}	V_{R2}
1N2992	39	65	11	300	1.0	210	5	29.7	28.1
1N2993	43	60	12	400	1.0	195	5	32.7	31.0
1N2995	47	55	14	400	1.0	175	5	35.8	33.8
1N2996	50	50	15	500	1.0	165	5	38.0	36.0
1N2997	51	50	15	500	1.0	163	5	38.8	36.7
1N2998	52	50	15	500	1.0	160	5	39.5	37.4
1N2999	56	45	16	500	1.0	150	5	42.6	40.3
1N3000	62	40	17	600	1.0	130	5	47.1	44.6
1N3001	68	37	18	600	1.0	120	5	51.7	49.0
1N3002	75	33	22	600	1.0	110	5	56.0	54.0
1N3003	82	30	25	700	1.0	100	5	62.2	59.0
1N3004	91	28	35	800	1.0	85	5	69.2	65.5
1N3005	100	25	40	900	1.0	80	5	76.0	72.0
1N3006	105	25	45	1,000	1.0	75	5	79.8	75.6
1N3007	110	23	55	1,100	1.0	72	5	83.6	79.2
1N3008	120	20	75	1,200	1.0	67	5	91.2	86.4
1N3009	130	19	100	1,300	1.0	62	5	98.8	93.6
1N3010	140	18	125	1,400	1.0	58	5	106.4	100.8
1N3011	150	17	175	1,500	1.0	54	5	114.0	108.0
1N3012	160	16	200	1,600	1.0	50	5	121.6	115.2
1N3014	180	14	260	1,850	1.0	45	5	136.8	129.6
1N3015	200	12	300	2,000	1.0	40	5	152.0	144.0

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

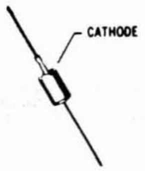
1 — Nominal zener voltages between those shown.
2 — Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  b. Two or more units matched to one another with any specified tolerance.
3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

*V_{R1} – Test Voltage for 5% Tolerance Device. V_{R2} – Test Voltage for 10% Tolerance Device. No Leakage Specified as 20% Tolerance Device.

1N3016 thru 1N3051

1 W
6.8 — 200 V

CASE 52
(DO-13)



Hermetically sealed package, with 36 standard voltage ratings and 5%, 10% and 20% standard tolerances. Cathode connected to case.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C.
D C Power Dissipation: 1 Watt. (Derate 6.67 mW/°C above 25°C).

The type numbers shown have a standard tolerance of ±20% on the nominal zener voltage. Add suffix "A" for ±10% units or "B" for ±5% units. (2% and 1% tolerance also available. *See Selector Guide for details)*

1N3016 thru 1N3051 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 30°C$ unless otherwise noted)

$V_F = 1.5$ V max @ 200 mA on all types.

Type No.	Nominal Zener Voltage V_Z @ I_{ZT} Volts	Test Current I_{ZT} mA	Max Zener Impedance			Reverse Leakage Current*			Max DC Zener Current I_{ZM} mA	Typical Zener Voltage Temp. Coeff. %/ C
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} Ohms	I_{ZK} mA	I_R Max (μA)	V_{R1}	V_{R2}		
1N3016	6.8	37	3.5	700	1.0	150	5.2	4.9	130	.040
1N3017	7.5	34	4.0	700	0.5	75	5.7	5.4	120	.045
1N3018	8.2	31	4.5	700	0.5	50	6.2	5.9	105	.048
1N3019	9.1	28	5.0	700	0.5	25	6.9	6.6	95	.051
1N3020	10	25	7	700	0.25	10	7.6	7.2	85	.055
1N3021	11	23	8	700	0.25	5	8.4	8.0	75	.060
1N3022	12	21	9	700	0.25	5	9.1	8.6	70	.065
1N3023	13	19	10	700	0.25	5	9.9	9.4	65	.065
1N3024	15	17	14	700	0.25	5	11.4	10.8	56	.070
1N3025	16	15.5	16	700	0.25	5	12.2	11.5	53	.070
1N3026	18	14	20	750	0.25	5	13.7	13.0	46	.075
1N3027	20	12.5	22	750	0.25	5	15.2	14.4	42	.075
1N3028	22	11.5	23	750	0.25	5	16.7	15.8	38	.080
1N3029	24	10.5	25	750	0.25	5	18.2	17.3	35	.080
1N3030	27	9.5	35	750	0.25	5	20.6	19.4	30	.085
1N3031	30	8.5	40	1,000	0.25	5	22.8	21.6	28	.085
1N3032	33	7.5	45	1,000	0.25	5	25.1	23.8	26	.085
1N3033	36	7.0	50	1,000	0.25	5	27.4	25.9	24	.085
1N3034	39	6.5	60	1,000	0.25	5	29.7	28.1	20	.090
1N3035	43	6.0	70	1,500	0.25	5	32.7	31.0	19	.090
1N3036	47	5.5	80	1,500	0.25	5	35.8	33.8	17	.090
1N3037	51	5.0	95	1,500	0.25	5	38.8	36.7	16	.090
1N3038	56	4.5	110	2,000	0.25	5	42.6	40.3	15	.090
1N3039	62	4.0	125	2,000	0.25	5	47.1	44.6	13	.090
1N3040	68	3.7	150	2,000	0.25	5	51.7	49.0	12	.090
1N3041	75	3.3	175	2,000	0.25	5	56.0	54.0	11	.090
1N3042	82	3.0	200	3,000	0.25	5	62.2	59.0	10	.090
1N3043	91	2.8	250	3,000	0.25	5	69.2	65.5	9	.090
1N3044	100	2.5	350	3,000	0.25	5	76.0	72.0	8	.090
1N3045	110	2.3	450	4,000	0.25	5	83.6	79.2	7.2	.095
1N3046	120	2.0	550	4,500	0.25	5	91.2	86.4	7.0	.095
1N3047	130	1.9	700	5,000	0.25	5	98.8	93.6	6.0	.095
1N3048	150	1.7	1,000	6,000	0.25	5	114.0	108.0	5.5	.095
1N3049	160	1.6	1,100	6,500	0.25	5	121.6	115.2	5.2	.095
1N3050	180	1.4	1,200	7,000	0.25	5	136.8	129.6	4.6	.095
1N3051	200	1.2	1,500	8,000	0.25	5	152.0	144.0	4.0	.100

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

1 — Nominal zener voltages between those shown.
2 — Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  b. Two or more units matched to one another with any specified tolerance.
3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

*V_{R1} — Test Voltage for 5% Tolerance Device
V_{R2} — Test Voltage for 10% Tolerance Device
No Leakage Specified as 20% Tolerance Device

1N3154, A (SILICON)
thru
1N3157, A

8.4 V ± 5.0%

Temperature-compensated zener reference diodes utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.

CASE 51
(DO-7)

MAXIMUM RATINGS

Junction Temperature: -55 to +175°C

Storage Temperature: -65 to +175°C

DC Power Dissipation: 500 mW @ T_A = 25°C

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

JEDEC Type No. (Note 1)	Maximum Voltage Change ΔV_Z (Volts) (Note 2)	Test Temperature °C	Temperature Coefficient %/°C (Note 2)	Maximum Dynamic Impedance Z_{ZT} (Ohms) (Note 3)
V_Z = 8.4 V ±5.0%* @ I_{ZT} = 10 mA				
1N3154	0.130	-55, 0, +25, +75, +100	0.01	15
1N3155	0.065		0.005	
1N3156	0.026		0.002	
1N3157	0.013		0.001	
1N3154A	0.172	-55, 0, +25, +75, +100, +150	0.01	15
1N3155A	0.086		0.005	
1N3156A	0.034		0.002	
1N3157A	0.017		0.001	

*Tighter-tolerance units available on special request.

CAPACITANCE (C) = 20 to 180 pF @ 90% of V_Z

FORWARD BREAKDOWN VOLTAGE (V_f) = 100 to 800 V

MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(with I_{ZT} = 10 mA ±0.01 mA) (See Note 4)

1N3154 thru 1N3157

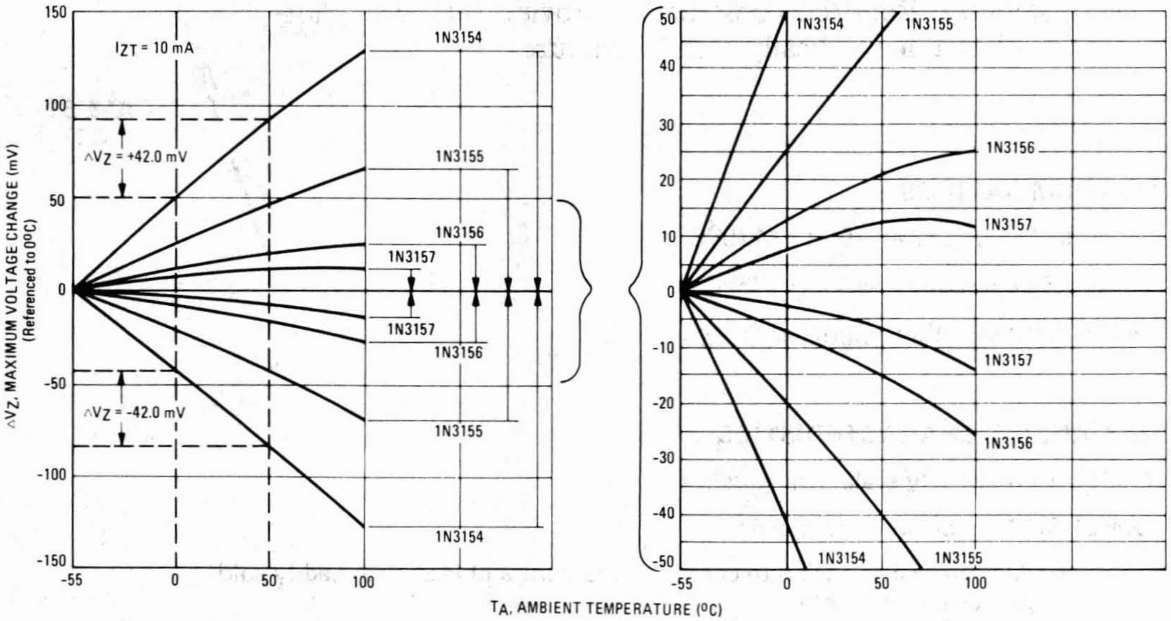


FIGURE 1a

FIGURE 1b

MAXIMUM VOLTAGE CHANGE versus AMBIENT TEMPERATURE

(with I_{ZT} = 10 mA ±0.01 mA) (See Note 4)

1N3154A thru 1N3157A

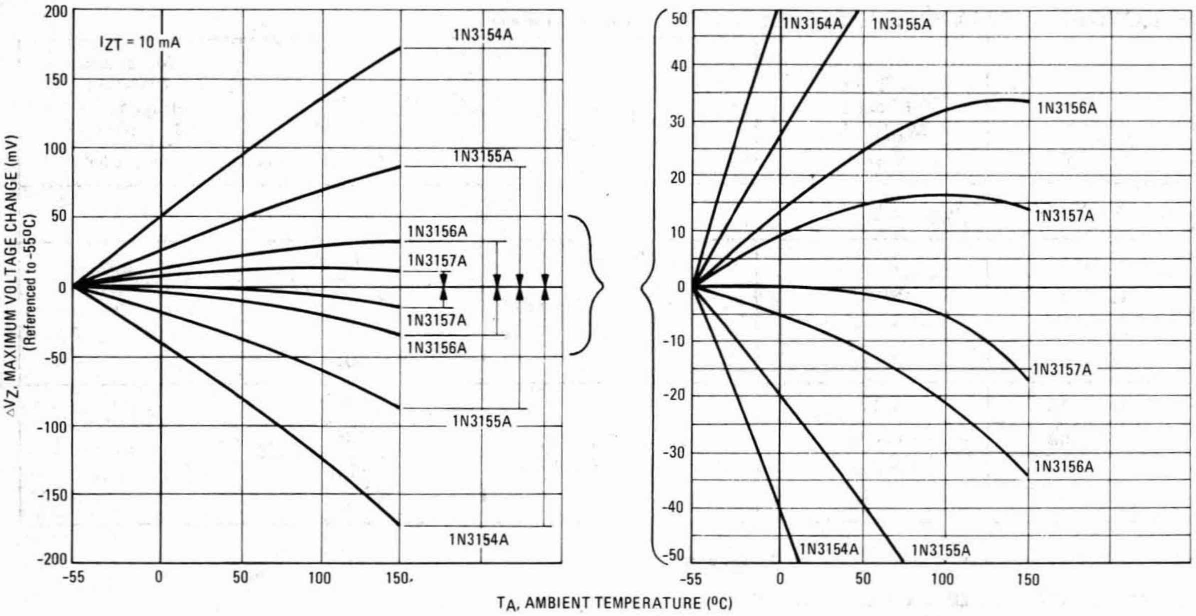


FIGURE 2a

FIGURE 2b

1N3154, A thru 1N3157, A (continued)

FIGURE 3 – ZENER CURRENT versus MAXIMUM VOLTAGE CHANGE (at specified temperatures)
(See Note 5)

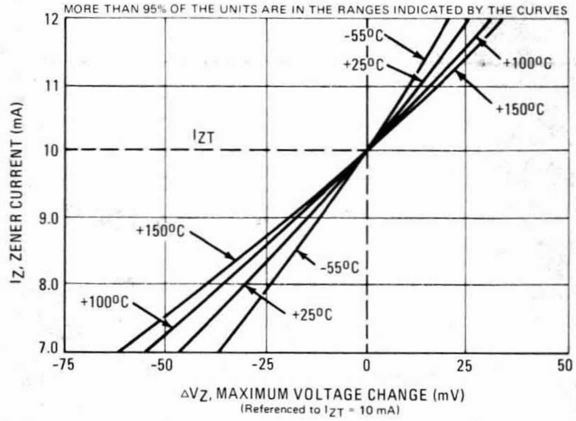


FIGURE 4 – MAXIMUM ZENER IMPEDANCE versus ZENER CURRENT
(See Note 3)

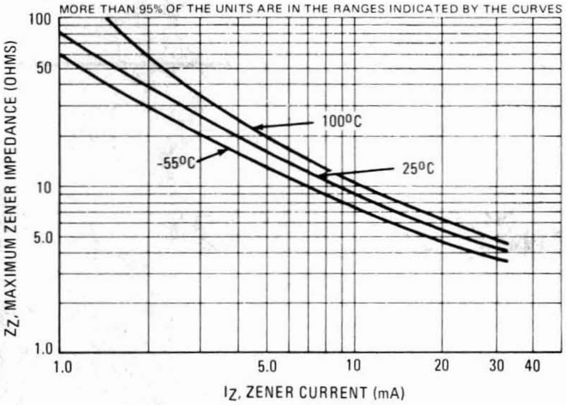
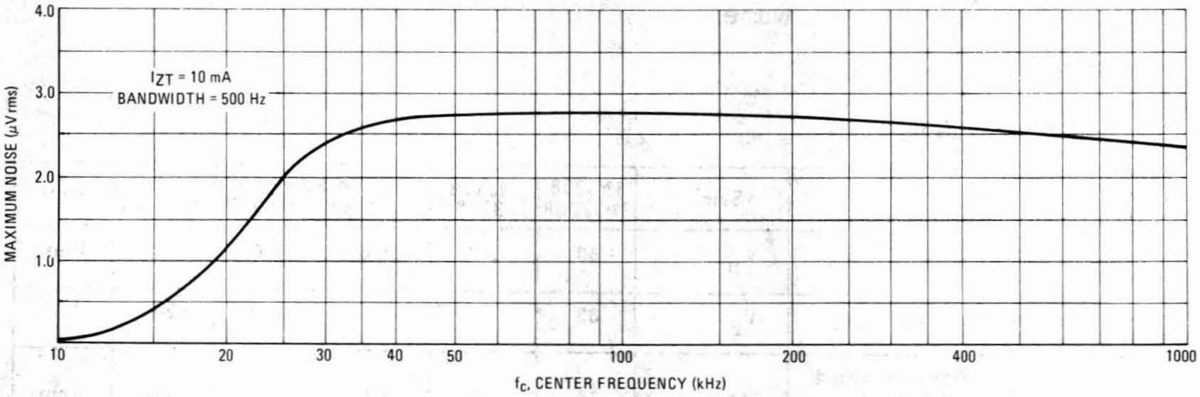


FIGURE 5 – DISTRIBUTION OF MAXIMUM GENERATED NOISE



NOTE 1:

Types 1N3154 thru 1N3157 are available to MIL-S-19500/158 and MEG-A-LIFE II, Levels 1, 2, & 3, specifications.

NOTE 2:

Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 3:

Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. Curves showing the variation of zener impedance with zener current for each series are given in Figure 4. A cathode-ray tube curve-trace test on a sample basis is used to ensure that each zener characteristic has a sharp and stable knee region.

NOTE 4:

These graphs can be used to determine the maximum voltage change of any device in the series over any specific temperature range. For example, a temperature change from 0 to +50°C will cause a voltage change no greater than +42 mV or -42 mV for 1N3154, as illustrated by the dashed lines in Figure 1. The boundaries given are maximum values. For greater resolution, expanded views of the shaded areas in Figures 1a and 2a are shown in Figures 1b and 2b respectively.

NOTE 5:

The maximum voltage change, ΔV_Z, in Figure 3 is due entirely to the impedance of the device. If both temperature and I_{ZT} are varied, then the total voltage change may be obtained by adding ΔV_Z in Figure 3 to the ΔV_Z in Figure 1 or 2 for the device under consideration. If the device is to be operated at some stable current other than the specified test current, a new set of characteristics may be plotted by superimposing the data in Figure 3 on Figure 1 or 2.

1N3189 thru 1N3191

Obsolete, discontinued types, replace with devices from the 1N4001 series.

1N3208 thru 1N3212

V_R — to 400V
I_O = 15 A

CASE 42
(DO-5)

Medium-current silicon rectifiers. Cathode connected to case, but reverse polarity (anode-to-case connection) also available by adding suffix "R" to type number, e.g. 1N3208R. Supplied with mounting hardware.

MAXIMUM RATINGS

Rating	Symbol	1N3208 1N3208R	1N3209 1N3209R	1N3210 1N3210R	1N3211 1N3211R	1N3212 1N3212R	Unit
D C Blocking Voltage	V_R	50	100	200	300	400	Volts
RMS Reverse Voltage	V_r	35	70	140	210	280	Volts
Average Half-Wave Rectified Forward Current With Resistive Load	I_O*	15	15	15	15	15	Amp
Peak One Cycle Surge Current (60 cps & 25°C Case Temp)	$I_{FM(surge)}$	250	250	250	250	250	Amp
Operating Junction Temperature	T_J	-65 to + 175					°C
Storage Temperature	T_{stg}	-65 to + 175					°C

*T_C = 150°C

ELECTRICAL CHARACTERISTICS (All Types) at 25°C Case Temp.

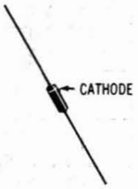
Characteristic	Symbol	Value	Unit
Maximum Forward Voltage at 40 Amp D-C Forward Current	V_F	1.5	Volts
Maximum Reverse Current at Rated D-C Reverse Voltage	I_R	1.0	mAdc
Typical Thermal Resistance, Junction To Case	θ_{JC}	1.7	°C/W

1N3213, 1N3214

For Specifications, See **1N248B** Data.

1N3282 thru 1N3286

V_R — to 3000 V
I_O = 100 mA



CASE 51
(DO-7)

Low-current silicon rectifiers for applications requiring extremely high reverse-voltage capability. Hermetically sealed, subminiature glass package, offering excellent stability and reliability under environmental extremes.

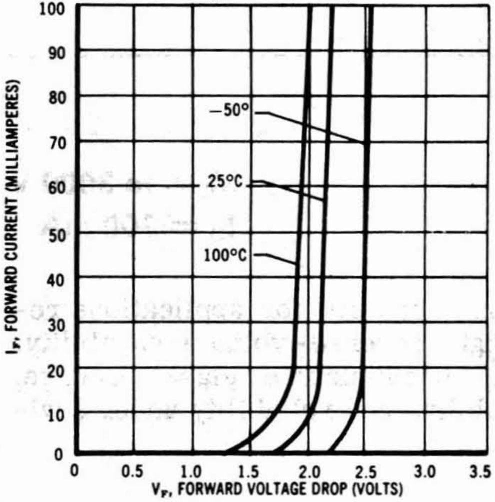
MAXIMUM RATINGS (At 60 cps Sinusoidal Input, Resistive or Inductive Load)

Rating	Symbol	1N3282	1N3283	1N3284	1N3285	1N3286	Unit
Peak Repetitive Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ V_R	1000	1500	2000	2500	3000	Volts
RMS Reverse Voltage	V_r	700	1050	1400	1750	2100	Volts
Average Half-Wave Rectified Forward Current (25°C Ambient)	I_O	100	100	100	100	100	mA
(100°C Ambient)		50	50	50	50	50	mA
Peak Surge Current (1/2-cycle, 60 Hz)	$I_{FM(surge)}$	2.5	2.5	2.5	2.5	2.5	Amp
Peak Repetitive Forward Current	$I_{FM(rep)}$	0.50	0.50	0.50	0.50	0.50	Amp
Operating and Storage Temperature Range	T_J, T_{stg}	-65 to + 150					°C

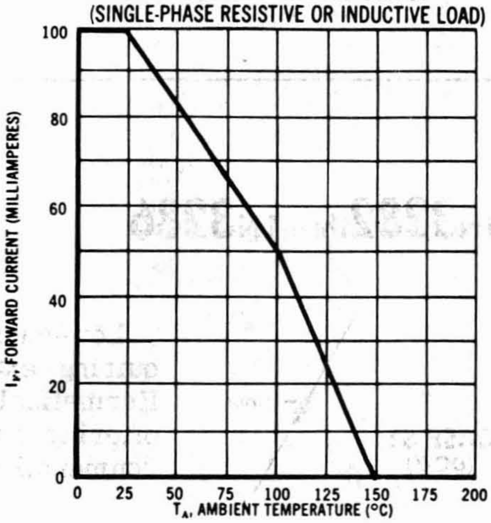
ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Value	Unit
Maximum Forward Voltage Drop @ 100 mA, Continuous DC (25°C)	V_F	2.5	Volts
Maximum Full-Cycle Average Forward Voltage Drop @ Rated Current (100°C)	$V_{F(AV)}$	1.2	Volts
Maximum Reverse Current @ Rated DC Voltage (25°C)	I_R	1.0	μA
(100°C)		10.0	
Maximum Full-Cycle Average Reverse Current @ Max Rated PIV and Current (as Half-Wave Rectifier, Resistive Load, 100°C)	$I_{R(AV)}$	10.0	μA
Typical Thermal Resistance, Junction to Ambient	θ_{JA}	400	°C/W

1N3282 thru 1N3286 (continued)



TYPICAL FORWARD CHARACTERISTICS
(FOR ALL TYPES)



MAXIMUM ALLOWABLE DC OUTPUT
(SINGLE-PHASE RESISTIVE OR INDUCTIVE LOAD)

1N3305 thru 1N3350

For Specifications, see 1N2804 Data.

1N3491 thru 1N3495 (SILICON)
MR322 thru MR328
MR330, MR331

V_R — to 1000 V
$I_O = 25$ A

CASE 43
(DO-21)

Medium-current silicon rectifiers – compact, highly efficient silicon rectifiers for medium-current applications.

MAXIMUM RATINGS

Rating	Symbol	1N3491 MR322	1N3492 MR323	1N3493 MR324	1N3494 MR325	1N3495 MR326	MR327	MR328	MR330	MR331	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	200	300	400	500	600	800	1000	Volts
Non-Repetitive Peak Reverse Voltage (halfwave, single phase, 60 cycle peak)	$V_{RM(non-rep)}$	100	200	300	400	500	600	720	1000	1200	Volts
RMS Reverse Voltage	V_r	35	70	140	210	280	350	420	560	700	Volts
Average Rectified Forward Current (single phase, resistive load, 60 Hz , see Figure 3) $T_C = 130^oC$	I_O	25									Amp
Non-Repetitive Peak Surge Current (surge applied at rated load conditions, see Figure 5)	$I_{FM(surge)}$	300 (for 1/2 cycle)									Amp
I^2t Rating (non-repetitive, for t greater than 1 ms and less than 8.3 ms)	I^2t	375									$A_{(rms)}^2$ sec
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175									^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.2	^oC/Watt

MECHANICAL CHARACTERISTICS

CASE: Welded, hermetically sealed construction.

FINISH: All external surfaces corrosion-resistant and the terminal lead is readily solderable.

POLARITY: CATHODE TO CASE (reverse polarity units are available upon request and are designated by an "R" suffix i.e. MR327R or 1N3491R).

MOUNTING POSITIONS: Any.

ELECTRICAL CHARACTERISTICS

Characteristic and Conditions	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop (rated I_O and V_r, single phase, 60 Hz, T_C = 150°C)	$V_{F(AV)}$	0.6	Volts
Instantaneous Forward Voltage Drop (i_F = 100 Amps, T_J = 25°C)	V_F	1.5	Volts
Full Cycle Average Reverse Current (rated I_O and V_r, single phase, 60 Hz, T_C = 150°C)	$I_{R(AV)}$		mA
1N3491/MR322		10	
1N3492/MR323		10	
1N3493/MR324		8	
1N3494/MR325		6	
1N3495/MR326		4	
MR327		3	
MR328		2.5	
MR330		2	
MR331		1.5	
DC Reverse Current (Rated V_R, T_C = 25°C)	I_R	1.0	mA

FIGURE 1 — MAXIMUM FORWARD VOLTAGE DROP

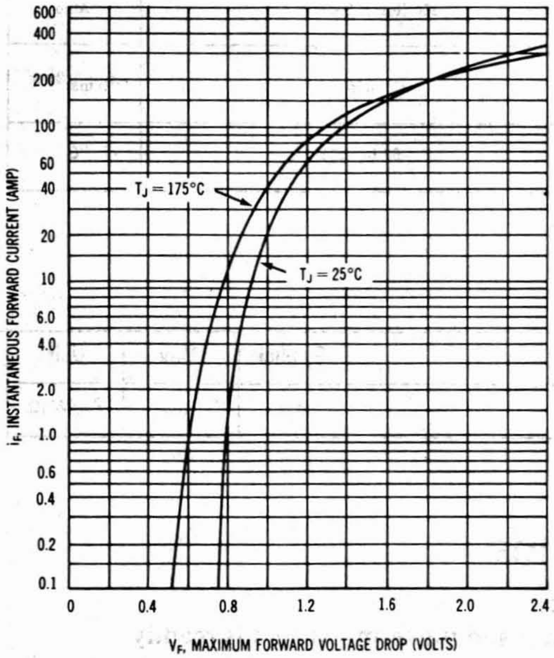
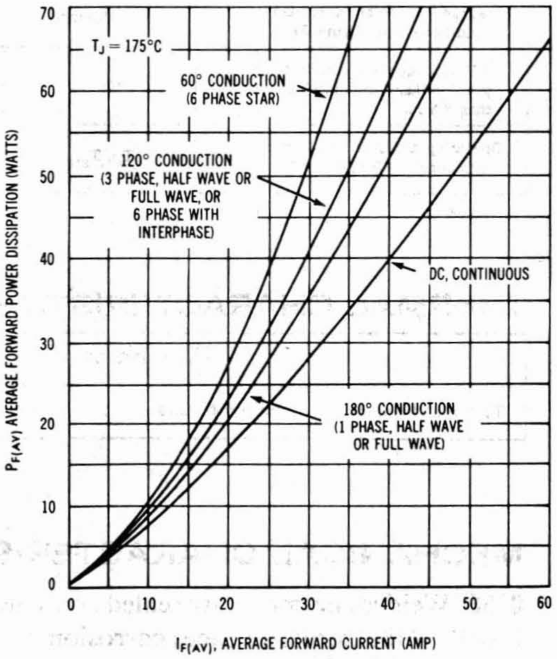


FIGURE 2 — MAXIMUM FORWARD POWER DISSIPATION



1N3491 thru 1N3495 (continued)

FIGURE 3 — MAXIMUM CURRENT RATINGS

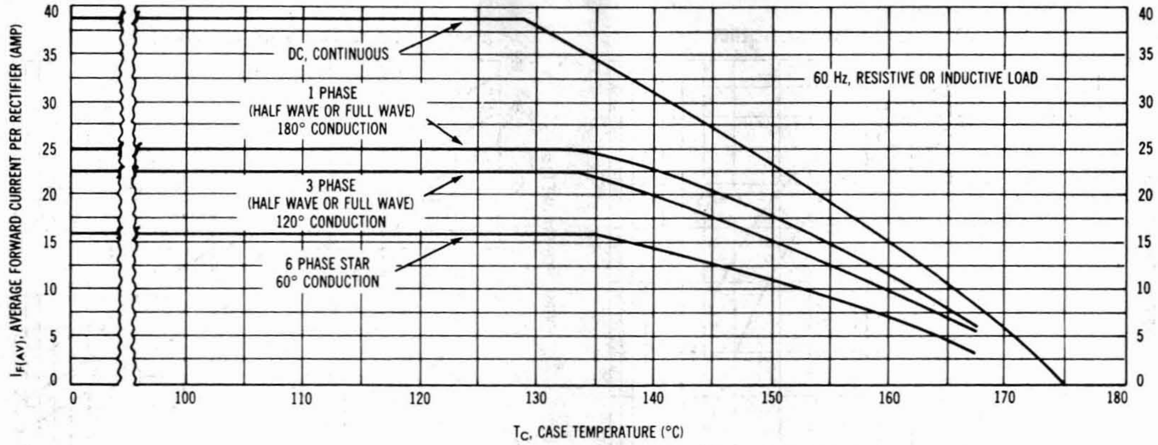


FIGURE 4 — MAXIMUM EFFECTIVE TRANSIENT THERMAL IMPEDANCE

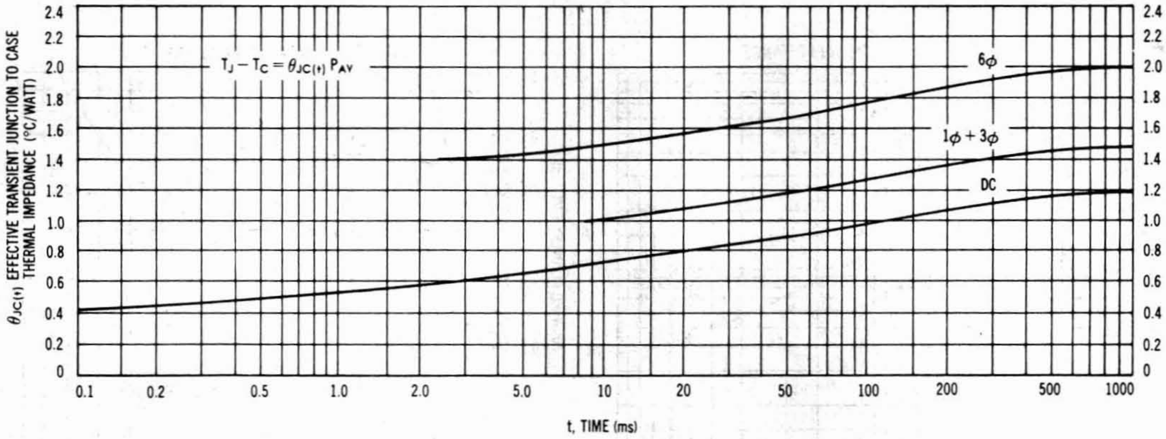
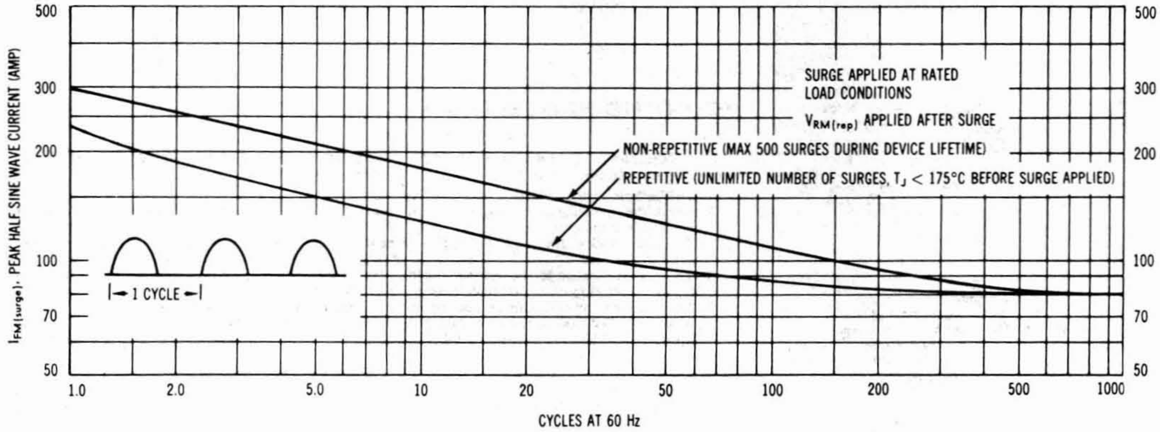


FIGURE 5 — MAXIMUM ALLOWABLE SURGE CURRENT



TYPICAL DYNAMIC CHARACTERISTICS

FIGURE 6 — RECTIFICATION EFFICIENCY

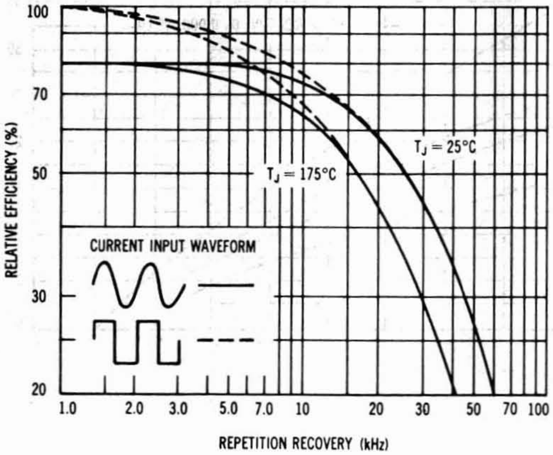


FIGURE 7 — REVERSE RECOVERY TIME

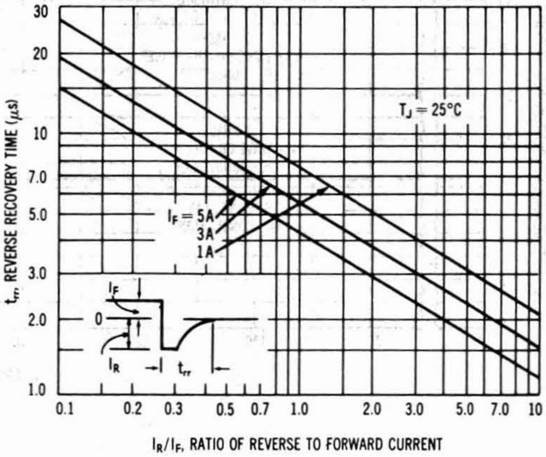


FIGURE 8 — JUNCTION CAPACITANCE

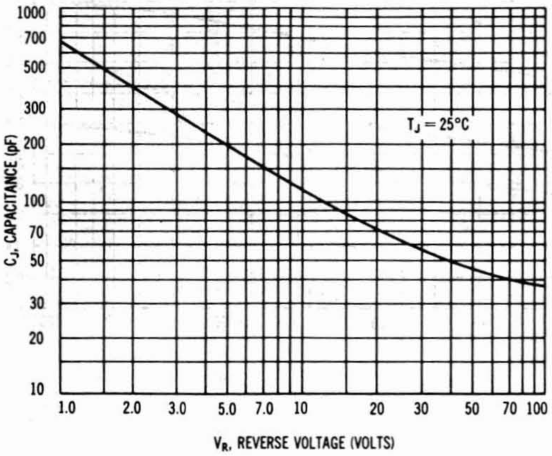
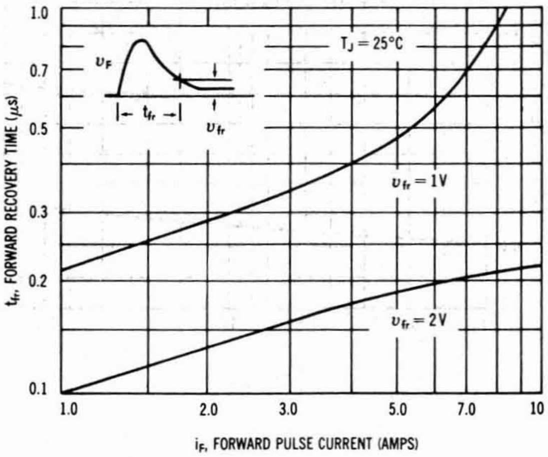
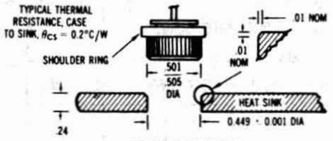
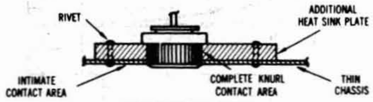


FIGURE 9 — FORWARD RECOVERY TIME




TYPICAL THERMAL RESISTANCE, CASE TO SINK, $\theta_{CS} = 0.2°C/W$
SHOULDER RING
.501
.505
DIA
.01 NOM
.01
NOM
HEAT SINK
.24
0.449 · 0.001 DIA

HEAT SINK MOUNTING


RIVET
ADDITIONAL HEAT SINK PLATE
INTIMATE CONTACT AREA
COMPLETE KNURL CONTACT AREA
THIN CHASSIS

THIN-CHASSIS MOUNTING

MOUNTING PROCEDURES

MR322-MR331 and 1N3491-1N3495 rectifiers are designed to be press-fitted in a heat sink in order to attain full device ratings. Recommended procedures for this type of mounting are as follows:

1. Drill a hole in the heat sink 0.499 ± .001 inch in diameter.
2. Break the hole edge as shown to prevent shearing off the knurled edge of the rectifier when it is pressed into the hole.
3. The depth and width of the break should be 0.010 inch maximum to retain maximum heat sink surface contact.
4. To prevent damage to the rectifier during press-in, the pressing force should be applied only on the shoulder ring of the rectifier case as shown in the figure.
5. The pressing force should be applied evenly about the shoulder ring to avoid tilting or canting of the rectifier case in the hole during the press-in operation. Also, the use of a light industrial lubricant will be of considerable aid.

1N3580, A, B thru 1N3583, A, B

For Specifications, See 1N2163 Data.

1N3649, 1N3650

Obsolete, discontinued types, replace with devices from the MR1120 series.

1N3659 thru 1N3663

V_R — 400 V
I_O = 30 A

CASE 43
(DO-21)

Low-cost silicon rectifiers in hermetically sealed, press-fit case, designed for operation under severe environmental conditions. Cathode connected to case, but available with reverse polarity by adding suffix "R" to type number.

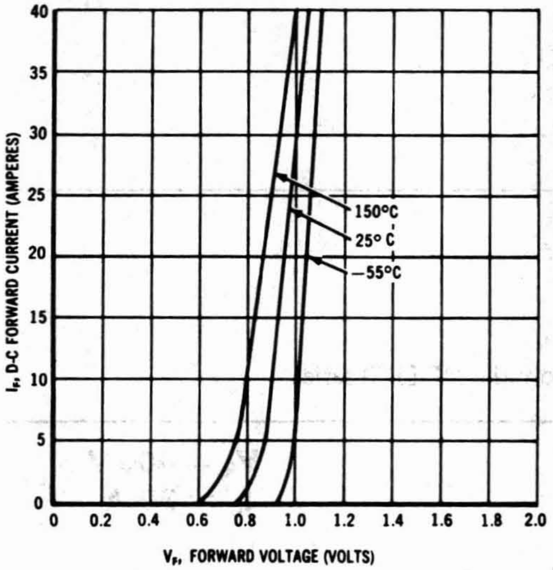
MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

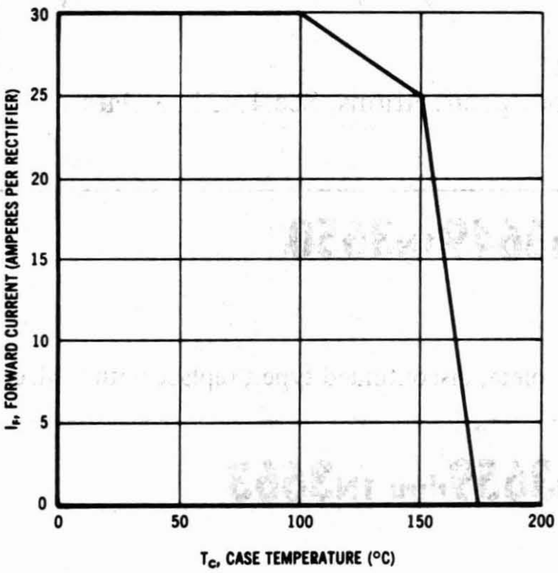
Rating	Symbol	1N3659 1N3659R	1N3660 1N3660R	1N3661 1N3661R	1N3662 1N3662R	1N3663 1N3663R	Units
Peak Repetitive Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ V_R	50	100	200	300	400	Volts
RMS Reverse Voltage	V_r	35	70	140	210	280	Volts
Average Half-Wave Rectified Forward Current with Resistive Load @ 100°C case @ 150°C case	I_O	30 25					Amp Amp
Peak One Cycle Surge Current (150°C case temp, 60 Hz)	$I_{FM(surge)}$	400					Amp
Operating Junction Temperature	T_J	−65 to +175					°C
Storage Temperature	T_{stg}	−65 to +200					°C

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	1N3659 1N3659R	1N3660 1N3660R	1N3661 1N3661R	1N3662 1N3662R	1N3663 1N3663R	Unit
Maximum Forward Voltage at 25 Amp DC Forward Current	V_F	1.2	1.2	1.2	1.2	1.2	Volts
Maximum Full Cycle Average Forward Voltage Drop @ Rated PIV and Current	$V_{F(AV)}$	0.7	0.7	0.7	0.7	0.7	Volts
Maximum Full Cycle Average Reverse Current @ Rated PIV and Current (as half-wave rectifier, resistive load, 150°C)	$I_{R(AV)}$	5.0	4.5	4.0	3.5	3.0	mA
Thermal Resistance	θ_{JC}	1.0					°C/W

1N3659 thru 1N3663 (continued)



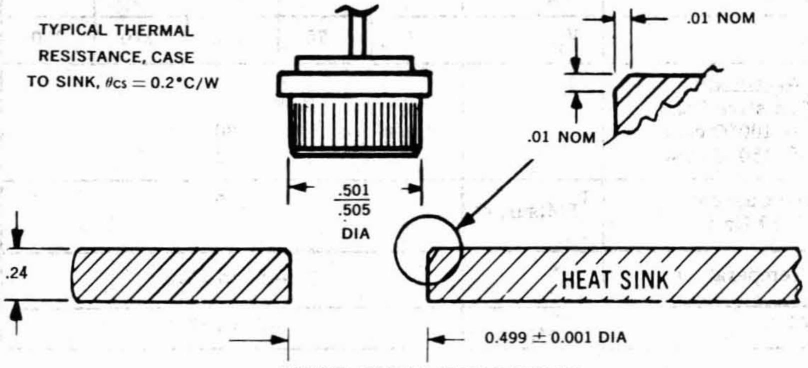


1N3659-1N3663 rectifiers are designed for press-fitted mounting in a heat sink. Recommended procedures for this type of mounting are as follows:

1. Drill a hole in the heat sink 0.499 ± .001 inch in diameter.
2. Break the hole edge as shown to prevent shearing off the knurled edge of the rectifier when it is pressed into the hole.
3. The depth of the break should be 0.010 inch maximum to retain maximum heat sink surface contact with the knurled rectifier surface.
4. Width of the break should be 0.010 inch as shown.

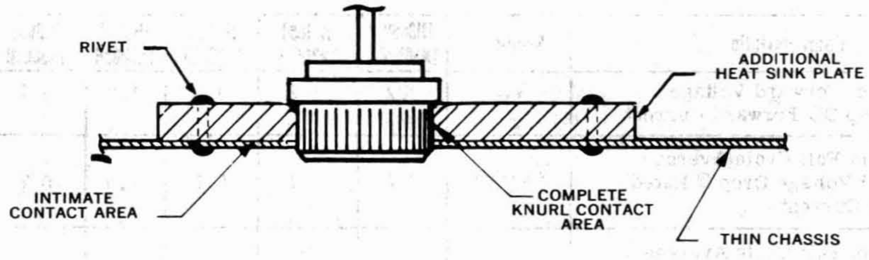
These procedures will allow proper entry of the rectifier knurled surface, provide good rectifier-heat sink surface contact, and assure reliable rectifier operation. If the break is made too deep, thereby reducing contact area for heat transfer, reliability of operation will be impaired.

These devices can be mounted in a thin chassis by inserting the rectifier through an additional heat sink plate which is mounted in intimate contact with the upper side of the chassis. This provides additional contact area for the rectifier knurled edge, as well as additional heat sink capacity.



TYPICAL THERMAL RESISTANCE, CASE TO SINK, θ_{CS} = 0.2°C/W
.01 NOM
.01 NOM
.501
.505
DIA
.24
HEAT SINK
0.499 ± 0.001 DIA

HEAT SINK MOUNTING

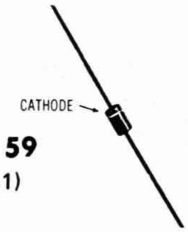


RIVET
ADDITIONAL HEAT SINK PLATE
INTIMATE CONTACT AREA
COMPLETE KNURL CONTACT AREA
THIN CHASSIS

THIN-CHASSIS MOUNTING

1N3675 thru 1N3703

¾ W
6.8 — 100 V



CASE 59
(DO-41)

Oxide passivated silicon zener diodes in void-free, transfer-molded, thermosetting plastic case. Offer 3/4-watt performance in a package no larger in volume than a conventional 400 mW glass package.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C.
D C Power Dissipation: 750 Milliwatts at 50°C Ambient.
(Derate 6 mW/°C)
Lead Temperature, 1/16 ± 1/32 inch from case: +235°C for 12 seconds.
(Method 2031, MIL-STD-750).

The type numbers shown have a standard tolerance of ±20% on the nominal zener voltage. Add suffix "A" for ±10% units or "B" for ±5% units.

ELECTRICAL CHARACTERISTICS 25°C Ambient $V_F = 1.5$ V @ $I_F = 200$ mA for all units)

Type No.	Nominal Zener Voltage V_Z @ I_{ZT} Volts	Test Current I_{ZT} mA	Max Zener Impedance		Max DC Zener Current I_{ZM} mA	I_R = 5 μA Max @ Reverse Voltage
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} Ohms		
1N3675	6.8	18.5	4.5	700	100	5.2
1N3676	7.5	16.5	5.5	700	90	5.7
1N3677	8.2	15.0	6.5	700	80	6.2
1N3678	9.1	14.0	7.5	700	70	6.9
1N3679	10	12.5	8.5	700	65	7.6
1N3680	11	11.5	9.5	700	55	8.4
1N3681	12	10.5	11.5	700	53	9.1
1N3682	13	9.5	13.0	700	50	9.9
	14	9.0	14.5	700	45	10.6
1N3683	15	8.5	16.0	700	42	11.4
1N3684	16	7.8	17.0	700	40	12.2
	17	7.2	19.0	700	38	13.0
1N3685	18	7.0	21.0	750	35	13.7
	19	6.5	23.0	750	33	14.4
1N3686	20	6.2	25.0	750	32	15.2
1N3687	22	5.6	29.0	750	29	16.7
1N3688	24	5.2	33.0	750	26	18.2
	25	5.0	36.0	750	24	19.0
1N3689	27	4.6	41.0	750	23	20.6
1N3690	30	4.2	49.0	1000	21	22.8
1N3691	33	3.8	58.0	1000	20	25.1
1N3692	36	3.4	70.0	1000	18	27.4
1N3693	39	3.2	80.0	1000	15	29.7
1N3694	43	3.0	93.0	1500	14	32.7
	45	2.8	99.0	1500	13.5	34.2
1N3695	47	2.7	105.0	1500	13	35.8
1N3696	51	2.5	125.0	1500	12.2	38.8
1N3697	56	2.2	150.0	2000	11	42.6
1N3698	62	2.0	185.0	2000	10	47.1
1N3699	68	1.8	230.0	2000	9.0	51.7
1N3700	75	1.7	270.0	2000	8.5	56.0
1N3701	82	1.5	330.0	3000	7.5	62.2
1N3702	91	1.4	400.0	3000	7.0	69.2
1N3703	100	1.3	500.0	3000	6.0	76.0

1N3785 thru 1N3820

1.5 W
6.8 — 200 V

CASE 55

Low silhouette single-ended package for printed circuit or socket mounting. Cathode connected to case.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C.
D C Power Dissipation: 1.5 Watts at 25°C Ambient. (Derate 10 mW/°C).

The type numbers shown have a standard tolerance of ±20% on the zener voltage. Standard tolerances of ±10% and ±5% on individual units are also available and are indicated by suffixing "A" for ±10% and "B" for ±5% units to the standard type number.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

V_F = 1.5 V max @ 300 mA

Type No.	Nominal Zener Voltage @ I_{ZT} (V_Z) Volts	Test Current (I_{ZT}) mA	Max Zener Impedance			Max DC Zener Current (I_{ZM}) mA	Reverse Leakage Current*			Typical Zener Voltage Temp. Coeff. %/°C
			Z_{ZT} @ I_{ZT} ohms	Z_{ZK} @ I_{ZK} ohms	I_{ZK} mA		I_R Max (μA)	V_{R1}	V_{R2}	
1N3785	6.8	55	2.7	700	1.0	195	150	5.2	4.9	.040
1N3786	7.5	50	3.0	700	0.5	175	75	5.7	5.4	.045
1N3787	8.2	46	3.5	700	0.5	155	50	6.2	5.9	.048
1N3788	9.1	41	4.0	700	0.5	140	25	6.9	6.6	.051
1N3789	10	37	5	700	0.25	125	10	7.6	7.2	.055
1N3790	11	34	6	700	0.25	115	5	8.4	8.0	.060
1N3791	12	31	7	700	0.25	105	5	9.1	8.6	.065
1N3792	13	29	8	700	0.25	98	5	9.9	9.4	.065
1N3793	15	25	10	700	0.25	85	5	11.4	10.8	.070
1N3794	16	23	11	700	0.25	80	5	12.2	11.5	.070
1N3795	18	21	13	750	0.25	70	5	13.7	13.0	.075
1N3796	20	19	15	750	0.25	62	5	15.2	14.4	.075
1N3797	22	17	16	750	0.25	56	5	16.7	15.8	.080
1N3798	24	16	17	750	0.25	51	5	18.2	17.3	.080
1N3799	27	14	20	750	0.25	46	5	20.6	19.4	.085
1N3800	30	12	25	1,000	0.25	41	5	22.8	21.6	.085
1N3801	33	11	30	1,000	0.25	38	5	25.1	23.8	.085
1N3802	36	10	35	1,000	0.25	35	5	27.4	25.9	.085
1N3803	39	10	40	1,000	0.25	31	5	29.7	28.1	.090
1N3804	43	9.0	45	1,500	0.25	28	5	32.7	31.0	.090
1N3805	47	8.0	55	1,500	0.25	26	5	35.8	33.8	.090
1N3806	51	7.4	65	2,000	0.25	24	5	38.8	36.6	.090
1N3807	56	6.7	75	2,000	0.25	22	5	42.6	40.3	.090
1N3808	62	6.0	85	2,000	0.25	20	5	47.1	44.6	.090
1N3809	68	5.5	95	2,000	0.25	18	5	51.7	49.0	.090
1N3810	75	5.0	110	2,000	0.25	16	5	56.0	54.0	.090
1N3811	82	4.5	130	3,000	0.25	14	5	62.0	59.0	.090
1N3812	91	4.1	150	3,000	0.25	13	5	69.2	65.5	.090
1N3813	100	3.7	200	3,000	0.25	12.0	5	76.0	72.0	.090
1N3814	110	3.4	300	4,000	0.25	11.0	5	83.6	79.2	.095
1N3815	120	3.1	350	4,500	0.25	10.5	5	91.2	86.4	.095
1N3816	130	2.9	400	5,000	0.25	9.0	5	98.8	93.6	.095
1N3817	150	2.5	700	6,000	0.25	8.0	5	114.0	108.0	.095
1N3818	160	2.3	750	6,500	0.25	8.0	5	121.8	115.0	.095
1N3819	180	2.1	800	7,000	0.25	7.0	5	137.0	130.0	.095
1N3820	200	1.9	1,000	8,000	0.25	6.0	5	152.0	144.0	.100

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

1 — Nominal zener voltages between those shown.
2 — Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  b. Two or more units matched to one another with any specified tolerance.
3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

*V_{R1} — Test Voltage for 5% Tolerance Device. V_{R2} — Test Voltage for 10% Tolerance Device. No Leakage Specified as 20% Tolerance Device.

1N3821 thru 1N3830

1 W
3.3 — 7.5 V

1N3821A thru 1N3830A

CASE 52
(DO-13)

Low-voltage, alloy-junction zener diodes in hermetically sealed package with cathode connected-to-case. Available as standard industrial types as well as for military and high-reliability applications.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C.
D C Power Dissipation: 1 Watt. (Derate 6.67 mW/°C above 25°C).

The type numbers shown have a standard tolerance on the nominal zener voltage of ±10%. A standard tolerance of ±5% on individual units is also available and is indicated by suffixing "A" to the standard type number.

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

V_F = 1.5 V @ I_F = 200 mA for all units.

Type No.	Nominal Zener Voltage V_Z @ I_{ZT} Volts	Test Current I_{ZT} mA	Max Zener Impedance Z_{ZT} @ I_{ZT} Ohms	Max Zener Impedance Z_{ZK} @ I_{ZK} = 1.0 mA Ohms	Max DC Zener Current I_{ZM} mA	I_R = 10 μA max @ Reverse Voltage V_R	Typical Zener Voltage/temp. Coeff. %/°C
1N3821	3.3	76	10	400	276	1	-0.075
1N3821A	3.3	76	10	400	276	1	-0.075
1N3822	3.6	69	10	400	252	1	-0.065
1N3822A	3.6	69	10	400	252	1	-0.065
1N3823	3.9	64	9	400	238	1	-0.055
1N3823A	3.9	64	9	400	238	1	-0.055
1N3824	4.3	58	9	400	213	1	-0.040
1N3824A	4.3	58	9	400	213	1	-0.040
1N3825	4.7	53	8	500	194	1	-0.020
1N3825A	4.7	53	8	500	194	1	-0.020
1N3826	5.1	49	7	550	178	1	+0.005
1N3826A	5.1	49	7	550	178	1	+0.005
1N3827	5.6	45	5	600	162	2	+0.020
1N3827A	5.6	45	5	600	162	2	+0.020
1N3828	6.2	41	2	700	146	3	+0.035
1N3828A	6.2	41	2	700	146	3	+0.035
1N3829	6.8	37	1.5	500	133	3	+0.040
1N3829A	6.8	37	1.5	500	133	3	+0.040
1N3830	7.5	34	1.5	250	121	3	+0.045
1N3830A	7.5	34	1.5	250	121	3	+0.045

SPECIAL SELECTIONS AVAILABLE INCLUDE: **(See Selector Guide for details)**

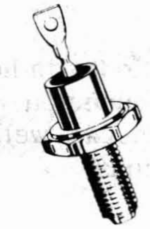
1 — Nominal zener voltages between those shown.
2 — Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  b. Two or more units matched to one another with any specified tolerance.
3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

1N3879 thru 1N3883, 1N3889 thru 1N3893 (SILICON)
1N3899 thru 1N3903, 1N3909 thru 1N3913

For Specifications, See 1N4933 Data.

1N3993 thru 1N4000

10 W
3.9 — 7.5 V



CASE 56
(DO-4)

Low-voltage, alloy-junction zener diodes in hermetically sealed package with cathode connected to case. Supplied with mounting hardware.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C.
D C Power Dissipation: 10 Watts. (Derate 83.3 mW/°C above 55°C).

The type numbers shown in the table have a standard tolerance on the nominal zener voltage of ±10%. A standard tolerance of ±5% on individual units is also available and is indicated by suffixing "A" to the standard type number.

ELECTRICAL CHARACTERISTICS

($T_B = 30°C \pm 3$, $V_F = 1.5$ max @ $I_F = 2$ amp for all units)

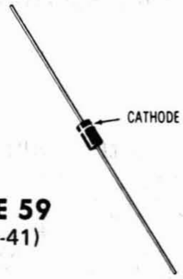
Type No.	Nominal Zener Voltage V_Z @ I_{ZT} Volts	Test Current I_{ZT} mA	Max Zener Impedance		Max DC Zener Current I_{ZM} mA	Reverse Leakage Current	
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} = 1.0 mA Ohms		I_R μA	V_R Volts
1N3993	3.9	640	2	400	2380	100	0.5
1N3994	4.3	580	1.5	400	2130	100	0.5
1N3995	4.7	530	1.2	500	1940	50	1
1N3996	5.1	490	1.1	550	1780	10	1
1N3997	5.6	445	1.0	600	1620	10	1
1N3998	6.2	405	1.1	750	1460	10	2
1N3999	6.8	370	1.2	500	1330	10	2
1N4000	7.5	335	1.3	250	1210	10	3

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

1 — Nominal zener voltages between those shown.
2 — Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  b. Two or more units matched to one another with any specified tolerance.
3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

1N4001 thru 1N4007

V_R = 50-1000 V
I_O = 1.0 A



CASE 59
(DO-41)

Surmetic rectifiers, subminiature size, axial lead mounted rectifiers for general purpose low-power applications.

MAXIMUM RATINGS

Rating	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	200	400	600	800	1000	Volts
Non-Repetitive Peak Reverse Voltage (halfwave, single phase, 60 Hz peak)	$V_{RM(non\text{-}rep)}$	75	150	300	600	900	1200	1500	Volts
RMS Reverse Voltage	V_r	35	70	140	280	420	560	700	Volts
Average Rectified Forward Current (single phase, resistive load, 60 Hz, see Figure 6, T_A = 75°C)	I_O	1.0							Amp
Non-Repetitive Peak Surge Current (surge applied at rated load conditions, see Figure 2)	$I_{FM(surge)}$	30 (for 1 cycle)							Amp
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175							°C

ELECTRICAL CHARACTERISTICS

Characteristic and Conditions	Symbol	Max	Unit
Maximum Instantaneous Forward Voltage Drop (i_F = 1.0 Amp, T_J = 25°C) Figure 1	V_F	1.1	Volts
Maximum Full-Cycle Average Forward Voltage Drop (I_O = 1.0 Amp, T_L = 75°C, 1 inch leads)	$V_{F(AV)}$	0.8	Volts
Maximum Reverse Current (rated dc voltage) T_J = 25°C T_J = 100°C	I_R	0.01 0.05	mA
Maximum Full-Cycle Average Reverse Current (I_O = 1.0 Amp, T_L = 75°C, 1 inch leads)	$I_{R(AV)}$	0.03	mA

MECHANICAL CHARACTERISTICS

CASE: Void free, Transfer Molded

MAXIMUM LEAD TEMPERATURE FOR SOLDERING PURPOSES: 350°C, ⅜″ from case for 10 seconds at 5 lbs. tension

FINISH: All external surfaces are corrosion-resistant, leads are readily solderable

POLARITY: Cathode indicated by color band

WEIGHT: 0.40 Grams (approximately)

FIGURE 1 — FORWARD VOLTAGE

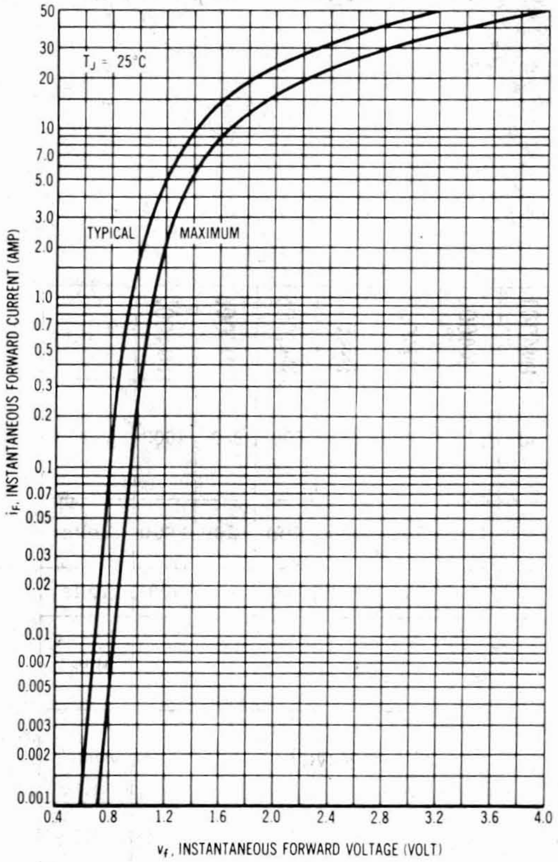


FIGURE 2 — MAXIMUM SURGE CAPABILITY

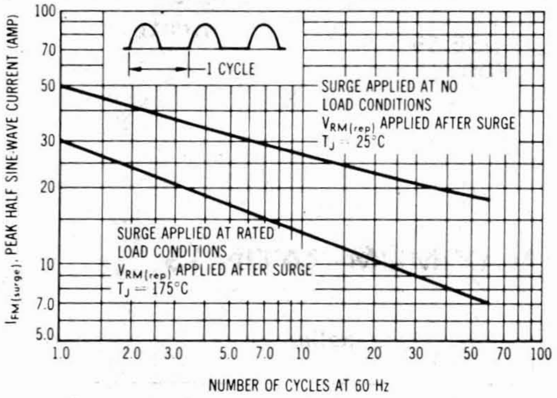


FIGURE 3 — FORWARD VOLTAGE TEMPERATURE COEFFICIENT

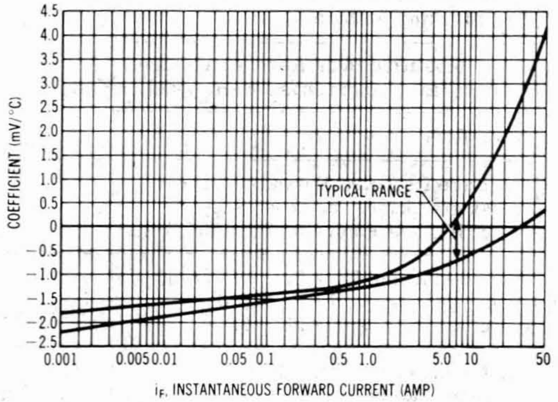
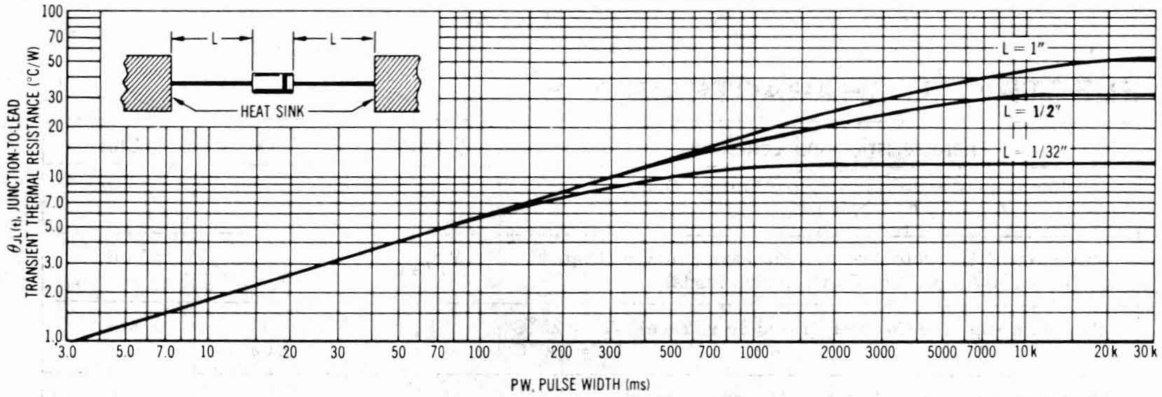


FIGURE 4 — TYPICAL TRANSIENT THERMAL RESISTANCE



FOR $\theta_{JL(t)}$ VALUES AT PULSE WIDTHS LESS THAN 3.0 ms, THE ABOVE CURVE CAN BE EXTRAPOLATED DOWN TO 10 μs AT A CONTINUING SLOPE OF 1/2

CURRENT DERATING DATA

FIGURE 5 — LEAD TEMPERATURE DERATING (DC ONLY)

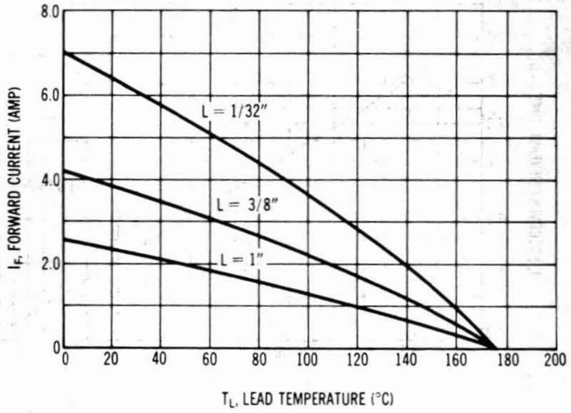


FIGURE 6 — RESISTIVE, INDUCTIVE LOADS

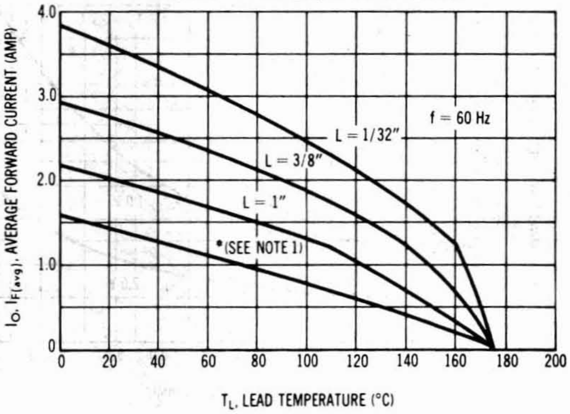


FIGURE 7 — CAPACITIVE LOADS

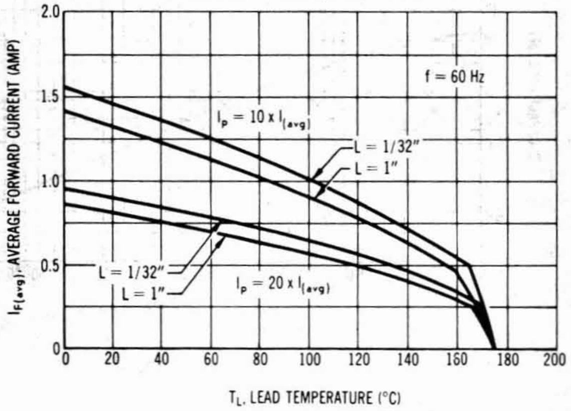
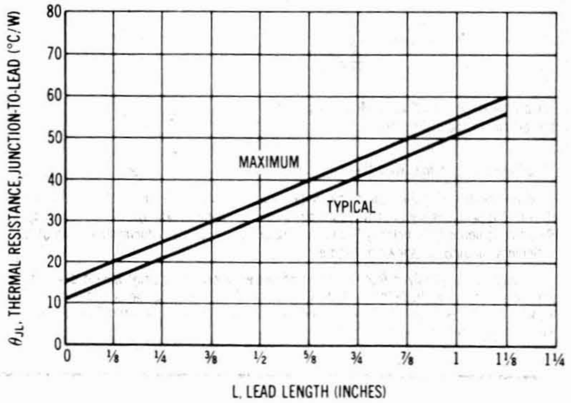


FIGURE 8 — STEADY-STATE THERMAL RESISTANCE

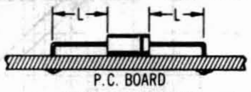


NOTES

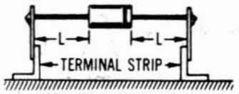
NOTE 1

Data shown for thermal resistance junction-to-ambient (θ_{JA}) for the mountings shown is to be used as typical guideline values for preliminary engineering or in case the tie point temperature cannot be measured.

TYPICAL VALUES FOR θ_{JA} IN STILL AIR



MOUNTING METHOD 1

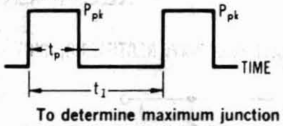


MOUNTING METHOD 2

MOUNTING METHOD	LEAD LENGTH, L (IN.)			θ_{JA}
	1/32	3/8	1	
1	—	75	85	°C/W
2	55	72	85	°C/W

•Using Mounting Method 1 or 2 with L = 1″ the curve marked • in Figure 6 can be used for 60 Hz half-wave resistive/inductive load (Rating vs. Ambient Temperature). The abscissa of Figure 6 then indicates T_A in °C.

NOTE 2



DUTY CYCLE, $D = t_p/t_1$

PEAK POWER, P_{pk}, is peak of an equivalent square power pulse.

To determine maximum junction temperature of the diode in a given situation, the following procedure is recommended:

The temperature of the lead should be measured using a thermocouple placed on the lead as close as possible to the tie point. The thermal mass connected to the tie point is normally large enough so that it will not significantly respond to heat surges generated in the diode as a result of pulsed operation once steady-state conditions are achieved. Using the measured value of T_L, the junction temperature may be determined by:

$$T_J = T_L + \triangle T_{JL},$$

where $\triangle T_{JL}$ is the increase in junction temperature above the lead temperature. It may be determined by:

$$\triangle T_{JL} = P_{pk}\left[\theta_{JL(\infty)} \cdot D + (1 - D) \cdot \theta_{JL(t_1 + t_p)} + \theta_{JL(t_p)} - \theta_{JL(t_1)}\right]$$

where $\theta_{JL(t)}$ = value of transient thermal resistance at time t, i.e.:

$\theta_{JL(t_1+t_p)}$ = value of $\theta_{JL(t)}$ at time t_1+t_p

$\theta_{JL(t_p)}$ = value of $\theta_{JL(t)}$ at end of pulse width t_p

$\theta_{JL(t_1)}$ = value of $\theta_{JL(t)}$ at time t_1

1N4001 thru 1N4007 (continued)

TYPICAL DYNAMIC CHARACTERISTICS

FIGURE 9 — FORWARD RECOVERY TIME

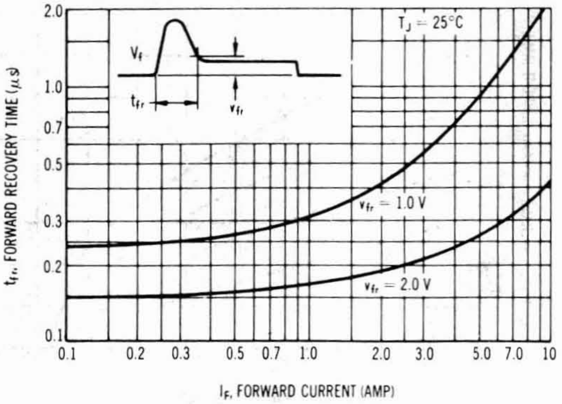


FIGURE 10 — REVERSE RECOVERY TIME

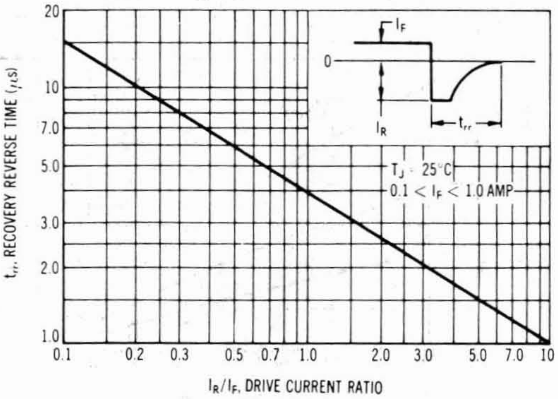


FIGURE 11 — RECTIFICATION WAVEFORM EFFICIENCY

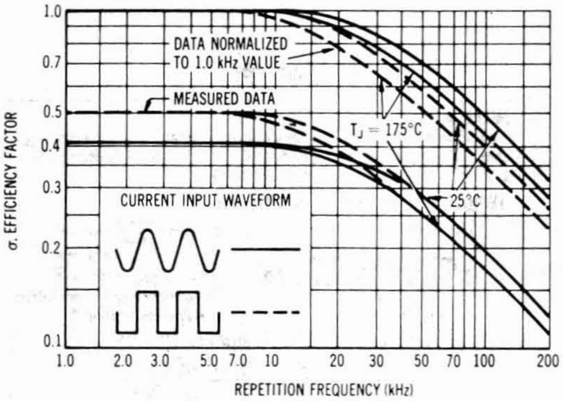
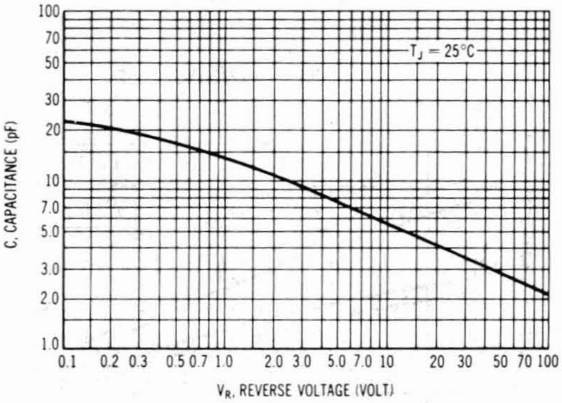
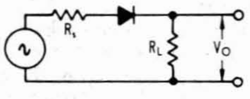


FIGURE 12 — JUNCTION CAPACITANCE



RECTIFIER EFFICIENCY NOTE

FIGURE 13 — SINGLE-PHASE HALF-WAVE RECTIFIER CIRCUIT



The rectification efficiency factor σ shown in Figure 11 was calculated using the formula:

$$\sigma = \frac{P_{dc}}{P_{rms}} = \frac{\dfrac{V^2{}_O(dc)}{R_L}}{\dfrac{V^2{}_O(rms)}{R_L}} \cdot 100\% = \frac{V^2{}_O(dc)}{V^2{}_O(ac) + V^2{}_O(dc)} \cdot 100\% \quad (1)$$

For a sine wave input $V_m \sin(\omega t)$ to the diode, assumed lossless, the maximum theoretical efficiency factor becomes:

$$\sigma(\text{sine}) = \frac{\dfrac{V^2{}_m}{\pi^2 R_L}}{\dfrac{V^2{}_m}{4R_L}} \cdot 100\% = \frac{4}{\pi^2} \cdot 100\% = 40.6\% \quad (2)$$

For a square wave input of amplitude V_m, the efficiency factor becomes:

$$\sigma_{(\text{square})} = \frac{\dfrac{V^2{}_m}{2R_L}}{\dfrac{V^2{}_m}{R_L}} \cdot 100\% = 50\% \quad (3)$$

(A full wave circuit has twice these efficiencies)

As the frequency of the input signal is increased, the reverse recovery time of the diode (Figure 10) becomes significant, resulting in an increasing ac voltage component across R_L which is opposite in polarity to the forward current, thereby reducing the value of the efficiency factor σ, as shown on Figure 11.

It should be emphasized that **Figure 11 shows waveform efficiency only; it does not provide a measure of diode losses.** Data was obtained by measuring the ac component of V_O with a true rms ac voltmeter and the dc component with a dc voltmeter. The data was used in Equation 1 to obtain points for Figure 11.

1N4057, A thru 1N4085, A

For Specifications, See 1N429 Data.

1N4099 thru 1N4135
(MZ4614 thru MZ4627)

LOW-LEVEL SILICON PASSIVATED ZENER DIODES

. . . designed for 250 mW applications requiring low leakage, low impedance, and low noise.

- Voltage Range from 1.8 to 100 Volts
- First Zener Diode Series to Specify Noise—50% Lower than Conventional Diffused Zeners
- Zener Impedance and Zener Voltage Specified for Low-Level Operation at I_{ZT} = 250 μA
- Low Leakage Current — I_R from 0.01 to 10 μA over Voltage Range
- Expanded Temperature Range — T_J = -65 to +200°C

SILICON ZENER DIODES

(±5.0% TOLERANCE)

250 MILLIWATTS
1.8-100 VOLTS

SILICON OXIDE
PASSIVATED JUNCTION

MAXIMUM RATINGS

Rating	Value	Unit
DC Power Dissipation, 25°C Ambient	250	mW
Derating Factor	1.43	mW/°C
Junction and Storage Temperature	-65 to +200	°C

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass.

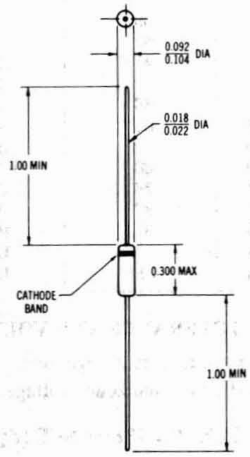
DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

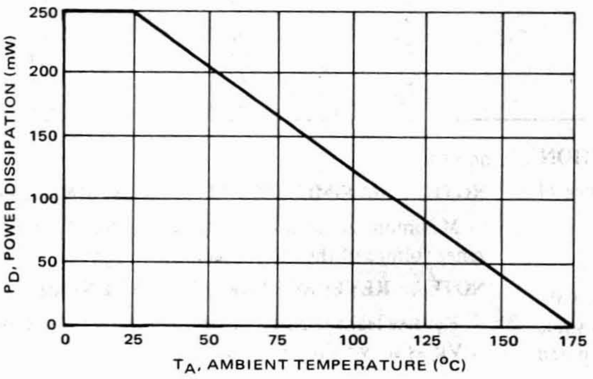
WEIGHT: 0.2 gram (approx)

MOUNTING POSITION: Any



CASE 51
(DO-7)

POWER TEMPERATURE DERATING CURVE



ELECTRICAL CHARACTERISTICS

(At 25°C Ambient temperature unless otherwise specified) I_{ZT} = 250 µA and V_F = 1.0 V max @ I_F = 200 mA on all Types

Type Number (Note 1)	Nominal Zener Voltage V_Z (Note 1) (Volts)	Max Zener Impedance Z_{ZT} (Note 2) (Ohms)	Max Reverse Current I_R (µA)	@ (Note 4)	Test Voltage V_R (Volts)	Max Noise Density At I_{ZT} = 250 µA N_D (Fig 1) (micro-volts per Square Root Cycle)	Max Zener Current I_{ZM} (Note 3) (mA)
MZ4614	1.8	1200	7.5		1.0	1.0	120
MZ4615	2.0	1250	5.0		1.0	1.0	110
MZ4616	2.2	1300	4.0		1.0	1.0	100
MZ4617	2.4	1400	2.0		1.0	1.0	95
MZ4618	2.7	1500	1.0		1.0	1.0	90
MZ4619	3.0	1600	0.8		1.0	1.0	85
MZ4620	3.3	1650	7.5		1.5	1.0	80
MZ4621	3.6	1700	7.5		2.0	1.0	75
MZ4622	3.9	1650	5.0		2.0	1.0	70
MZ4623	4.3	1600	4.0		2.0	1.0	65
MZ4624	4.7	1550	10		3.0	1.0	60
MZ4625	5.1	1500	10		3.0	2.0	55
MZ4626	5.6	1400	10		4.0	4.0	50
MZ4627	6.2	1200	10		5.0	5.0	45
1N4099	6.8	200	10		5.2	40	35
1N4100	7.5	200	10		5.7	40	31.8
1N4101	8.2	200	1.0		6.3	40	29.0
1N4102	8.7	200	1.0		6.7	40	27.4
1N4103	9.1	200	1.0		7.0	40	26.2
1N4104	10	200	1.0		7.6	40	24.8
1N4105	11	200	0.05		8.5	40	21.6
1N4106	12	200	0.05		9.2	40	20.4
1N4107	13	200	0.05		9.9	40	19.0
1N4108	14	200	0.05		10.7	40	17.5
1N4109	15	100	0.05		11.4	40	16.3
1N4110	16	100	0.05		12.2	40	15.4
1N4111	17	100	0.05		13.0	40	14.5
1N4112	18	100	0.05		13.7	40	13.2
1N4113	19	150	0.05		14.5	40	12.5
1N4114	20	150	0.01		15.2	40	11.9
1N4115	22	150	0.01		16.8	40	10.8
1N4116	24	150	0.01		18.3	40	9.9
1N4117	25	150	0.01		19.0	40	9.5
1N4118	27	150	0.01		20.5	40	8.8
1N4119	28	200	0.01		21.3	40	8.5
1N4120	30	200	0.01		22.8	40	7.9
1N4121	33	200	0.01		25.1	40	7.2
1N4122	36	200	0.01		27.4	40	6.6
1N4123	39	200	0.01		29.7	40	6.1
1N4124	43	250	0.01		32.7	40	5.5
1N4125	47	250	0.01		35.8	40	5.1
1N4126	51	300	0.01		38.8	40	4.6
1N4127	56	300	0.01		42.6	40	4.2
1N4128	60	400	0.01		45.6	40	4.0
1N4129	62	500	0.01		47.1	40	3.8
1N4130	68	700	0.01		51.7	40	3.5
1N4131	75	700	0.01		57.0	40	3.1
1N4132	82	800	0.01		62.4	40	2.9
1N4133	87	1000	0.01		66.2	40	2.7
1N4134	91	1200	0.01		69.2	40	2.6
1N4135	100	1500	0.01		76.0	40	2.3

NOTE 1: TOLERANCE AND VOLTAGE DESIGNATION

The type numbers shown have a standard tolerance of ±5.0% on the nominal zener voltage.

NOTE 2: ZENER IMPEDANCE (Z_{ZT}) DERIVATION

The zener impedance is derived from the 60 cycle ac voltage, which results when an ac current having an rms value equal to 10% of the dc zener current (I_{ZT}) is superimposed on I_{ZT}.

NOTE 3: MAXIMUM ZENER CURRENT RATINGS (I_{ZM})

Maximum zener current ratings are based on maximum zener voltage of the individual units.

NOTE 4: REVERSE LEAKAGE CURRENT I_R

Reverse leakage currents are guaranteed and are measured at V_R as shown on the table.

ZENER NOISE DENSITY

A zener diode generates noise when it is biased in the zener direction. A small part of this noise is due to the internal resistance associated with the device. A larger part of zener noise is a result of the zener breakdown phenomenon and is called microplasma noise. This microplasma noise is generally considered "white" noise with equal amplitude for all frequencies from about zero cycles to approximately 200,000 cycles. To eliminate the higher frequency components of noise a small shunting capacitor can be used. The lower frequency noise generally must be tolerated since a capacitor required to eliminate the lower frequencies would degrade the regulation properties of the zener in many applications.

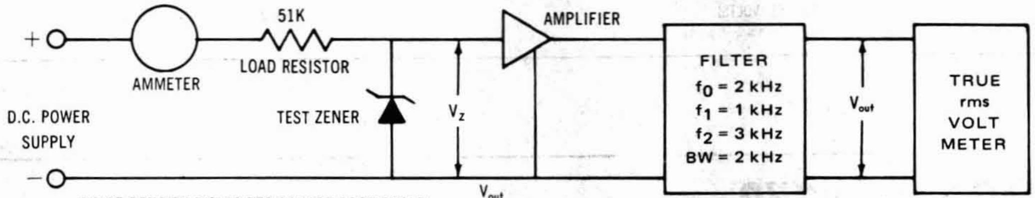
Motorola is rating this series with a maximum noise density at 250 microamperes. The rating of microvolts RMS per square root cycle enables calculation of the maximum RMS noise for any bandwidth.

Noise density decreases as zener current increases. This can be seen by the graph in Figure 2 where a typical noise density is plotted as a function of zener current.

The junction temperature will also change the zener noise levels. Thus the noise rating must indicate bandwidth, current level and temperature.

The block diagram given in Figure 1 shows the method used to measure noise density. The input voltage and load resistance is high so that the zener is driven from a constant current source. The amplifier must be low noise so that the amplifier noise is negligible compared to the test zener. The filter bandpass is known so that the noise density in volts RMS per square root cycle can be calculated.

FIGURE 1 — NOISE DENSITY MEASUREMENT METHOD



$$\text{NOISE DENSITY (VOLTS PER SQUARE ROOT CYCLE)} = \frac{V_{out}}{\text{OVERALL GAIN}\sqrt{BW}}$$

WHERE: BW = FILTER BANDWIDTH (CYCLES)

V_{out} = OUTPUT NOISE (VOLTS RMS)

FIGURE 2 — TYPICAL NOISE DENSITY versus ZENER CURRENT

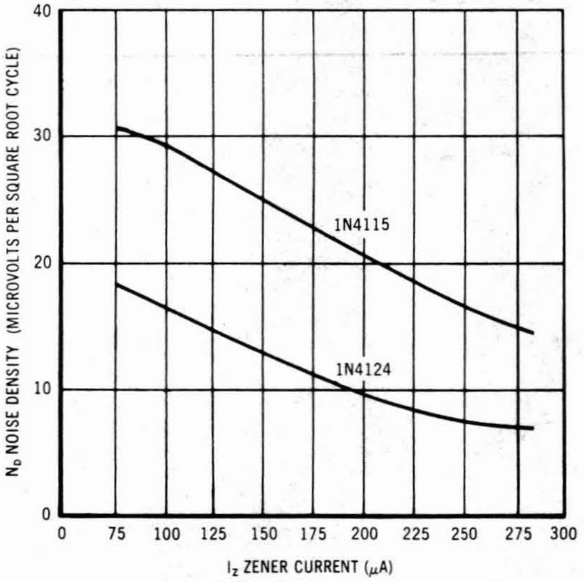


FIGURE 3 – TYPICAL CAPACITANCE

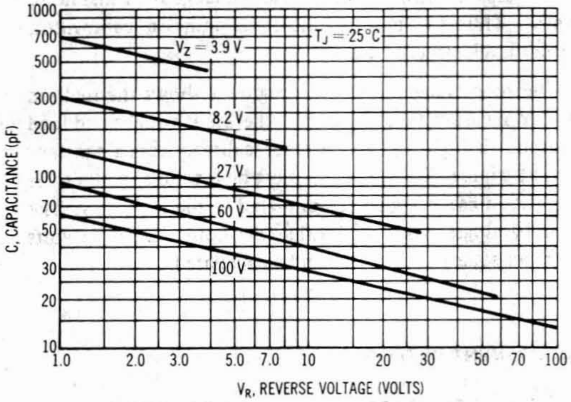
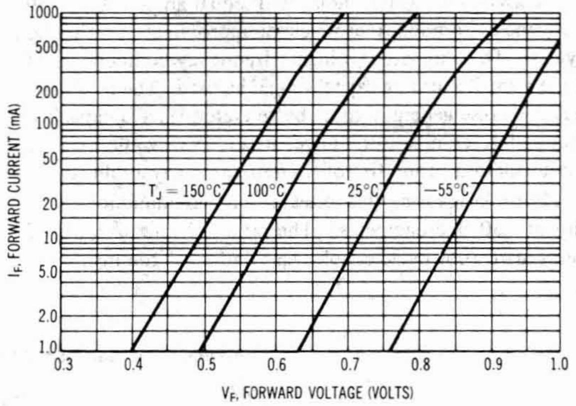


FIGURE 4 – TYPICAL FORWARD CHARACTERISTICS



1N4370 thru 1N4372
1N4370A thru 1N4372A

For Specifications, see 1N746 thru 1N759 Data.

1N4387
(MV1804)

CASE 44
(DO-4)

cathode connected to stud

Silicon varactor diode for high-power frequency multiplication applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	150	Vdc
RF Power Input	P_{in}	40	Watts
Total Device Dissipation @ T_C = 75°C Derate above 75°C	P_D	20 200	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C

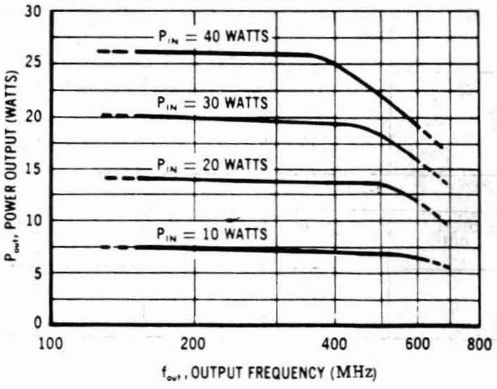
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage (I_R = 10 μAdc)	BV_R	150	200	-	Vdc
Series Resistance (V_R = 6.0 Vdc, f = 50 MHz)	R_S	-	1.0	1.5	Ohms
Junction Capacitance (V_R = 6.0 Vdc, f = 1.0 MHz)	C_J	-	25	35	pF
Figure of Merit (V_R = 6.0 Vdc, f = 50 MHz)	Q	150	200	-	-

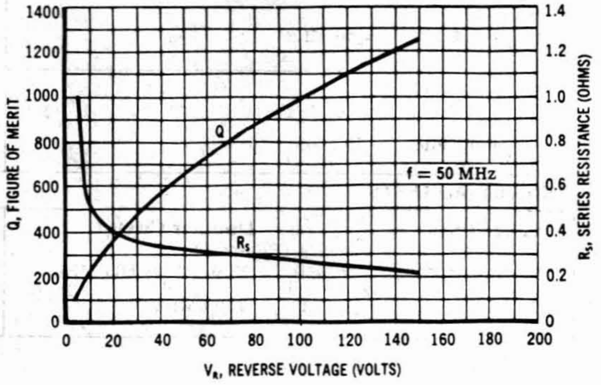
FUNCTIONAL TESTS

Power Output	Tripler Circuit P_{in} = 30 W, f_{in} = 150 MHz, f_{out} = 450 MHz	P_{out}	15	18	-	Watts
Efficiency		η	50	60	-	%

POWER OUTPUT versus OUTPUT FREQUENCY FOR HARMONIC TRIPLING



SERIES RESISTANCE AND FIGURE OF MERIT versus REVERSE VOLTAGE



1N4388
(MV1806)

Silicon varactor diode for high-frequency harmonic generation applications.

cathode connected to stud

CASE 44
(DO-4)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	100	Vdc
Forward Current	I_F	1.0	Amp
RF Power Input	P_{in}	25	Watts
Total Device Dissipation @ T_C = 75° C Derate above 75° C	P_D	10 0.10	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

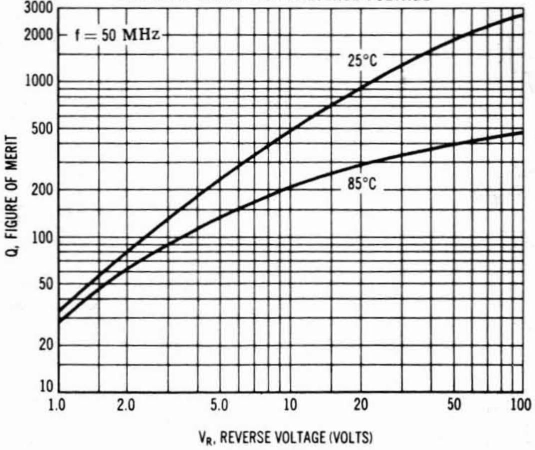
Characteristic	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage (I_R = 10 μAdc)	BV_R	100	150	-	Vdc
Reverse Current	I_R				μAdc
(V_R = 75 Vdc)		-	0.5	2.0	
(V_R = 75 Vdc, T_A = 150° C)		-	-	100	
Diode Capacitance	C_T*				pF
(V_R = 6.0 Vdc, f = 1.0 MHz)		-	10	20	
(V_R = 90 Vdc, f = 1.0 MHz)		-	5.0	10	
Series Resistance (V_R = 6.0 Vdc, f = 50 MHz)	R_S	-	1.2	2.0	Ohms
Figure of Merit	Q				-
(V_R = 6.0 Vdc, f = 50 MHz)		200	300	-	
(V_R = 90 Vdc, f = 50 MHz)		1000	-	-	

FUNCTIONAL TESTS

Power Output	**Doubler Circuit** (Figure 1) P_{in} = 20 W, f_{in} = 500 MHz, f_{out} = 1000 MHz	P_{out}	11.0	12.0	-	Watts
Efficiency		η	55	60	-	%

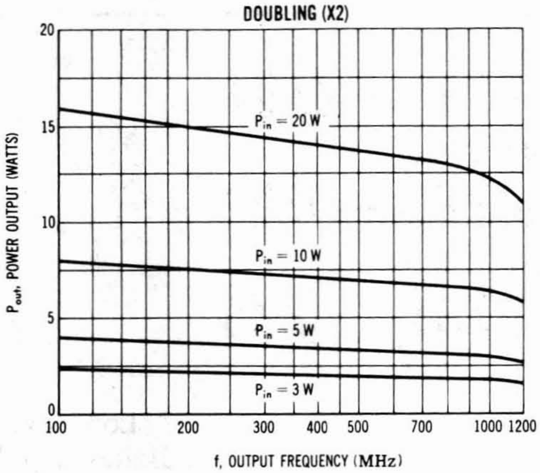
*$C_T = C_J + C_C$

FIGURE OF MERIT versus REVERSE VOLTAGE

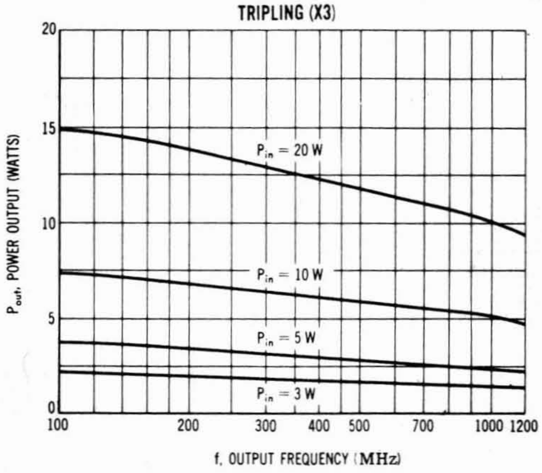


POWER OUTPUT versus OUTPUT FREQUENCY

DOUBLING (X2)



TRIPLING (X3)



QUADRUPLING (X4)

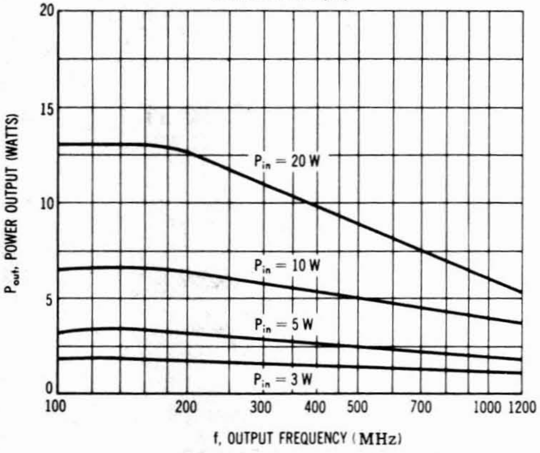
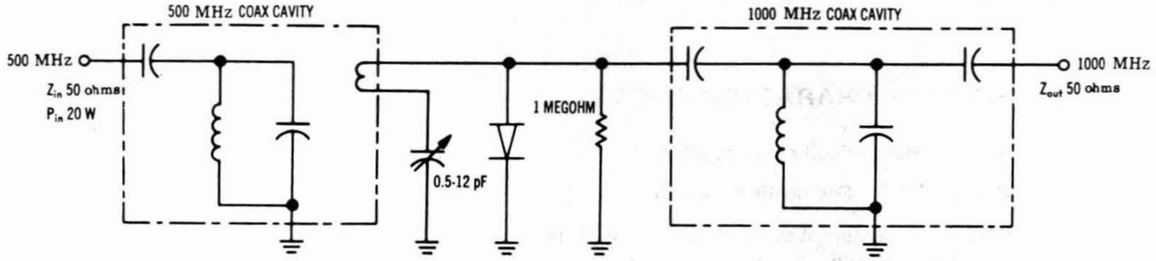


FIGURE 1 — HARMONIC DOUBLER EFFICIENCY TEST CIRCUIT


500 MHz COAX CAVITY
500 MHz
Z_in 50 ohms
P_in 20 W
0.5-12 pF
1 MEGOHM
1000 MHz COAX CAVITY
1000 MHz
Z_out 50 ohms

1N4549 thru 1N4556
1N4557 thru 1N4564

For Specifications, See 1N2804 Data

1N4565-1N4584
6.4 V ± 5.0%
1N4775-1N4784
8.5 V ± 5.0%
1N4765-1N4774
9.1 V ± 5.0%

Low level temperature-compensated zener reference diodes–highly reliable reference sources utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.

CASE 51
(DO-7)

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C

DC Power Dissipation: 400 Milliwatts at 50°C Ambient
(Derate 3.2 mW/°C Above 50°C)

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

DIMENSIONS: See outline drawing.

FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any

1N4565-1N4584/1N4775-1N4784/1N4765-1N4774 (continued)

TYPE	ΔV_Z (Note 1) Volts Max	@ Test Temperature °C	Temperature Coefficient for Reference %/°C (Note 1)	Dynamic Imped. Ohms Max (Note 2)
$V_Z = 6.4$ Volts ±5% ($I_{ZT} = 0.5$ mA)				
1N4565	0.048	0, +25, +75	0.01	200
1N4566	0.024		0.005	
1N4567	0.010		0.002	
1N4568	0.005		0.001	
1N4569	0.002		0.0005	
1N4565A	0.099	−55, 0, +25, +75, +100	0.01	200
1N4566A	0.050		0.005	
1N4567A	0.020		0.002	
1N4568A	0.010		0.001	
1N4569A	0.005		0.0005	
$V_Z = 6.4$ Volts ±5% ($I_{ZT} = 1.0$ mA)				
1N4570	0.048	0, +25, +75	0.01	100
1N4571	0.024		0.005	
1N4572	0.010		0.002	
1N4573	0.005		0.001	
1N4574	0.002		0.0005	
1N4570A	0.099	−55, 0, +25, +75, +100	0.01	100
1N4571A	0.050		0.005	
1N4572A	0.020		0.002	
1N4573A	0.010		0.001	
1N4574A	0.005		0.0005	
$V_Z = 6.4$ Volts ±5% ($I_{ZT} = 2.0$ mA)				
1N4575	0.048	0, +25, +75	0.01	50
1N4576	0.024		0.005	
1N4577	0.010		0.002	
1N4578	0.005		0.001	
1N4579	0.002		0.0005	
1N4575A	0.099	−55, 0, +25, +75, +100	0.01	50
1N4576A	0.050		0.005	
1N4577A	0.020		0.002	
1N4578A	0.010		0.001	
1N4579A	0.005		0.0005	
$V_Z = 6.4$ Volts ±5% ($I_{ZT} = 4.0$ mA)				
1N4580	0.048	0, +25, +75	0.01	25
1N4581	0.024		0.005	
1N4582	0.010		0.002	
1N4583	0.005		0.001	
1N4584	0.002		0.0005	
1N4580A	0.099	−55, 0, +25, +75, +100	0.01	25
1N4581A	0.050		0.005	
1N4582A	0.020		0.002	
1N4583A	0.010		0.001	
1N4584A	0.005		0.0005	

TYPE	ΔV_Z (Note 1) Volts Max	@ Test Temperature °C	Temperature Coefficient for Reference %/°C (Note 1)	Dynamic Imped. Ohms Max (Note 2)
$V_Z = 8.5$ Volts ±5% ($I_{ZT} = 0.5$ mA)				
1N4775	0.064	0, +25, +75	0.01	200
1N4776	0.032		0.005	
1N4777	0.013		0.002	
1N4778	0.006		0.001	
1N4779	0.003		0.0005	
1N4775A	0.132	−55, 0, +25, +75, +100	0.01	200
1N4776A	0.066		0.005	
1N4777A	0.026		0.002	
1N4778A	0.013		0.001	
1N4779A	0.007		0.0005	
$V_Z = 8.5$ Volts ±5% ($I_{ZT} = 1.0$ mA)				
1N4780	0.064	0, +25, +75	0.01	100
1N4781	0.032		0.005	
1N4782	0.013		0.002	
1N4783	0.006		0.001	
1N4784	0.003		0.0005	
1N4780A	0.132	−55, 0, +25, +75, +100	0.01	100
1N4781A	0.066		0.005	
1N4782A	0.026		0.002	
1N4783A	0.013		0.001	
1N4784A	0.007		0.0005	
$V_Z = 9.1$ Volts ±5% ($I_{ZT} = 0.5$ mA)				
1N4765	0.068	0, +25, +75	0.01	350
1N4766	0.034		0.005	
1N4767	0.014		0.002	
1N4768	0.007		0.001	
1N4769	0.003		0.0005	
1N4765A	0.141	−55, 0, +25, +75, +100	0.01	350
1N4766A	0.070		0.005	
1N4767A	0.028		0.002	
1N4768A	0.014		0.001	
1N4769A	0.007		0.0005	
$V_Z = 9.1$ Volts ±5% ($I_{ZT} = 1.0$ mA)				
1N4770	0.068	0, +25, +75	0.01	200
1N4771	0.034		0.005	
1N4772	0.014		0.002	
1N4773	0.007		0.001	
1N4774	0.003		0.0005	
1N4770A	0.141	−55, 0, +25, +75, +100	0.01	200
1N4771A	0.070		0.005	
1N4772A	0.028		0.002	
1N4773A	0.014		0.001	
1N4774A	0.007		0.0005	

NOTE 1:

Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

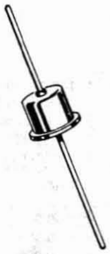
NOTE 2:

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. A cathode-ray tube curve-trace test on a sample basis is used to ensure that the zener has a sharp and stable knee region.

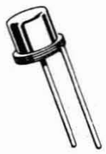
1N4719 thru 1N4725
1N4997 thru 1N5003
MR1030 thru MR1036, MR1038, MR1040

V_R — to 1000 V

I_O = 3.0 A



CASE 60
1N4719 THRU 1N4725
MR1030A THRU MR1040A



CASE 70
1N4997 thru 1N5003
MR1030B THRU MR1040B

Silicon high-conductance rectifiers available in either axial-lead or single-ended packages. Type numbers shown have cathode connected to case. For anode-to-case connection, add suffix "R" to type number, i. e. 1N4719R

MAXIMUM RATINGS (Both Package Types) T_A = 25°C unless otherwise noted

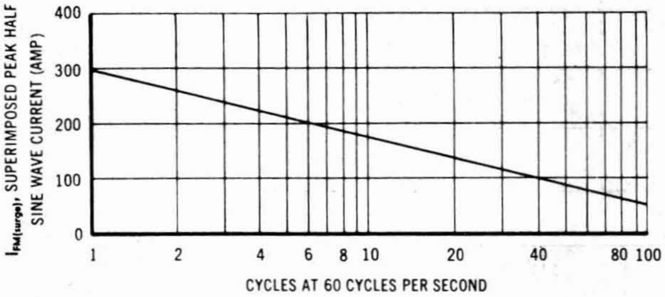
Rating	Symbol	1N 4719 MR 1030	1N 4720 MR 1031	1N 4721 MR 1032	MR 1033	1N 4722 MR 1034	MR 1035	1N 4723 MR 1036	1N 4724 MR 1038	1N 4725 MR 1040	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RM} (rep) V_{RM} (wkg) V_R	50	100	200	300	400	500	600	800	1000	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single phase, 60 cycle peak)	V_{RM} (non-rep)	100	200	300	400	500	600	720	1000	1200	Volts
RMS Reverse Voltage	V_r	35	70	140	210	280	350	420	560	700	Volts
Average Rectified Forward Current (single phase, resistive load, 60 cps, T_A = 75°C) see figure 4	I_O	3.0									Amp.
Peak Repetitive Forward Current (T_A = 75°C)	I_{FM} (rep)	25									Amp
Non-Repetitive Peak Surge Current (superimposed on rated current at rated voltage, T_A = 75°C) see figure 1	I_{FM} (surge)	300 (for 1/2 cycle)									Amp
I^2t Rating (non-repetitive, 1 msec <t <8.3 msec)	I^2t	185									$A_{(rms)}{}^2s$
Operating and Case Temperature	T_J, T_{stg}	-65 to + 175									°C
Thermal Resistance	θ_{JA}	30									°C/Watt

1N4719 thru 1N4725 (Continued)

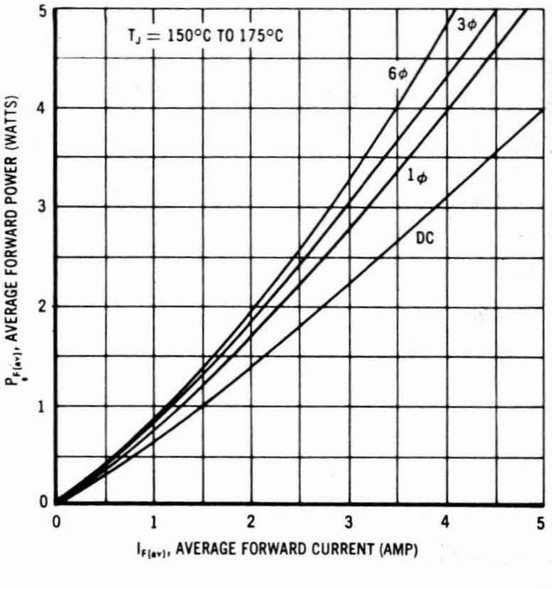
ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Max Limit	Unit
Full Cycle Average Forward Voltage Drop (I_O = 3.0 Amps and Rated V_r, T_A = 75°C, Half Wave Rectifier)	$V_{F(AV)}$	0.45	Volts
DC Forward Voltage Drop (I_F = 3.0 Adc, T_A = 25°C)	V_F	0.9	Volts
Full Cycle Average Reverse Current (I_O = 3.0 Amps and Rated V_r, T_A = 75°C, Half Wave Rectifier)	$I_{R(AV)}$	1.5	mA
DC Reverse Current (Rated V_R, T_A = 25°C)	I_R	0.5	mA

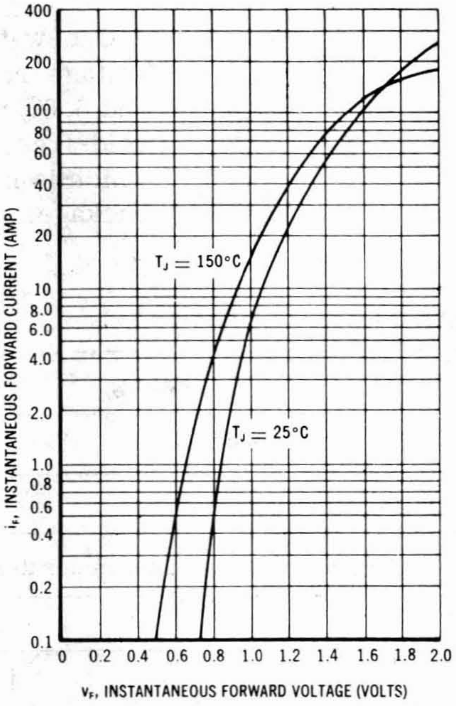
MAXIMUM SURGE CURRENT T_A = 75°C)



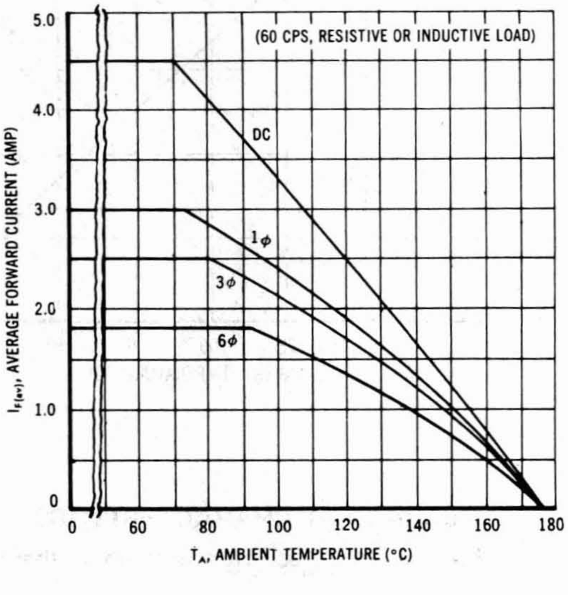
MAXIMUM FORWARD POWER DISSIPATION versus AVERAGE FORWARD CURRENT



FORWARD VOLTAGE CHARACTERISTICS

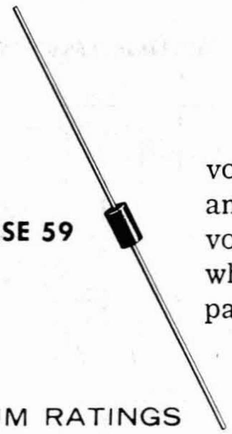


MAXIMUM FORWARD CURRENT versus AMBIENT TEMPERATURE



1N4728 thru 1N4764
1M110ZS thru 1M200ZS

1 W
3.3 — 200 V

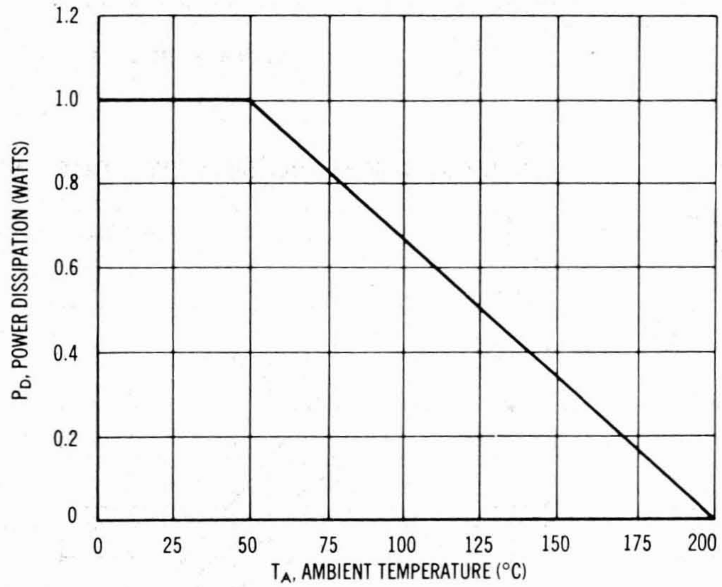


CASE 59

One-watt silicon zener diodes designed for constant voltage reference from 3.3 thru 100 volts, with 10% and 5.0% tolerances. These diodes are packaged in a void-free, transfer-molded thermosetting plastic case which is no larger than the conventional 400 mW glass package.

MAXIMUM RATINGS

Rating	Value	Unit
DC Power Dissipation	1.0	Watt
Derating Factor	6.67	mW/°C
Junction and Storage Temperature	-65 to +200	°C



POWER RATING versus AMBIENT TEMPERATURE

MECHANICAL CHARACTERISTICS

CASE: Void free, transfer molded, thermosetting plastic.

FINISH: All external surfaces are corrosion resistant. Leads are readily solderable.

POLARITY: Cathode, indicated by color band. When operated in zener mode cathode will be positive with respect to anode.

MOUNTING POSITION: Any

WEIGHT: 0.42 gram (approximately)

1N4728 thru 1N4764 (continued)

IN--- type numbers have a standard tolerance of ±10% on the nominal zener voltage; "A" for ±5.0% units. For 1M--- type numbers, suffix 10 indicates 10% tolerance, suffix 5 indicates 5.0% tolerance.

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise specified)

$V_F = 1.5$ V max @ $I_F = 200$ mA on all types.

Type No.	Nominal Zener Voltage V_Z @ I_{ZT} Volts	Test Current I_{ZT} mA	Max Zener Impedance (Note 3)			REVERSE LEAKAGE CURRENT		Surge Current @ $T_A = 25°C$ i_R	Max DC Zener Current I_{ZM} mA
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ I_{ZK} Ohms	I_{ZK} mA	I_R µA Max @	V_R Volts		
1N4728	3.3	76	10	400	1.0	100	1	1380	276
1N4729	3.6	69	10	400	1.0	100	1	1260	252
1N4730	3.9	64	9	400	1.0	50	1	1190	234
1N4731	4.3	58	9	400	1.0	10	1	1070	217
1N4732	4.7	53	8	500	1.0	10	1	970	193
1N4733	5.1	49	7	550	1.0	10	1	890	178
1N4734	5.6	45	5	600	1.0	10	2	810	162
1N4735	6.2	41	2	700	1.0	10	3	730	146
1N4736	6.8	37	3.5	700	1.0	10	4	660	133
1N4737	7.5	34	4.0	700	0.5	10	5	605	121
1N4738	8.2	31	4.5	700	0.5	10	6	550	110
1N4739	9.1	28	5.0	700	0.5	10	7	500	100
1N4740	10	25	7	700	0.25	10	7.6	454	91
1N4741	11	23	8	700	0.25	5	8.4	414	83
1N4742	12	21	9	700	0.25	5	9.1	380	76
1N4743	13	19	10	700	0.25	5	9.9	344	69
1N4744	15	17	14	700	0.25	5	11.4	304	61
1N4745	16	15.5	16	700	0.25	5	12.2	285	57
1N4746	18	14	20	750	0.25	5	13.7	250	50
1N4747	20	12.5	22	750	0.25	5	15.2	225	45
1N4748	22	11.5	23	750	0.25	5	16.7	205	41
1N4749	24	10.5	25	750	0.25	5	18.2	190	38
1N4750	27	9.5	35	750	0.25	5	20.6	170	34
1N4751	30	8.5	40	1,000	0.25	5	22.8	150	30
1N4752	33	7.5	45	1,000	0.25	5	25.1	135	27
1N4753	36	7.0	50	1,000	0.25	5	27.4	125	25
1N4754	39	6.5	60	1,000	0.25	5	29.7	115	23
1N4755	43	6.0	70	1,500	0.25	5	32.7	110	22
1N4756	47	5.5	80	1,500	0.25	5	35.8	95	19
1N4757	51	5.0	95	1,500	0.25	5	38.8	90	18
1N4758	56	4.5	110	2,000	0.25	5	42.6	80	16
1N4759	62	4.0	125	2,000	0.25	5	47.1	70	14
1N4760	68	3.7	150	2,000	0.25	5	51.7	65	13
1N4761	75	3.3	175	2,000	0.25	5	56.0	60	12
1N4762	82	3.0	200	3,000	0.25	5	62.2	55	11
1N4763	91	2.8	250	3,000	0.25	5	69.2	50	10
1N4764	100	2.5	350	3,000	0.25	5	76.0	45	9
1M110ZS10	110	2.3	450	4,000	0.25	5.0	83.6	—	7.2
1M110ZS5	110	2.3	450	4,000	0.25	5.0	83.6	—	7.2
1M120ZS10	120	2.0	550	4,500	0.25	5.0	91.2	—	7.0
1M120ZS5	120	2.0	550	4,500	0.25	5.0	91.2	—	7.0
1M130ZS10	130	1.9	700	5,000	0.25	5.0	98.8	—	6.0
1M130ZS5	130	1.9	700	5,000	0.25	5.0	98.8	—	6.0
1M150ZS10	150	1.7	1,000	6,000	0.25	5.0	114	—	5.5
1M150ZS5	150	1.7	1,000	6,000	0.25	5.0	114	—	5.5
1M160ZS10	160	1.6	1,100	6,500	0.25	5.0	121.6	—	5.2
1M160ZS5	160	1.6	1,100	6,500	0.25	5.0	121.6	—	5.2
1M180ZS10	180	1.4	1,200	7,000	0.25	5.0	136.8	—	4.6
1M180ZS5	180	1.4	1,200	7,000	0.25	5.0	136.8	—	4.6
1M200ZS10	200	1.2	1,500	8,000	0.25	5.0	152	—	4.0
1M200ZS5	200	1.2	1,500	8,000	0.25	5.0	152	—	4.0

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

1 — Nominal zener voltages between those shown.

2 — Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.

  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.

  b. Two or more units matched to one another with any specified tolerance.

3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

1N4765 thru 1N4774
1N4775 thru 1N4784

For Specifications, See 1N4565 Data.

1N4896,A
thru
1N4915,A

12.8 V ± 5.0%

1N4916,A
thru
1N4932,A

19.2 V ± 5.0%

LOW NOISE
TEMPERATURE-COMPENSATED
ZENER REFERENCE DIODES

Highly reliable reference sources utilizing an oxide-passivated junction for long-term voltage stability. RamRod construction provides a rugged, glass-enclosed, hermetically sealed structure.

- Low Noise Density Specified for Critical Applications
- Low Power Drain
  Devices Specified @ 0.5 mA, 1.0 mA, 2.0 mA, 4.0 mA, and 7.5 mA
- Maximum Voltage Change Specified over Test Temperature Range
- Temperature Compensation Guaranteed over Two Standard Operating Temperature Ranges:
  +25 to +100°C
  -55 to +100°C

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C

DC Power Dissipation: 400 Milliwatts at 50°C Ambient
(Derate 3.2 mW/°C Above 50°C)

MECHANICAL CHARACTERISTICS

CASE: Hermetically sealed, all-glass

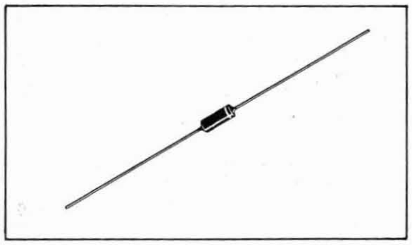
DIMENSIONS: See outline drawing.

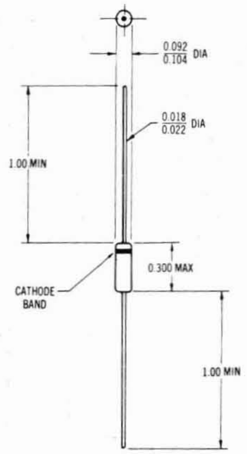
FINISH: All external surfaces are corrosion resistant and leads are readily solderable and weldable.

POLARITY: Cathode indicated by polarity band.

WEIGHT: 0.2 Gram (approx)

MOUNTING POSITION: Any





CASE 51
DO-7

V_Z = 12.8 V

TEMPERATURE RANGE:

STANDARD DEVICES
+25, +75, +100°C

"A" SUFFIX
-55, 0 + 25, +75, +100°C

Type Number	ΔV_Z Volts (Note 1)	Temp. Coeff. for Ref. %/°C (Note 1)	Dynamic Imped. Ohms Max (Note 2)
I_{ZT} = 0.5 mA *$N_D = 0.8 \frac{\mu V}{\sqrt{Hz}}$			
1N4896	0.096	0.01	400
1N4896A	0.198	0.01	
1N4897	0.048	0.005	
1N4897A	0.099	0.005	
1N4898	0.019	0.002	
1N4898A	0.040	0.002	
1N4899	0.010	0.001	
1N4899A	0.020	0.001	
I_{ZT} = 1.0 mA *$N_D = 0.4 \frac{\mu V}{\sqrt{Hz}}$			
1N4900	0.096	0.01	200
1N4900A	0.198	0.01	
1N4901	0.048	0.005	
1N4901A	0.099	0.005	
1N4902	0.019	0.002	
1N4902A	0.040	0.002	
1N4903	0.010	0.001	
1N4903A	0.020	0.001	
I_{ZT} = 2.0 mA *$N_D = 0.25 \frac{\mu V}{\sqrt{Hz}}$			
1N4904	0.096	0.01	100
1N4904A	0.198	0.01	
1N4905	0.048	0.005	
1N4905A	0.099	0.005	
1N4906	0.019	0.002	
1N4906A	0.040	0.002	
1N4907	0.010	0.001	
1N4907A	0.020	0.001	
I_{ZT} = 4.0 mA *$N_D = 0.22 \frac{\mu V}{\sqrt{Hz}}$			
1N4908	0.096	0.01	50
1N4908A	0.198	0.01	
1N4909	0.048	0.005	
1N4909A	0.099	0.005	
1N4910	0.019	0.002	
1N4910A	0.040	0.002	
1N4911	0.010	0.001	
1N4911A	0.020	0.001	
I_{ZT} = 7.5 mA *$N_D = 0.20 \frac{\mu V}{\sqrt{Hz}}$			
1N4912	0.096	0.01	25
1N4912A	0.198	0.01	
1N4913	0.048	0.005	
1N4913A	0.099	0.005	
1N4914	0.019	0.002	
1N4914A	0.040	0.002	
1N4915	0.010	0.001	
1N4915A	0.020	0.001	

V_Z = 19.2 V

TEMPERATURE RANGE:

STANDARD DEVICES
+25, +75, +100°C

"A" SUFFIX
-55, 0, +25, +75, +100°C

Type Number	ΔV_Z Volts (Note 1)	Temp. Coeff. for Ref. %/°C (Note 1)	Dynamic Imped. Ohms Max (Note 2)
I_{ZT} = 0.5 mA *$N_D = 1.0 \frac{\mu V}{\sqrt{Hz}}$			
1N4916	0. 44	0.01	600
1N4916A	0.298	0.01	
1N4917	0.072	0.005	
1N4917A	0.149	0.005	
1N4918	0.029	0.002	
1N4918A	0.060	0.002	
I_{ZT} = 1.0 mA *$N_D = 0.5 \frac{\mu V}{\sqrt{Hz}}$			
1N4919	0.144	0.01	300
1N4919A	0.298	0.01	
1N4920	0.072	0.005	
1N4920A	0.149	0.005	
1N4921	0.029	0.002	
1N4921A	0.060	0.002	
I_{ZT} = 2.0 mA *$N_D = 0.25 \frac{\mu V}{\sqrt{Hz}}$			
1N4922	0.144	0.01	150
1N4922A	0.298	0.01	
1N4923	0.072	0.005	
1N4923A	0.149	0.005	
1N4924	0.029	0.002	
1N4924A	0.060	0.002	
I_{ZT} = 4.0 mA *$N_D = 0.22 \frac{\mu V}{\sqrt{Hz}}$			
1N4925	0.144	0.01	75
1N4925A	0.298	0.01	
1N4926	0.072	0.005	
1N4926A	0.149	0.005	
1N4927	0.029	0.002	
1N4927A	0.060	0.002	
1N4928	0.014	0.001	
1N4928A	0.030	0.001	
I_{ZT} = 7.5 mA *$N_D = 0.20 \frac{\mu V}{\sqrt{Hz}}$			
1N4929	0.144	0.01	36
1N4929A	0.298	0.01	
1N4930	0.072	0.005	
1N4930A	0.149	0.005	
1N4931	0.029	0.002	
1N4931A	0.060	0.002	
1N4932	0.014	0.001	
1N4932A	0.030	0.001	

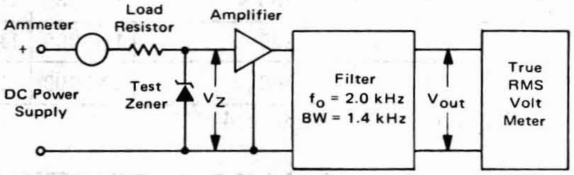
NOTE 1:
Voltage Variation (ΔV_Z) and Temperature Coefficient.

All reference diodes are characterized by the "box method". This guarantees a maximum voltage variation (ΔV_Z) over the specified temperature range, at the specified test current (I_{ZT}), verified by tests at indicated temperature points within the range. V_Z is measured and recorded at each temperature specified. The ΔV_Z between the highest and lowest values must not exceed the max ΔV_Z given. This method of indicating voltage stability is now used for JEDEC registration as well as for military qualification. The former method of indicating voltage stability – by means of temperature coefficient – accurately reflects the voltage deviation at the temperature extremes, but is not necessarily accurate within the temperature range because reference diodes have a nonlinear temperature relationship. The temperature coefficient, therefore, is given only as a reference.

NOTE 2: Zener Impedance Derivation

The dynamic zener impedance, Z_{ZT}, is derived from the 60-Hz ac voltage drop which results when an ac current with an rms value equal to 10% of the dc zener current, I_{ZT}, is superimposed on I_{ZT}. A cathode-ray tube curve-trace test on a sample basis is used to ensure that the zener has a sharp and stable knee region.

*NOISE DENSITY MEASUREMENT METHOD



$$\text{Noise Density (Volts per Square Root Bandwidth)} = \frac{V_{out}}{\text{Overall Gain} \quad \text{BW}}$$

Where BW = Filter Bandwidth (Hz)
V_{out} Output Noise (Volts RMS)

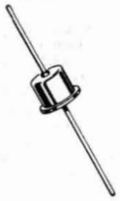
The input voltage and load resistance are high so that the zener diode is driven from a constant current source. The amplifier is low noise so that the amplifier noise is negligible compared to that of the test TC zener. The filter bandpass is known so that the noise density can be calculated from the formula shown.

1N4933 thru 1N4937 (SILICON)

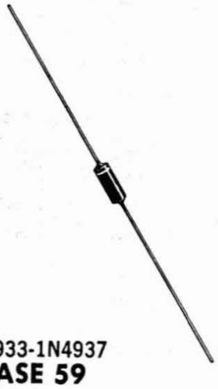
1N3879 thru 1N3883 — 1N3889 thru 1N3893
1N3899 thru 1N3903 — 1N3909 thru 1N3913
MR830 thru MR836 — MR1366, MR1376,
MR1386, MR1396

V_R = 50-600 V
I_O = 1.0-30 A

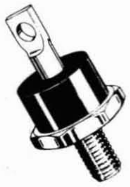
Fast recovery silicon rectifiers designed for special applications such as high frequency rectification, inverters, free-wheeling diodes, and other fast switching circuits. A complete line of rectifiers having typical recovery time of 0.1 microseconds providing high efficiency at frequencies of 250 kHz and higher.



MR830-MR836
CASE 60



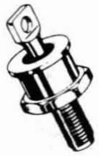
1N4933-1N4937
CASE 59
(DO-41)



1N3899-1N3903
MR1386

1N3909-1N3913
MR1396

CASE 42
(DO-5)



1N3879-1N3883
MR1366

1N3889-1N3893
MR1376

CASE 56A
(DO-4)

MAXIMUM RATINGS

I_O*	$I_{FM(surge)}$**	$V_{RM(rep)}$ $V_{RM(wkg)}$, $V_{R(Volts)}$					
Ampere	Ampere	50	100	200	300	400	600
1.0	30	1N4933	1N4934	1N4935	—	1N4936	1N4937
3.0	100	MR830	MR831	MR832	—	MR834	MR836
6.0	150	1N3879	1N3880	1N3881	1N3882	1N3883	MR1366
12	200	1N3889	1N3890	1N3891	1N3892	1N3893	MR1376
20	225	1N3899	1N3900	1N3901	1N3902	1N3903	MR1386
30	300	1N3909	1N3910	1N3911	1N3912	1N3913	MR1396

* Figure 3 ** Figure 4

THERMAL CHARACTERISTICS

Characteristic	Symbol	Value	Unit
Maximum Junction Operating Temperature Range	T_J	-65 to +150	°C
Maximum Case Storage Temperature Range	T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
1N4933 thru 1N4937			
DC Forward Voltage Drop (I_F = 1.0 Adc, T_A = 25°C)	V_F	1.2	Vdc
DC Reverse Current (Rated V_R) T_A = 25°C	I_R	5.0	µA
T_A = 100°C		100	
MR830 thru MR836			
DC Forward Voltage Drop (I_F = 3.0 Adc, T_A = 25°C)	V_F	1.1	Vdc
DC Reverse Current (Rated V_R) T_A = 25°C	I_R	0.05	mA
T_A = 100°C		2.5	
1N3879 thru 1N3883, MR1366			
DC Forward Voltage Drop (I_F = 6.0 Adc, T_C = 25°C)	V_F	1.4	Vdc
DC Reverse Current (Rated V_R) T_A = 25°C	I_R	0.015	mA
T_A = 100°C		1.0	
1N3889 thru 1N3893, MR1376			
DC Forward Voltage Drop (I_F = 12 Adc, T_C = 25°C)	V_F	1.4	Vdc
DC Reverse Current (Rated V_R) T_C = 25°C	I_R	0.025	mA
T_C = 100°C		3.0	
1N3899 thru 1N3903, MR1386			
DC Forward Voltage Drop (I_F = 20 Adc, T_A = 25°C)	V_F	1.4	Vdc
DC Reverse Current (Rated V_R) T_A = 25°C	I_R	0.05	mA
T_A = 100°C		6.0	
1N3909 thru 1N3913, MR1396			
DC Forward Voltage Drop (I_F = 30 Adc, T_A = 25°C)	V_F	1.4	Vdc
DC Reverse Current (Rated V_R) T_A = 25°C	I_R	0.08	mA
T_A = 100°C		10	

REVERSE RECOVERY TIME CHARACTERISTICS

Characteristics	Symbol	Max Limit	Unit
Maximum Reverse Recovery Time (I_F = 1.0 Amp min, Figure 2 test circuit)	t_{rr}	0.2	μs
Maximum Overshoot Current (Figure 2)	I_{os}		Amp
1N4933, MR830, 1N3879, 1N3889 Series MR1366, MR1367		2.0	
1N3899, 1N3909 Series MR1386, MR1396		3.0	

FIGURE 1 — TYPICAL RECOVERY PATTERN

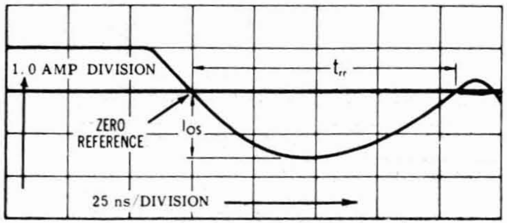
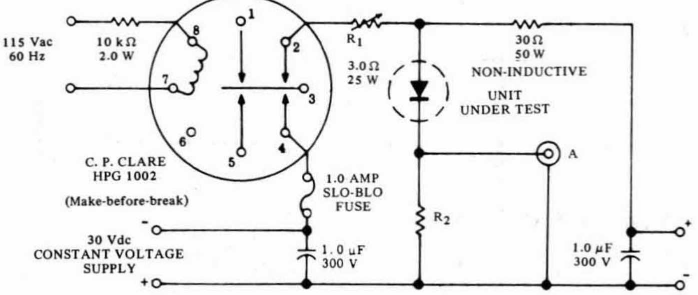


FIGURE 2 — TEST CIRCUIT


115 Vac
60 Hz
10 kΩ
2.0 W
1
2
3
4
5
6
7
8
C. P. CLARE
HPG 1002
(Make-before-break)
R_1
3.0 Ω
25 W
30 Ω
50 W
NON-INDUCTIVE
UNIT
UNDER TEST
A
1.0 AMP
SLO-BLO
FUSE
R_2
30 Vdc
CONSTANT VOLTAGE
SUPPLY
1.0 μF
300 V
1.0 μF
300 V
+
−

A – TEKTRONIX 545A, K PLUG-IN PRE-AMP, P6000 PROBE OR EQUIVALENT

R_1 – ADJUST TO APPROXIMATELY 1.4 Ω

TO GIVE A MAX I_{os} WHICH IS NOT GREATER THAN THE MAX SPECIFIED VALUE. t_{rr} IS THEN MEASURED.

R_2 – TEN 1.0 W, 10 Ω, 1% CARBON COMPOUND RESISTORS IN PARALLEL

$T_A = 25^{+10}_{-0}$ °C FOR RECTIFIER

MINIMIZE ALL LEAD LENGTHS

1.0 Adc FROM CONSTANT VOLTAGE SUPPLY
RIPPLE = 3.0 mV RMS MAX

Z_{out} = 1/2 Ω Max dc to 2.0 kHz.

FIGURE 3 — MAXIMUM CURRENT RATING

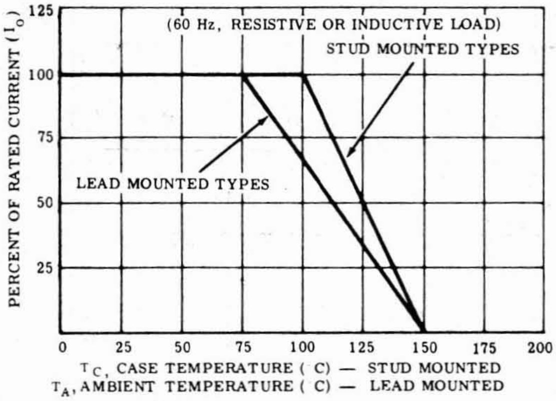
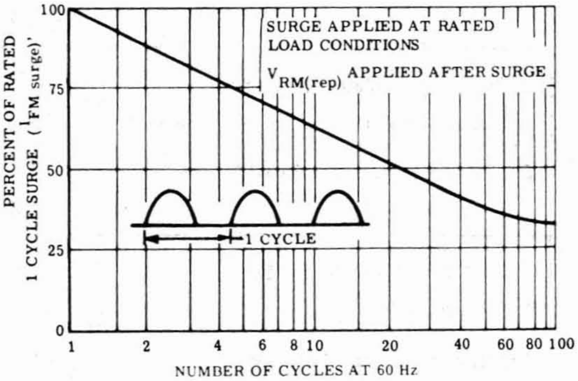


FIGURE 4 — MAXIMUM ALLOWABLE SURGE CURRENT



IN4997 thru IN5003

For Specifications, See 1N4719 Data.

1N5139,A thru 1N5148,A

CASE 51
(DO-7)

Polarity band on cathode end

Silicon voltage-variable capacitance diodes, designed for electronic tuning and harmonic-generation applications, and providing solid-state reliability to replace mechanical tuning methods.

MAXIMUM RATINGS ($T_C = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	60	Vdc
Forward Current	I_F	250	mAdc
RF Power Input †	P_{in} †	5	Watts
Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	400 2.67	mW mW/°C
Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_C	2 13.3	Watts mW/°C
Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

† The RF power input rating assumes that an adequate heat sink is provided.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic – All Types	Test Conditions	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage	I_R = 10 μAdc	B_{VR}	60	70	—	Vdc
Reverse Voltage Leakage Current	V_R = 55 Vdc, T_A = 25°C V_R = 55 Vdc, T_A = 150°C	I_R	— —	— —	0.02 20	μAdc
Series Inductance	f = 250 MHz, L ≈ 1/16"	L_S	—	5	—	nH
Case Capacitance	f = 1 MHz, L ≈ 1/16"	C_C	—	0.25	—	pF
Diode Capacitance Temperature Coefficient	V_R = 4 Vdc, f = 1 MHz	TC_C	—	200	300	ppm/°C

	C_T, Diode Capacitance V_R = 4 Vdc, f = 1 MHz pF			Q, Figure of Merit V_R = 4 Vdc, f = 50 MHz	α V_R = 4 Vdc, f = 1 MHz		TR, Tuning Ratio C_4/C_{60} f = 1 MHz	
Device	Min	Typ	Max	Min	Min	Typ	Min	Typ
1N5139	6.1	6.8	7.5	350	0.37	0.40	2.7	2.9
1N5139A	6.5	6.8	7.1	350	0.37	0.40	2.7	2.9
1N5140	9.0	10.0	11.0	300	0.38	0.41	2.8	3.0
1N5140A	9.5	10.0	10.5	300	0.38	0.41	2.8	3.0
1N5141	10.8	12.0	13.2	300	0.38	0.41	2.8	3.0
1N5141A	11.4	12.0	12.6	300	0.38	0.41	2.8	3.0
1N5142	13.5	15.0	16.5	250	0.38	0.41	2.8	3.0
1N5142A	14.3	15.0	15.7	250	0.38	0.41	2.8	3.0
1N5143	16.2	18.0	19.8	250	0.38	0.41	2.8	3.0
1N5143A	17.1	18.0	18.9	250	0.38	0.41	2.8	3.0
1N5144	19.8	22.0	24.2	200	0.43	0.45	3.2	3.4
1N5144A	20.9	22.0	23.1	200	0.43	0.45	3.2	3.4
1N5145	24.3	27.0	29.7	200	0.43	0.45	3.2	3.4
1N5145A	25.7	27.0	28.3	200	0.43	0.45	3.2	3.4
1N5146	29.7	33.0	36.3	200	0.43	0.45	3.2	3.4
1N5146A	31.4	33.0	34.6	200	0.43	0.45	3.2	3.4
1N5147	36.1	39.0	42.9	200	0.43	0.45	3.2	3.4
1N5147A	37.1	39.0	40.9	200	0.43	0.45	3.2	3.4
1N5148	42.3	47.0	51.7	200	0.43	0.45	3.2	3.4
1N5148A	44.7	47.0	49.3	200	0.43	0.45	3.2	3.4

FIGURE 1 — DIODE CAPACITANCE versus REVERSE VOLTAGE

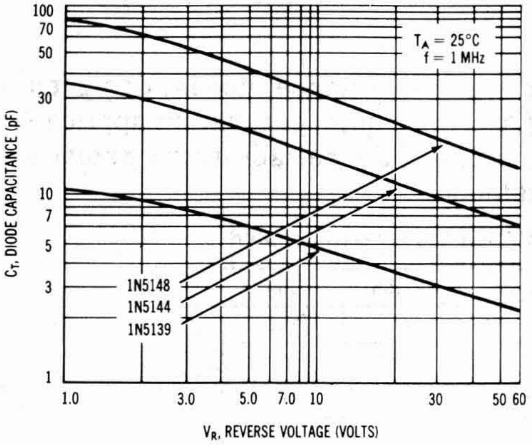


FIGURE 2 — FIGURE OF MERIT versus REVERSE VOLTAGE

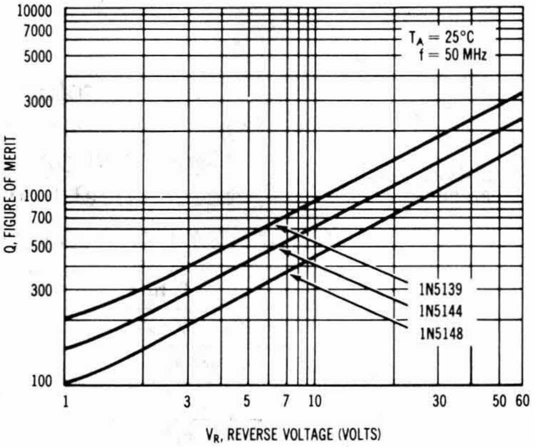


FIGURE 3 — NORMALIZED DIODE CAPACITANCE versus JUNCTION TEMPERATURE

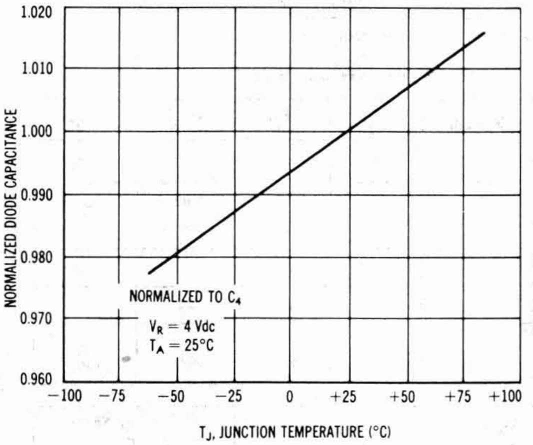


FIGURE 4 — NORMALIZED FIGURE OF MERIT versus JUNCTION TEMPERATURE

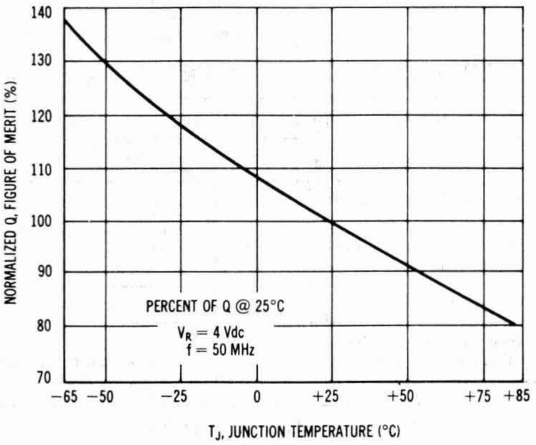


FIGURE 5 — REVERSE CURRENT versus REVERSE BIAS VOLTAGE

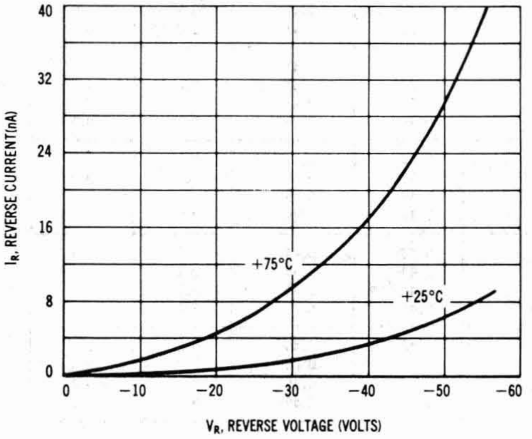
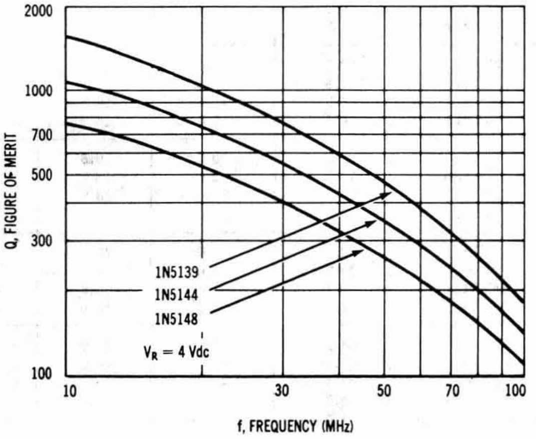


FIGURE 6 — FIGURE OF MERIT versus FREQUENCY



1N5149
(MV1806C)

1N5150
(MV1807C)

CASE 47

Silicon high-frequency step-recovery power varactors for 100 MHz to 2.0 GHz harmonic-generation applications with output power to 25 watts at 1.0 GHz.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating		Symbol	Value	Unit
Reverse Voltage		V_R	80	Vdc
Forward Current		I_F	1.0	Amp
RF Power Input	1N5149 1N5150	P_{in}	25 40	Watts
Total Device Dissipation @ $T_A = 75°C$	1N5149 1N5150	P_D	10 14	Watts
Derate above 75°C	1N5149 1N5150		0.08 0.11	W/°C
Junction Temperature		T_J	+200	°C
Storage Temperature Range		T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Reverse Breakdown Voltage	BV_R	$I_R = 10\ \mu Adc$	80	90	—	Vdc
Reverse Current	I_R	$V_R = 70$ Vdc	—	—	2	μAdc
		$V_R = 70$ Vdc, $T_A = 150°C$	—	—	100	
Diode Capacitance	C_T	$V_R = 6$ Vdc, f = 1.0 MHz	5	11.5	20	pF
Figure of Merit	Q	$V_R = 6$ Vdc, f = 50 MHz	—	800	—	—
Thermal Resistance	θ_{JC}	IN5150	—	—	9	°C/W

FUNCTIONAL TEST

1N5149

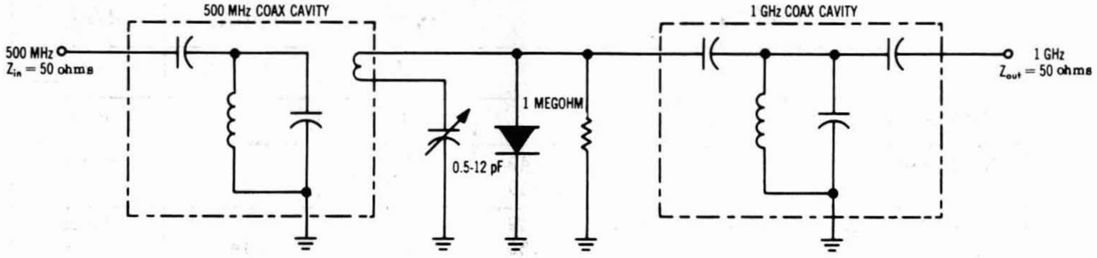
RF Power Output	P_{out}	Test Setup Figure 1 $P_{in} = 20$ W $f_{in} = 0.5$ GHz $f_{out} = 1.0$ GHz	11	—	—	Watts
Doubler Efficiency	η		55	—	—	%

1N5150

RF Power Output	P_{out}	Test Setup Figure 1 $P_{in} = 37$ W $f_{in} = 0.5$ GHz $f_{out} = 1.0$ GHz	24	25	—	Watts
Doubler Efficiency	η		65	68	—	%

1N5149, 1N5150 (continued)

FIGURE 1 — HARMONIC DOUBLER EFFICIENCY TEST CIRCUIT


500 MHz COAX CAVITY
1 GHz COAX CAVITY
500 MHz
Z$_{in}$ = 50 ohms
1 MEGOHM
0.5-12 pF
1 GHz
Z$_{out}$ = 50 ohms

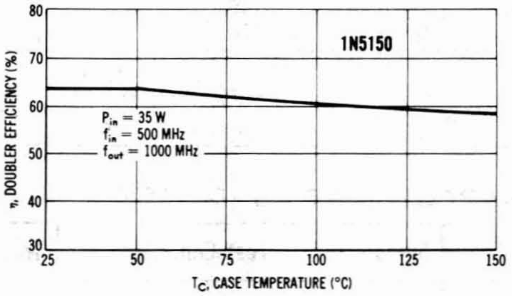


FIGURE 2 — LINEARITY CHARACTERISTIC WITHOUT RETUNING

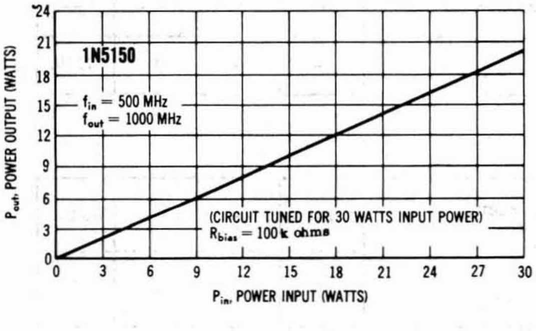
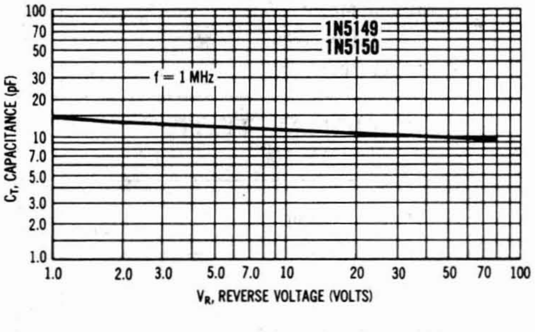


FIGURE 3 — CAPACITANCE versus REVERSE VOLTAGE



POWER OUTPUT versus OUTPUT FREQUENCY

1N5149

FIGURE 4A — DOUBLING (X2)

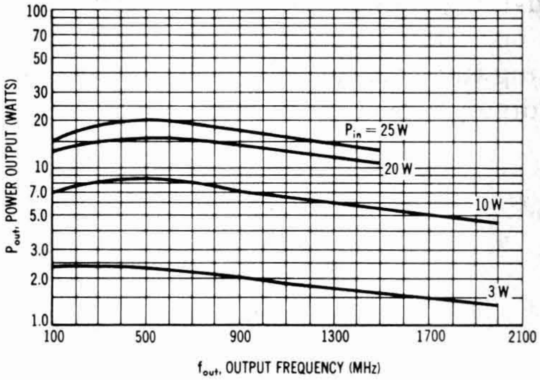


FIGURE 4B — TRIPLING (X3)

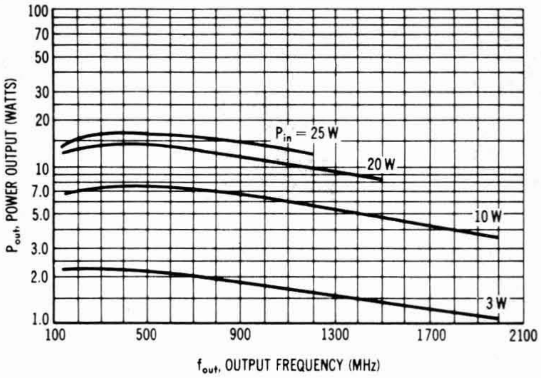
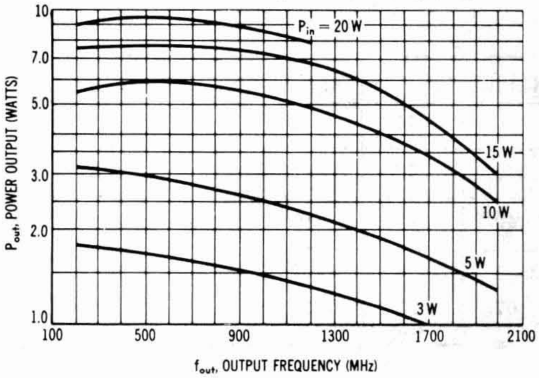


FIGURE 4C — QUADRUPLING (X4)



1N5150

FIGURE 5A — DOUBLING (X2)

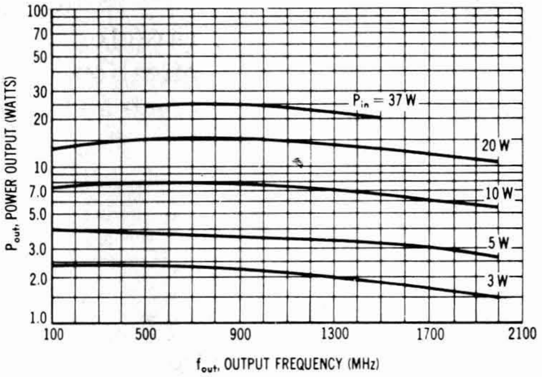


FIGURE 5B — TRIPLING (X3)

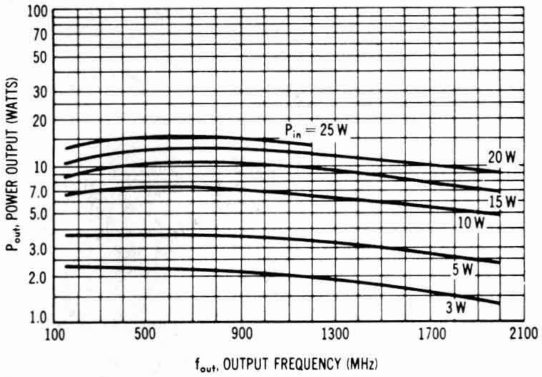
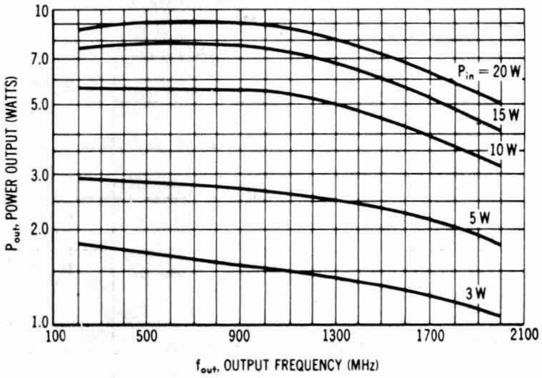
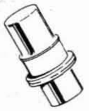


FIGURE 5C — QUADRUPLING (X4)



1N5150A (SILICON)
(MV1807C1)
1N5152A
(MV1808B1)
1N5153A
(MV1808C1)
1N5155A
(MV1810B1)

Silicon high-frequency step-recovery power varactor devices optimized for critical multiplier applications requiring tight control of junction capacitance and power dissipation.



CASE 46

CASE 47

1N5152A
MV1808B1

1N5155A
MV1810B1

1N5150A
MV1807C1

1N5153A
MV1808C1

MAXIMUM RATINGS

Rating	Symbol	1N5150A	1N5152A	1N5153A	1N5155A	Unit
Reverse Voltage	V_R	80	75	75	35	Vdc
Forward Current	I_F	1000	250	250	200	mAdc
RF Power Input	P_{in}	40	15	15	7.0	Watts
Total Device Dissipation @ $T_C = 25°C$	P_D	29.2	11.7	11.7	8.75	Watts
Derate above 25°C		167	66.7	66.7	50	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →				°C

1N5150A, 52A, 53A, 55A (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristics		Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage		BV_R				Vdc
(I_R = 10 μAdc)	1N5150A		80	-	-	
	1N5152A, 1N5153A		75	-	-	
	1N5155A		35	-	-	
Reverse Current		I_R				μAdc
(V_R = 70 Vdc)	1N5150A		-	-	2.0	
(V_R = 70 Vdc, T_A = 150°C)	1N5150A		-	-	100	
(V_R = 60 Vdc)	1N5152A, 1N5153A		-	-	1.0	
(V_R = 60 Vdc, T_A = 150°C)	1N5152A, 1N5153A		-	-	100	
(V_R = 26 Vdc)	1N5155A		-	-	1.0	
(V_R = 26 Vdc, T_A = 150°C)	1N5155A		-	-	100	
Series Resistance		R_S				Ohms
(V_R = 6.0 Vdc, f = self-resonant frequency)						
	1N5150A		-	0.25	-	
	1N5152A, 1N5153A		-	0.5	-	
	1N5155A		-	0.9	-	
Series Inductance		L_S				nH
	1N5150A		-	1.5	-	
	1N5152A		-	0.8	-	
	1N5153A		-	1.7	-	
	1N5155A		-	0.9	-	
Diode Capacitance ($C_J + C_C$)		C_T				pF
(V_R = 6.0 Vdc, f = 1.0 MHz)	1N5150A		10.8	-	13.2	
	1N5152A		5.4	-	6.6	
	1N5153A		5.8	-	7.0	
	1N5155A		1.71	-	2.09	
Figure of Merit		Q				-
(V_R = 6.0 Vdc, f = 50 MHz)	1N5150A		-	800	-	
	1N5152A, 1N5153A		-	1100	-	
	1N5155A		-	1700	-	
Thermal Resistance		θ_{JC}				°C/W
	1N5150A		-	-	6.0	
	1N5152A, 1N5153A		-	-	15	
	1N5155A		-	-	20	

FUNCTIONAL TEST

1N5150A

RF Power Output	P_{in} = 37 W, f_{in} = 500 MHz,	P_{out}	25.1	-	-	Watts
Doubling Efficiency	f_{out} = 1.0 GHz	η	68	-	-	%

1N5152A, 1N5153A

RF Power Output	P_{in} = 12 W, f_{in} = 1.0 GHz,	P_{out}	7.2	-	-	Watts
Doubling Efficiency	f_{out} = 2.0 GHz	η	60	-	-	%

1N5155A

RF Power Output	P_{in} = 5.0 W, f_{in} = 2.0 GHz,	P_{out}	2.0	-	-	Watts
Tripling Efficiency	f_{out} = 6.0 GHz	η	40	-	-	%

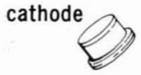
For typical curves and test circuits, see the following data sheets: 1N5149-1N5150, 1N5151 thru 1N5153, and 1N5154-1N5155.

1N5151
(MV1808A)

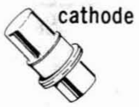
1N5152
(MV1808B)

1N5153
(MV1808C)

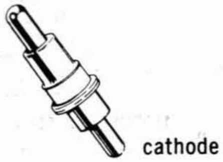
Silicon high-frequency step-recovery power varactors, designed for high-power, high-frequency harmonic generation applications.



CASE 48
(1N5151)
(pill)



CASE 46
(1N5152)
(pill with prongs)



CASE 47
(1N5153)
(cartridge)

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	75	Vdc
Forward Current	I_F	0.25	Adc
RF Power Input	P_{in}	15	Watts
Total Device Dissipation @ $T_C = 75°C$ Derate above 75°C	P_D	5.5 45	Watts mW/°C
Junction Temperature	T_J	+200	°C
Storage Temperature	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Condition	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage	$I_R = 10\ \mu Adc$	BV_R	75	80	–	Vdc
Reverse Current	$V_R = 60$ Vdc $V_R = 60$ Vdc, $T_A = 150°C$	I_R	– –	0.5 –	1 100	μAdc
Series Resistance	$V_R = 6$ Vdc, f = 50 MHz	R_S	–	0.5	–	Ohms
Diode Capacitance	$V_R = 6$ Vdc, f = 1.0 MHz $V_R = 70$ Vdc, f = 1.0 MHz	C_T*	5.0 –	5.8 4	7.5 –	pF
Figure of Merit	$V_R = 6$ Vdc, f = 50 MHz	Q	–	1100	–	–
Power Output	DOUBLER TEST CIRCUIT (Figure 1)	P_{out}	6.0	7.2	–	Watts
Efficiency	$P_{in} = 12$ W, $f_{in} = 1$GHz $f_{out} = 2$ GHz	η	50	60	–	%
Thermal Resistance		θ_J	–	19	23	°C/Watt

$*C_T = C_J + C_C$

FIGURE 1 — HARMONIC DOUBLER EFFICIENCY TEST CIRCUIT

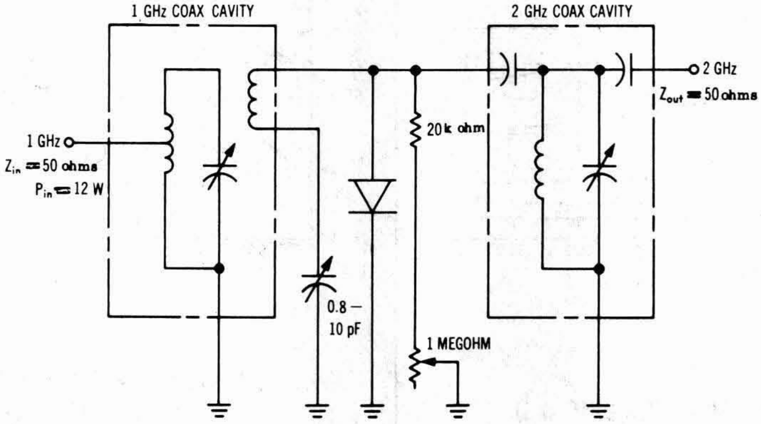
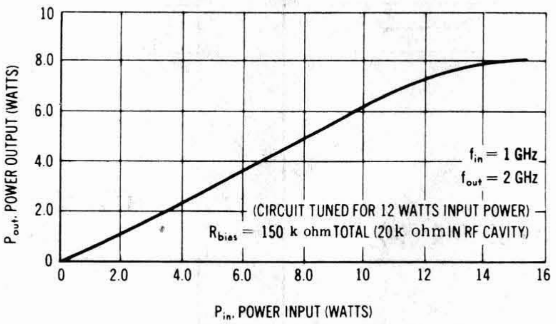

1 GHz COAX CAVITY
2 GHz COAX CAVITY
1 GHz
Z_{in} = 50 ohms
P_{in} = 12 W
20 k ohm
0.8 — 10 pF
1 MEGOHM
2 GHz
Z_{out} = 50 ohms

FIGURE 2 — LINEARITY CHARACTERISTIC WITHOUT RETUNING



POWER OUTPUT versus OUTPUT FREQUENCY

FIGURE 3A — DOUBLING (X2)

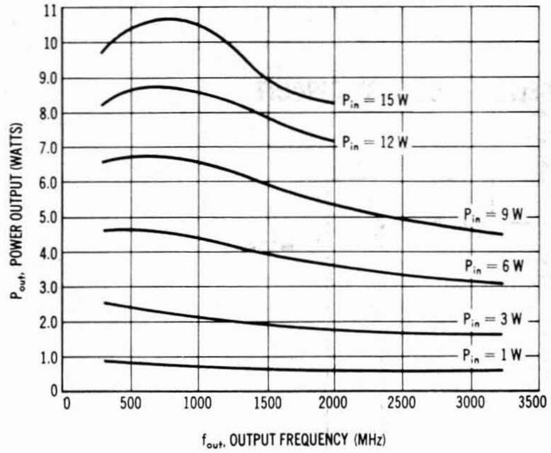


FIGURE 3B — TRIPLING (X3)

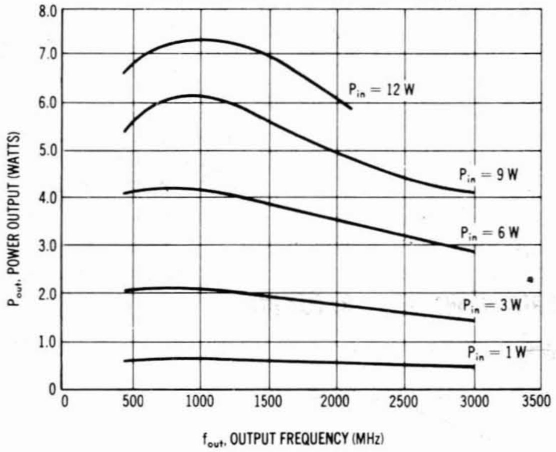
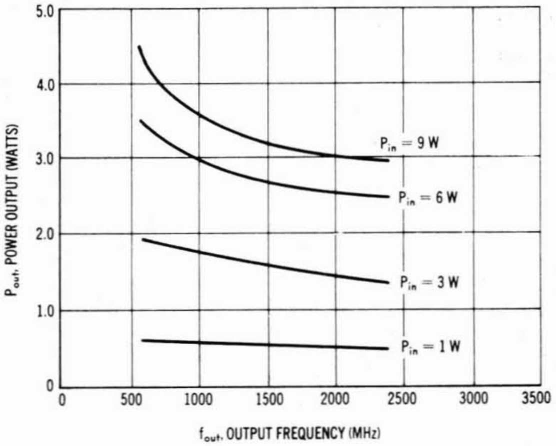


FIGURE 3C — QUADRUPLING (X4)



TYPICAL CHARACTERISTICS at 25°C

FIGURE 4 — FIGURE OF MERIT versus REVERSE VOLTAGE

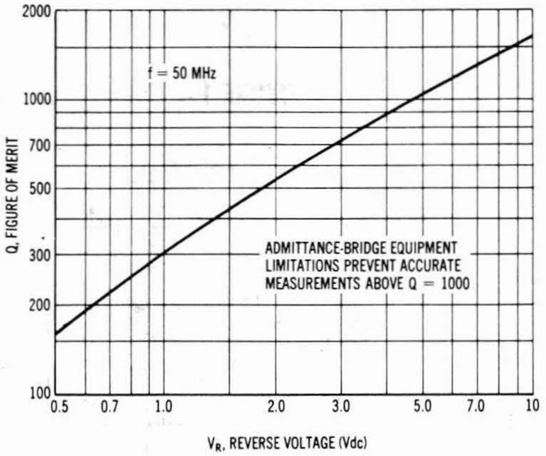


FIGURE 5 — VARACTOR CAPACITANCE versus REVERSE VOLTAGE

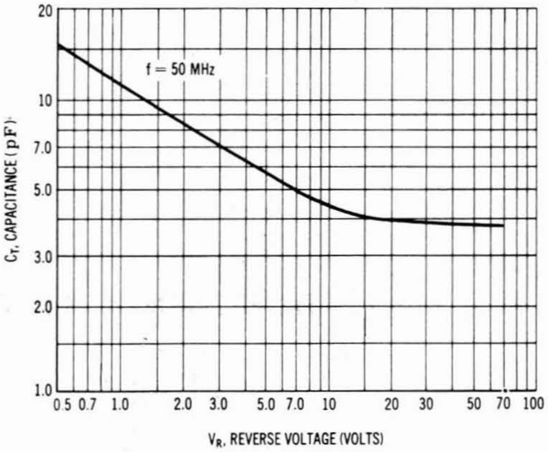
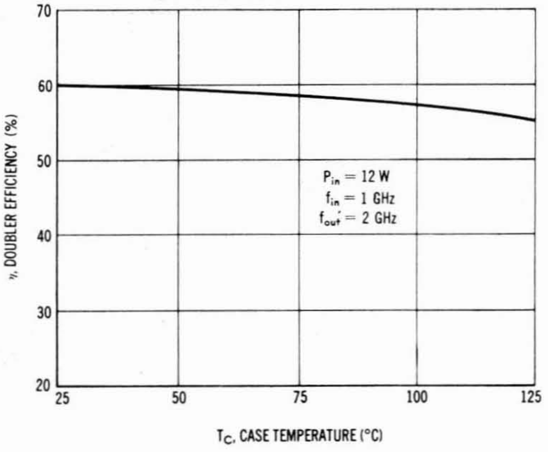


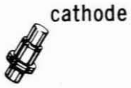
FIGURE 6 — DOUBLER EFFICIENCY versus CASE TEMPERATURE



1N5154
(MV1810A)
1N5155
(MV1810B)

CASE 48
(1N5154)
(pill)

CASE 46
(1N5155)
(pill with prongs)



Silicon high-frequency step-recovery power varactors, for multiplier applications from 2 to 8.5 GHz with 2 watts minimum power output guaranteed at 6 GHz.

MAXIMUM RATINGS (Tc = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	35	Vdc
Forward Current	I_F	200	mAdc
RF Power Input	P_{in}	7	Watts
Total Device Dissipation @ T_C = 75°C Derate above 75°C	P_D	3.5 30	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to + 200	°C

ELECTRICAL CHARACTERISTICS (TA = 25°C unless otherwise noted)

Characteristic	Conditions	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage	I_R = 10 μAdc	BV_R	35	45	—	Vdc
Reverse Current	V_R = 26 Vdc V_R = 26 Vdc, T_A = 150°C	I_R	— —	— —	1 100	μAdc
Series Resistance	V_R = 6 Vdc, f = 50 MHz	R_S	—	0.9	—	Ohms
Diode Capacitance	V_R = 6 Vdc, f = 1 MHz	C_T	1.0	2.1	3.0	pF
Figure of Merit	V_R = 6 Vdc, f = 50 MHz	Q	—	1700	—	—
Thermal Resistance		θ_{JC}	—	—	35	°C/W

FUNCTIONAL TEST

RF Power Output	Test Circuit Figure 5 P_{in} = 5 watts, f_{in} = 2 GHz, f_{out} = 6 GHz	P_{out}	2	—	—	Watts
Tripling Efficiency		η	40	—	—	%

POWER OUTPUT versus OUTPUT FREQUENCY

FIGURE 1A — DOUBLING (X2)

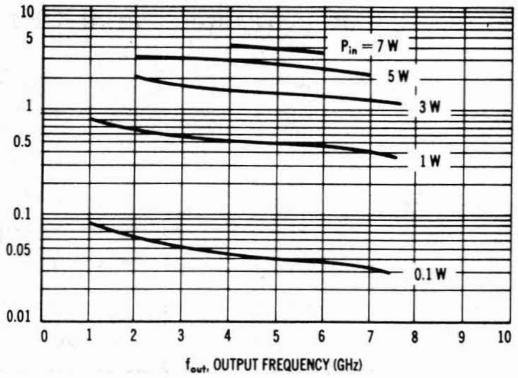


FIGURE 1B — TRIPLING (X3)

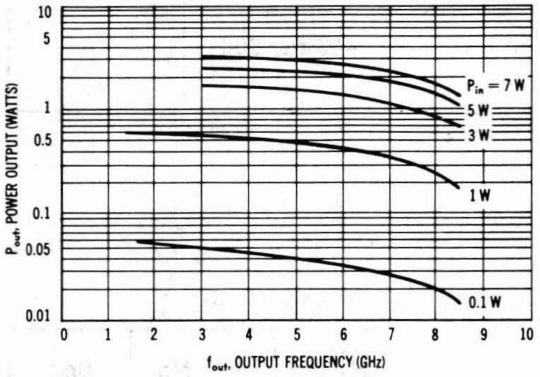
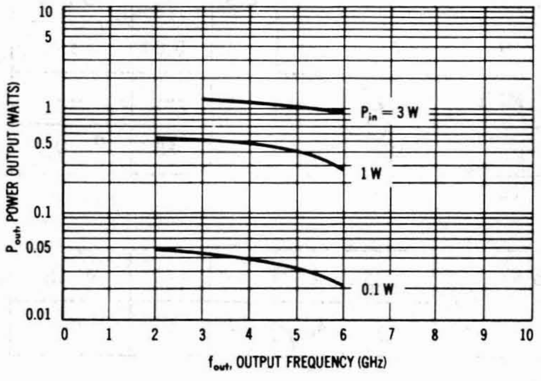


FIGURE 1C — QUADRUPLING (X4)



TYPICAL CHARACTERISTICS
$T_C = 25°C$

FIGURE 2 — VARACTOR CAPACITANCE versus REVERSE VOLTAGE

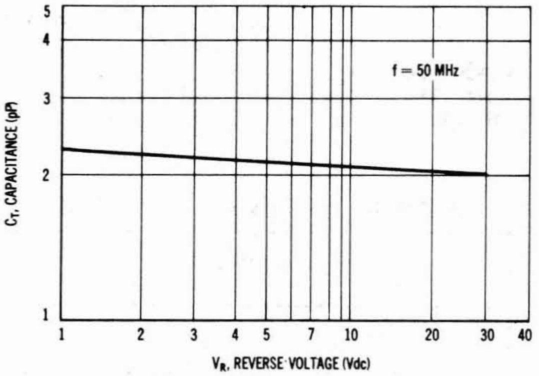


FIGURE 3 — TRIPLER POWER OUTPUT versus TEMPERATURE 2 GHz to 6 GHz

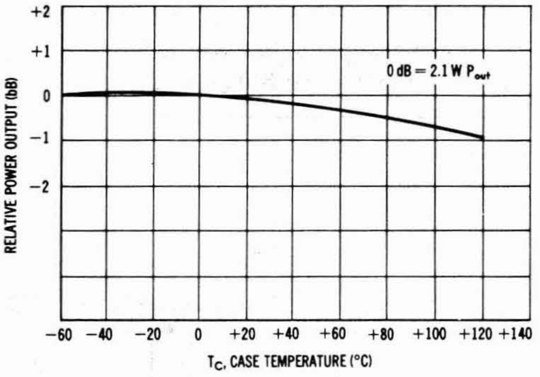


FIGURE 4 — TRIPLER LINEARITY CHARACTERISTIC

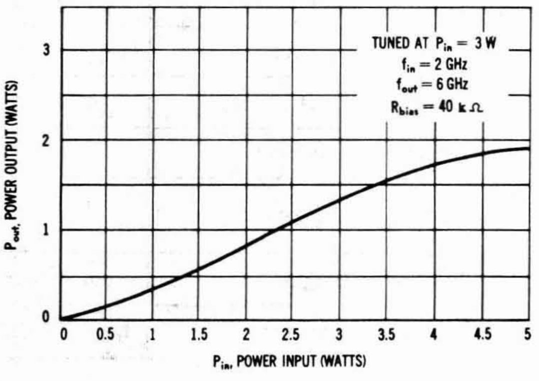


FIGURE 5 — HARMONIC TRIPLER — 2 GHz to 6 GHz

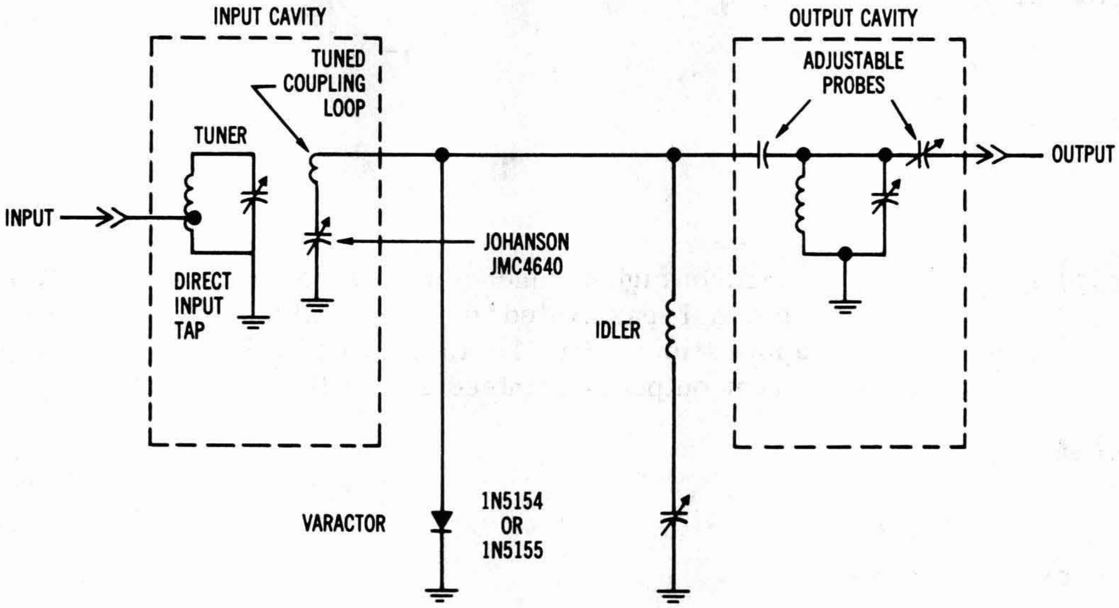
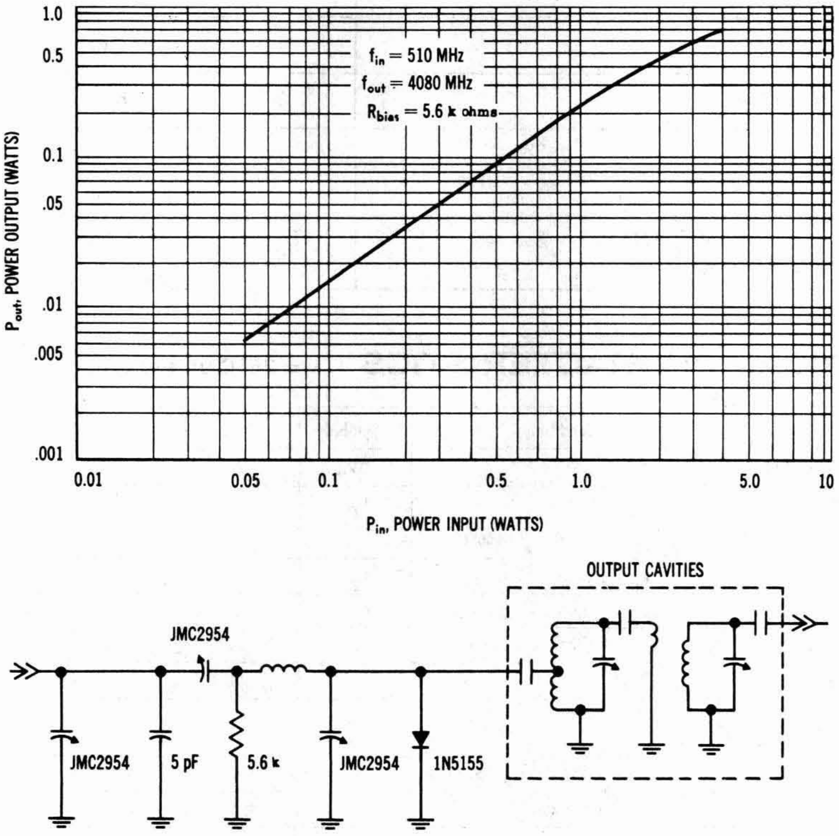
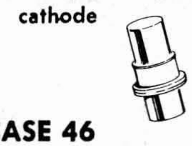

INPUT CAVITY
TUNED COUPLING LOOP
TUNER
INPUT
DIRECT INPUT TAP
JOHANSON JMC4640
OUTPUT CAVITY
ADJUSTABLE PROBES
OUTPUT
IDLER
VARACTOR
1N5154 OR 1N5155

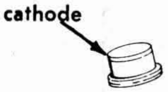
FIGURE 6 — HARMONIC OCTUPLER — 510 MHz to 4080 MHz



IN5156
(MV1812A)
IN5157
(MV1812B)



CASE 46



CASE 48

**AVAILABLE IN
PILL PACKAGE
ON SPECIAL REQUEST**

Silicon high-frequency step-recovery power varactors; epitaxial-passivated devices designed for multiplier applications from 1.0 to 13 GHz with 1.0 W minimum power output guaranteed at 10 GHz.

MAXIMUM RATINGS (Tc = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	20	Vdc
Forward Current	I_F	160	mAdc
RF Power Input	P_{in}	5.0	Watts
Total Device Dissipation @ $T_C = 75°C$ Derate above 75°C	P_D	3.25 26	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (TA = 25°C unless otherwise noted)

Characteristic	Conditions	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage	$I_R = 10\ \mu Adc$	BV_R	20	–	–	Vdc
Reverse Current	$V_R = 16$ Vdc	I_R	–	–	0.1	μAdc
	$V_R = 16$ Vdc, $T_A = 150°C$		–	–	100	
Series Resistance	$V_R = 6.0$ Vdc, f = 50 MHz	R_S	–	1.1	–	Ohms
Diode Capacitance	$V_R = 6.0$ Vdc, f = 1.0 MHz	C_T	0.6	–	1.0	pF
Figure of Merit	$V_R = 6.0$ Vdc, f = 50 MHz	Q	–	3600	–	–
Thermal Resistance		θ_{JC}	–	–	38.5	°C/W

FUNCTIONAL TEST

RF Power Output	$P_{in} = 2.6$ W, $f_{in} = 5.0$ GHz $f_{out} = 10$ GHz	P_{out}	1.0	–	–	Watt
Doubling Efficiency		η	38.5	–	–	%

1N5158 thru 1N5160 (SILICON)
M4L3052 thru M4L3056

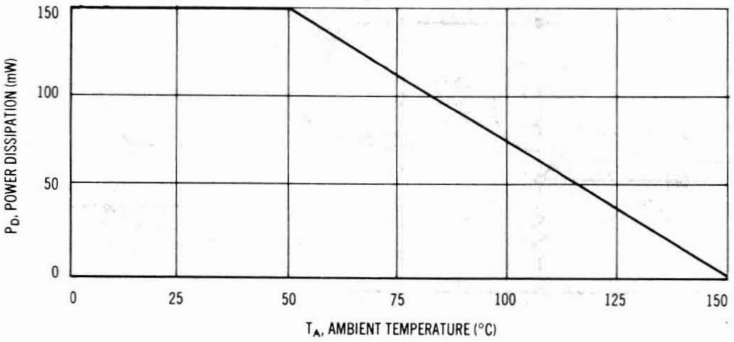
CASE 51
(DO-7)

PNPN 4-layer diodes, two-terminal, fast switching devices specifically designed for low voltage applications such as logic circuits, pulse generators, memory and relay devices, relay replacement, alarm circuit, multivibrators, ring counters, and signal switching circuits. These devices feature low breakover (switching) voltage, fast switching speeds, low junction capacitance, low breakover currents, and sub-miniature package.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage	$V_{RM(rep)}$		Volts
1N5158 (M4L3052)		10	
1N5159 (M4L3053)		11	
1N5160 (M4L3054)		12	
(M4L3055)		13	
(M4L3056)		14	
Continuous Forward Current	I_F	150	mA
Steady State Power Dissipation @ T_A = 50°C	P_D	150	mW
Derate above 50°C		1.5	mW/°C
Peak Pulse Current (50 µs maximum pulse width)	I_{pulse}	10	Amp
Operating Junction Temperature Range	T_J	-65 to +150	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

POWER-TEMPERATURE DERATING CURVE



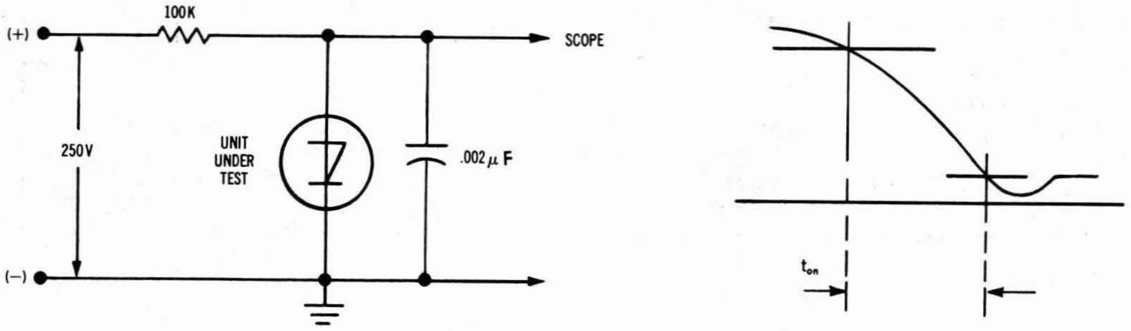
1N5158 thru 1N5160 (M4L3052 thru M4L3056 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

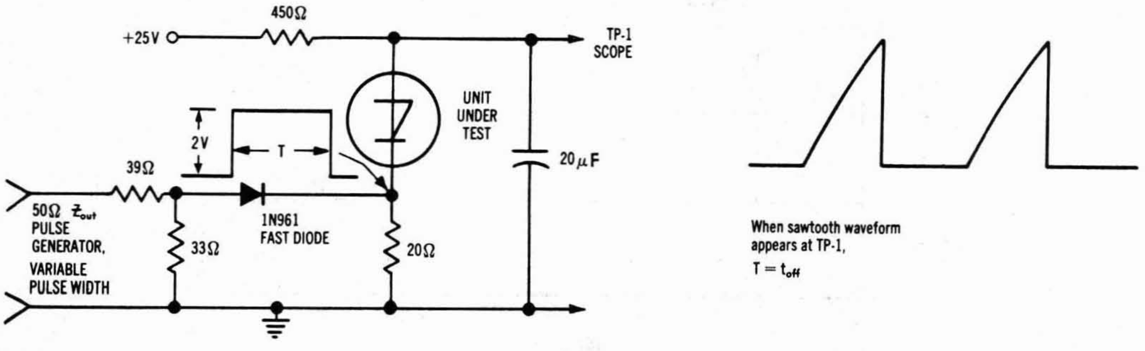
Characteristic	Symbol	Min	Typ	Max	Unit
Forward Breakover (Switching) Voltage	$V_{(BR)F}$				Volts
1N5158 (M4L3052)		8.0	–	10	
1N5159 (M4L3053)		9.0	–	11	
1N5160 (M4L3054)		10	–	12	
(M4L3055)		–	–	13	
(M4L3056)		–	–	14	
Forward Breakover (Switching) Current	$I_{(BR)F}$	–	5.0	50	μA
Forward Blocking Current (Measured at 75% of $V_{(BR)F}$)	I_{FM}	–	1.0	5.0	μA
Reverse Blocking Current (Measured at rated $V_{RM(rep)}$)	I_{RM}	–	2.0	10	μA
Holding Current	I_{HO}	1.0	4.0	20	mA
Forward On Voltage (I_F = 150 mAdc)	V_F	–	1.0	1.5	Volts
Junction Capacitance (AC Voltage = 10 mV, V_F = 0, f = 100 kHz)	C_J	–	42	–	pF
Turn-On Time*	t_{on}	–	50*	–	ns
Turn-Off Time*	t_{off}	–	100*	–	ns

*Time depends on a wide variety of circuit conditions. Consult manufacturer for further information.

TURN-ON TIME TEST CIRCUIT


(+)
100K
SCOPE
250V
UNIT
UNDER
TEST
.002μF
(−)
t_{on}

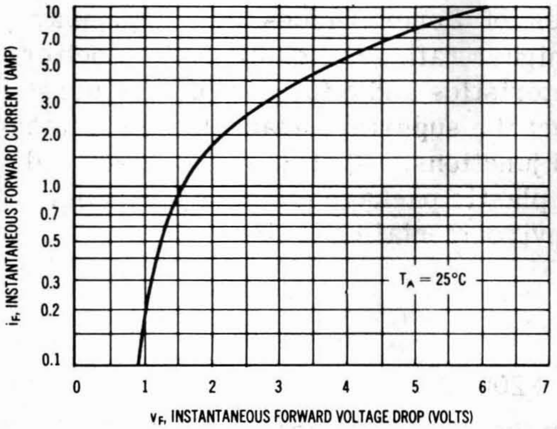
TURN-OFF TIME TEST CIRCUIT


450Ω
+25V
TP-1
SCOPE
2V
T
UNIT
UNDER
TEST
39Ω
20μF
50Ω Z_{out}
PULSE
GENERATOR,
VARIABLE
PULSE WIDTH
33Ω
1N961
FAST DIODE
20Ω

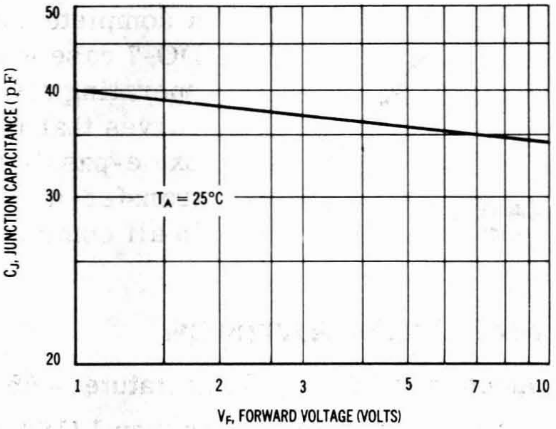
When sawtooth waveform appears at TP-1,
$T = t_{off}$

1N5158 thru 1N5160 (M4L3052 thru M4L3056) (continued)

TYPICAL FORWARD CONDUCTION CHARACTERISTICS

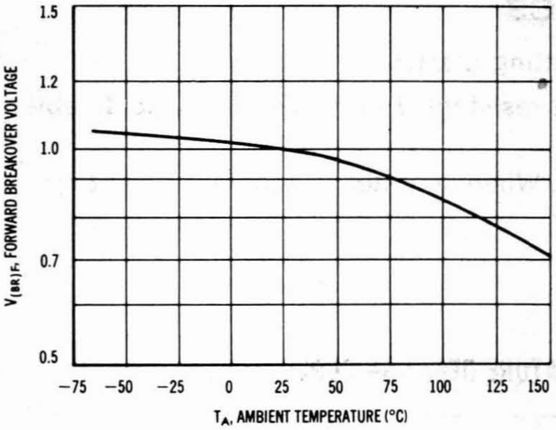


TYPICAL CAPACITANCE

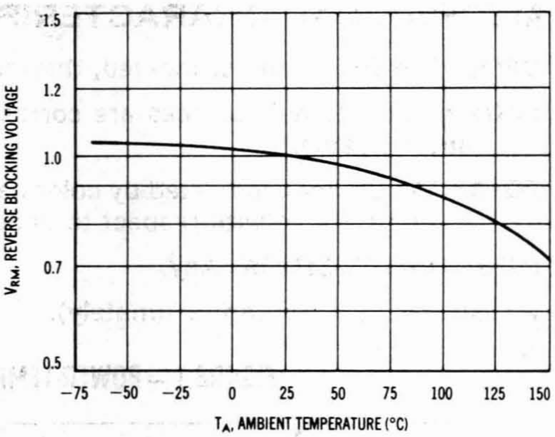


TYPICAL DC CHARACTERISTICS versus TEMPERATURE
(NORMALIZED to 25°C VALUE)

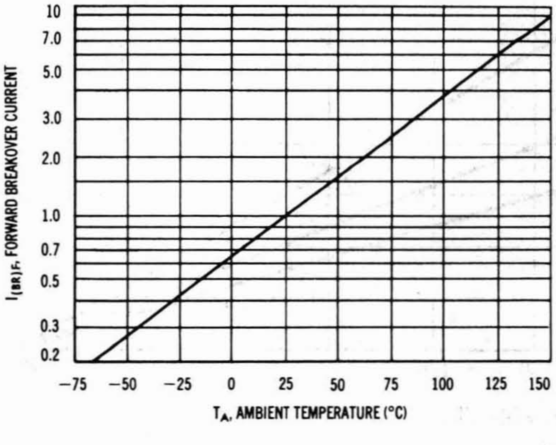
FORWARD BREAKOVER VOLTAGE



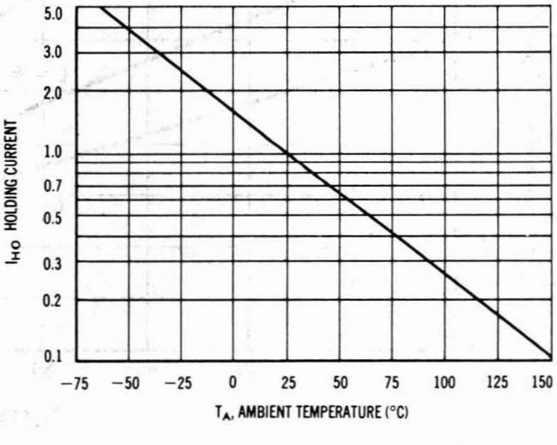
REVERSE BLOCKING VOLTAGE



FORWARD BREAKOVER CURRENT



HOLDING CURRENT



1N5221 thru 1N5281 series

P_D = 500 mW
V_Z = 2.4-200 V

CASE 51
(DO-7)

500 Milliwatt surmetic 20 silicon zener diodes-a complete series of Zener Diodes in the popular DO-7 case with higher ratings, tighter limits, better operating characteristics and a full set of designers' curves that reflect the superior capabilities of silicon-oxide-passivated junctions. All this in an axial-lead, transfer-molded plastic package offering protection in all common environmental conditions.

MAXIMUM RATINGS

Junction and Storage Temperature: —65 to +200°C

Lead Temperature not less than 1/16" from the case for 10 seconds: 230°C

DC Power Dissipation: 500 mW @ T_L = 75°C, Lead Length = ⅜"
(Derate 4.0 mW/°C above 75°C)

Surge Power: 10 Watts (Non-recurrent square wave @ PW = 8.3 ms, T_J = 55°C, Figure 16)

MECHANICAL CHARACTERISTICS

CASE: Void free, transfer molded, thermosetting plastic.

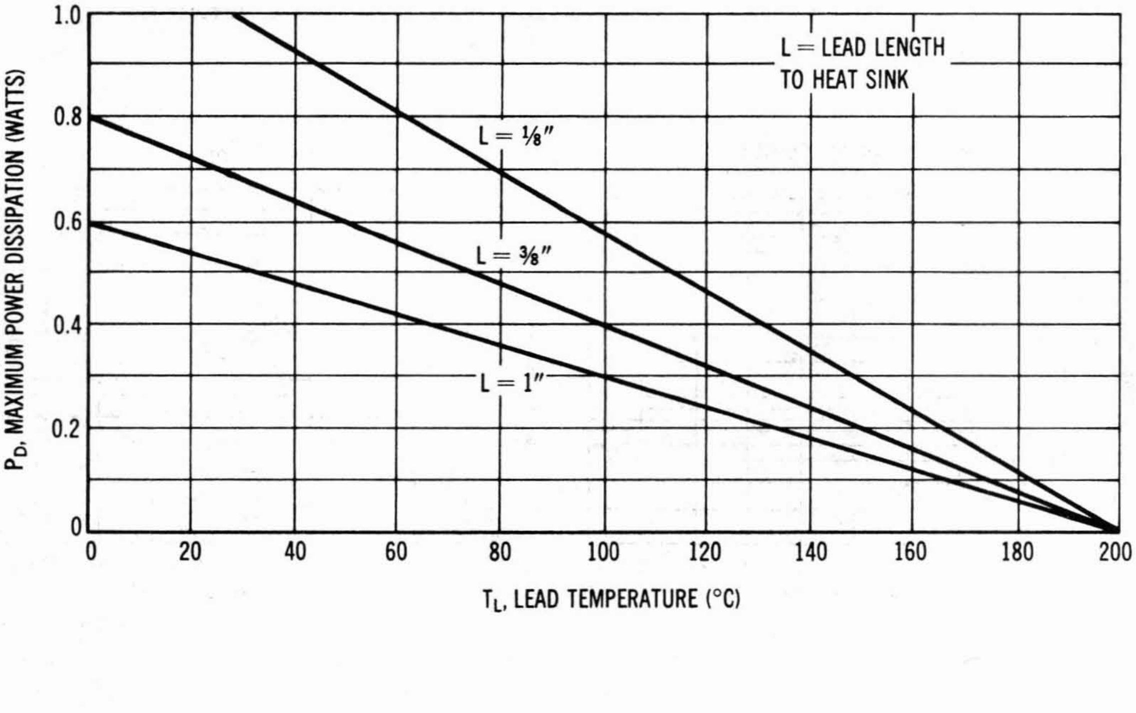
FINISH: All external surfaces are corrosion resistant. Leads are readily solderable and weldable.

POLARITY: Cathode indicated by color band. When operated in zener mode, cathode will be positive with respect to anode.

MOUNTING POSITION: Any.

WEIGHT: 0.18 gram (approximately).

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



1N5221 thru 1N5281 series (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted. Based on dc measurements at thermal equilibrium; lead length = 3/8"; thermal resistance of heat sink = 30°C/W) **$V_F = 1.1$ Max @ $I_F = 200$ mA for all types.**

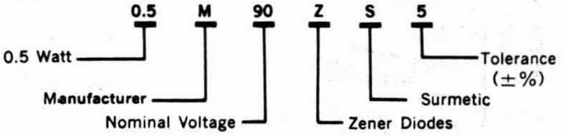
JEDEC Type No. (Note 1)	Nominal Zener Voltage V_Z @ I_{ZT} Volts (Note 2)	Test Current I_{ZT} mA	Max Zener Impedance A & B Suffix Only		Max Reverse Leakage Current				Max Zener Voltage Temp. Coeff. (A & B Suffix Only) θ_{VZ} (%/°C) (Note 3)
					A & B Suffix Only			Non-Suffix	
			Z_{ZT} @ I_{ZT} Ohms	Z_{ZK} @ $I_{ZK} = 0.25$ mA Ohms	I_R μA	@ V_R Volts		I_R @ V_R Used For Suffix A μA	
						A	B		
1N5221	2.4	20	30	1200	100	0.95	1.0	200	-0.085
1N5222	2.5	20	30	1250	100	0.95	1.0	200	-0.085
1N5223	2.7	20	30	1300	75	0.95	1.0	150	-0.080
1N5224	2.8	20	30	1400	75	0.95	1.0	150	-0.080
1N5225	3.0	20	29	1600	50	0.95	1.0	100	-0.075
1N5226	3.3	20	28	1600	25	0.95	1.0	100	-0.070
1N5227	3.6	20	24	1700	15	0.95	1.0	100	-0.065
1N5228	3.9	20	23	1900	10	0.95	1.0	75	-0.060
1N5229	4.3	20	22	2000	5.0	0.95	1.0	50	±0.055
1N5230	4.7	20	19	1900	5.0	1.9	2.0	50	±0.030
1N5231	5.1	20	17	1600	5.0	1.9	2.0	50	±0.030
1N5232	5.6	20	11	1600	5.0	2.9	3.0	50	+0.038
1N5233	6.0	20	7.0	1600	5.0	3.3	3.5	50	+0.038
1N5234	6.2	20	7.0	1000	5.0	3.8	4.0	50	+0.045
1N5235	6.8	20	5.0	750	3.0	4.8	5.0	30	+0.050
1N5236	7.5	20	6.0	500	3.0	5.7	6.0	30	+0.058
1N5237	8.2	20	8.0	500	3.0	6.2	6.5	30	+0.062
1N5238	8.7	20	8.0	600	3.0	6.2	6.5	30	+0.065
1N5239	9.1	20	10	600	3.0	6.7	7.0	30	+0.068
1N5240	10	20	17	600	3.0	7.6	8.0	30	+0.075
1N5241	11	20	22	600	2.0	8.0	8.4	30	+0.076
1N5242	12	20	30	600	1.0	8.7	9.1	10	+0.077
1N5243	13	9.5	13	600	0.5	9.4	9.9	10	+0.079
1N5244	14	9.0	15	600	0.1	9.5	10	10	+0.082
1N5245	15	8.5	16	600	0.1	10.5	11	10	+0.082
1N5246	16	7.8	17	600	0.1	11.4	12	10	+0.083
1N5247	17	7.4	19	600	0.1	12.4	13	10	+0.084
1N5248	18	7.0	21	600	0.1	13.3	14	10	+0.085
1N5249	19	6.6	23	600	0.1	13.3	14	10	+0.086
1N5250	20	6.2	25	600	0.1	14.3	15	10	+0.086
1N5251	22	5.6	29	600	0.1	16.2	17	10	+0.087
1N5252	24	5.2	33	600	0.1	17.1	18	10	+0.088
1N5253	25	5.0	35	600	0.1	18.1	19	10	+0.089
1N5254	27	4.6	41	600	0.1	20	21	10	+0.090
1N5255	28	4.5	44	600	0.1	20	21	10	+0.091
1N5256	30	4.2	49	600	0.1	22	23	10	+0.091
1N5257	33	3.8	58	700	0.1	24	25	10	+0.092
1N5258	36	3.4	70	700	0.1	26	27	10	+0.093
1N5259	39	3.2	80	800	0.1	29	30	10	+0.094
1N5260	43	3.0	93	900	0.1	31	33	10	+0.095
1N5261	47	2.7	105	1000	0.1	34	36	10	+0.095
1N5262	51	2.5	125	1100	0.1	37	39	10	+0.096
1N5263	56	2.2	150	1300	0.1	41	43	10	+0.096
1N5264	60	2.1	170	1400	0.1	44	46	10	+0.097
1N5265	62	2.0	185	1400	0.1	45	47	10	+0.097
1N5266	68	1.8	230	1600	0.1	49	52	10	+0.097
1N5267	75	1.7	270	1700	0.1	53	56	10	+0.098
1N5268	82	1.5	330	2000	0.1	59	62	10	+0.098
1N5269	87	1.4	370	2200	0.1	65	68	10	+0.099
1N5270	91	1.4	400	2300	0.1	66	69	10	+0.099
1N5271	100	1.3	500	2600	0.1	72	76	10	+0.110
1N5272	110	1.1	750	3000	0.1	80	84	10	+0.110
1N5273	120	1.0	900	4000	0.1	86	91	10	+0.110
1N5274	130	0.95	1100	4500	0.1	94	99	10	+0.110
1N5275	140	0.90	1300	4500	0.1	101	106	10	+0.110
1N5276	150	0.85	1500	5000	0.1	108	114	10	+0.110
1N5277	160	0.80	1700	5500	0.1	116	122	10	+0.110
1N5278	170	0.74	1900	5500	0.1	123	129	10	+0.110
1N5279	180	0.68	2200	6000	0.1	130	137	10	+0.110
1N5280	190	0.66	2400	6500	0.1	137	144	10	+0.110
1N5281	200	0.65	2500	7000	0.1	144	152	10	+0.110

NOTE 1 — TOLERANCE AND VOLTAGE DESIGNATION

Tolerance designation — The JEDEC type numbers shown indicate a tolerance of ±10% with guaranteed limits on only V_Z, I_R and V_F as shown in the above table. Units with guaranteed limits on all six parameters are indicated by suffix "A" for ±10% tolerance and suffix "B" for ±5.0% units.

Non-Standard voltage designation — To designate units with zener voltages other than those assigned JEDEC numbers, the type number should be used.

EXAMPLE:



NOTE 2 — SPECIAL SELECTIONS AVAILABLE INCLUDE:

1 — Nominal zener voltages between those shown.

2 — **Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.**

a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make zener voltages in excess of 200 volts possible as well as providing lower temperature coefficients, lower dynamic impedance and greater power handling ability.

b. Two or more units matched to one another with any specified tolerance.

3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

NOTE 3 — TEMPERATURE COEFFICIENT (θ_{VZ})

Test conditions for temperature coefficient are as follows:

a. $I_{ZT} = 7.5$ mA, $T_1 = 25°C$,
$T_2 = 125°C$ (1N5221A, B thru 1N5242A, B.)

b. I_{ZT} = Rated I_{ZT}, $T_1 = 25°C$,
$T_2 = 125°C$ (1N5243A, B thru 1N5281A, B.)

Device to be temperature stabilized with current applied prior to reading breakdown voltage at the specified ambient temperature.

1N5221 thru 1N5281 series (continued)

TYPICAL REVERSE CHARACTERISTICS FOR SELECTED ZENER DIODES

Curves marked T_A were obtained from dc measurements at thermal equilibrium; lead length = ⅜"; thermal resistance of heat sink = 30°C/W.
Curves marked T_J were obtained from pulse tests; mounting conditions are not a factor.

$V_{Z(Nominal)} = 3.3$ Volts

FIGURE 2

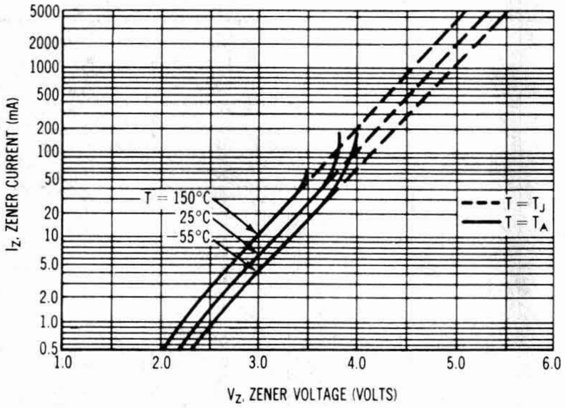
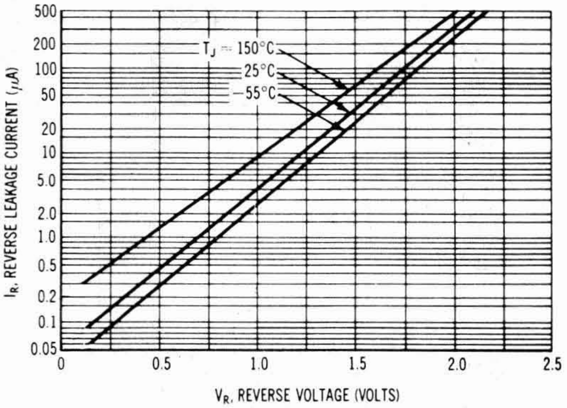


FIGURE 3



$V_{Z(Nominal)} = 5.1$ Volts

FIGURE 4

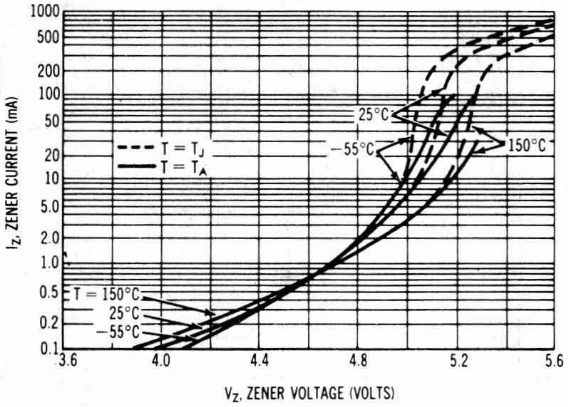
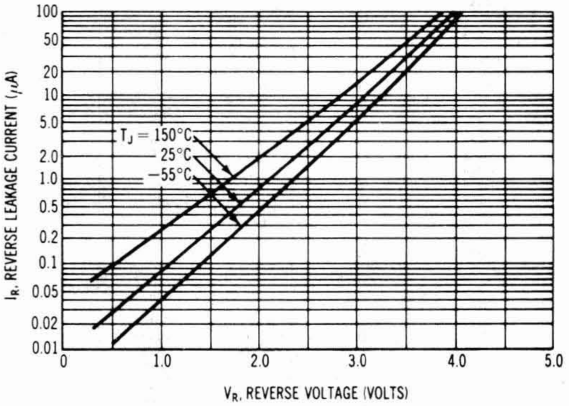


FIGURE 5



$V_{Z(Nominal)} = 27$ Volts

FIGURE 6

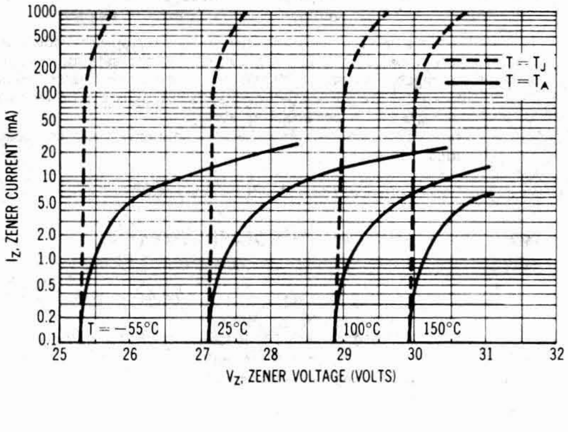
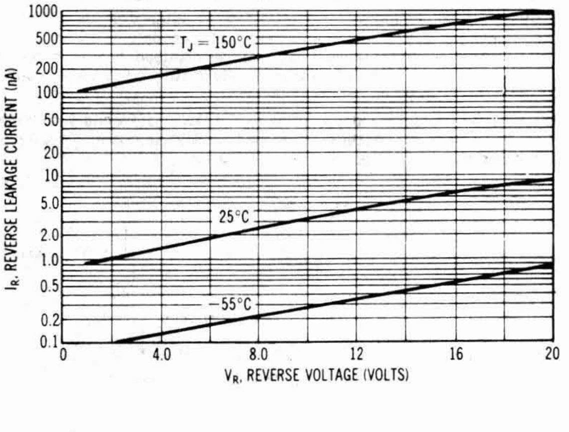


FIGURE 7



TEMPERATURE COEFFICIENTS AND VOLTAGE REGULATION

(90% of the units are in the ranges indicated)

FIGURE 8 — RANGE FOR UNITS TO 12 VOLTS

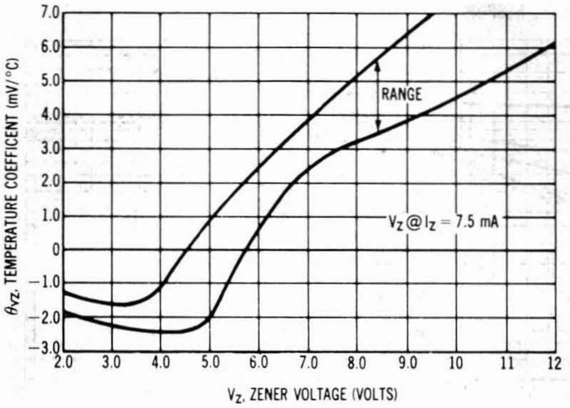


FIGURE 9 — RANGE FOR UNITS 12 TO 200 VOLTS

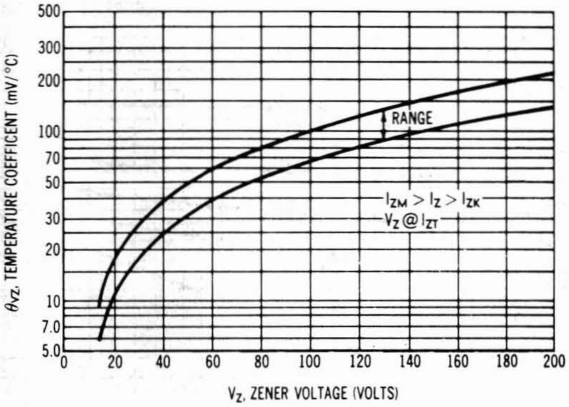


FIGURE 10 — EFFECT OF ZENER CURRENT

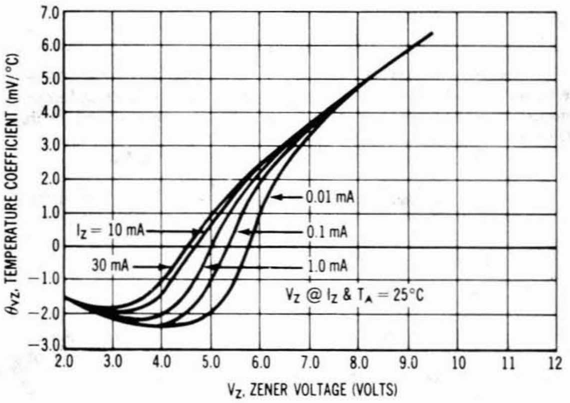
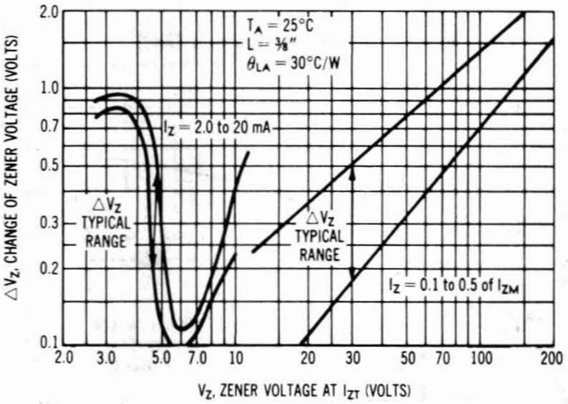


FIGURE 11 — VOLTAGE REGULATION



TYPICAL ZENER IMPEDANCE

FIGURE 12 — EFFECT OF ZENER CURRENT

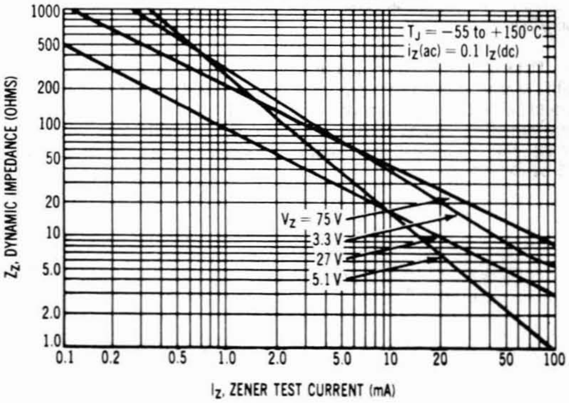


FIGURE 13 — EFFECT OF ZENER VOLTAGE

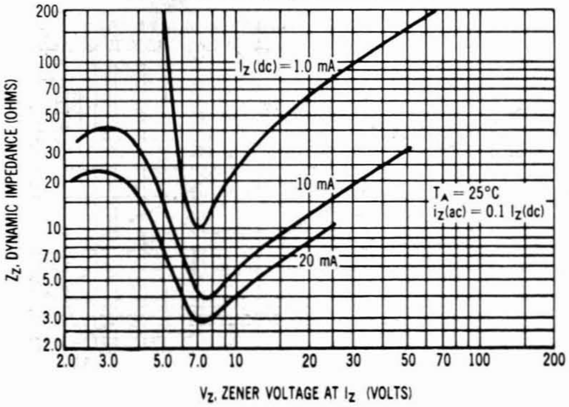


FIGURE 14 — TYPICAL THERMAL RESPONSE

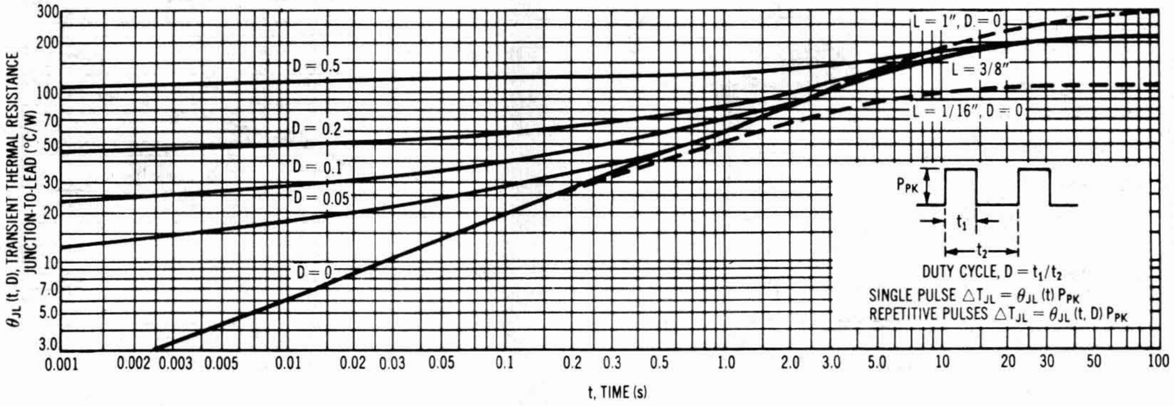


FIGURE 15 — TYPICAL THERMAL RESISTANCE

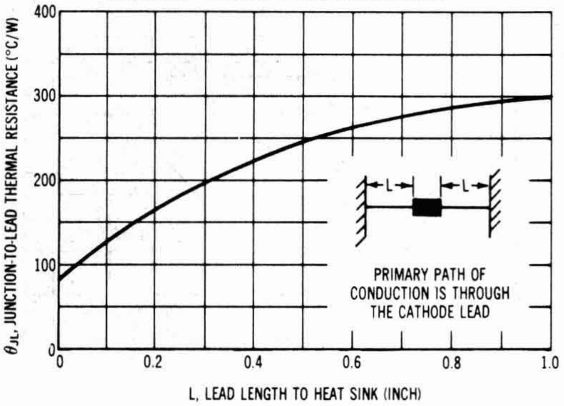
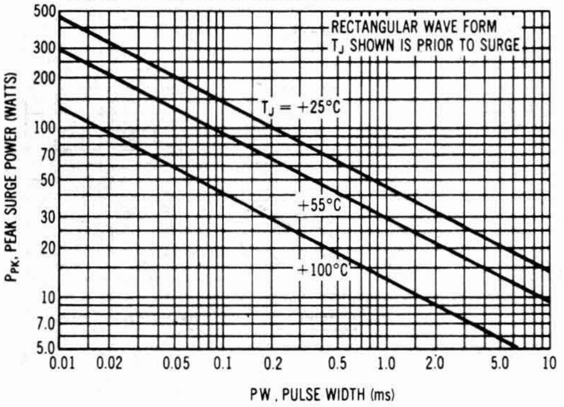


FIGURE 16 — MAXIMUM NON-REPETITIVE SURGE POWER



APPLICATION NOTE

Since the actual voltage available from a given zener diode is temperature dependent, it is necessary to determine junction temperature under any set of operating conditions, in order to calculate its value. The following procedure is recommended:

Lead Temperature, T_L, should be determined from:

$$T_L = \theta_{LA} P_D + T_A$$

θ_{LA} is the lead-to-ambient thermal resistance and P_D is the power dissipation. θ_{LA} is generally 30-40°C/W for the various clips and tie points in common use and for printed circuit board wiring.

Junction Temperature, T_J, may be found from:

$$T_J = T_L + \Delta T_{JL}$$

ΔT_{JL} is the increase in junction temperature above the lead temperature and may be found from Figure 14 for a train of power pulses or from Figure 15 for dc power.

For worst-case design, using expected limits of I_Z, limits of P_D and the extremes of T_J (ΔT_J) may be estimated. Changes in voltage, V_Z, can then be found from:

$$\Delta V = \theta_{VZ} \Delta T_J$$

θ_{VZ}, the zener voltage temperature coefficient, is found from Figures 8, 9, and 10.

Under high power-pulse operation, the zener voltage will vary with time and may also be affected significantly by the zener resistance. For best regulation, use short leads, especially to the cathode, and keep current excursions as low as possible.

Data of Figure 14 should not be used to compute surge capability. Surge limitations are given in Figure 16. They are lower than would be expected by considering only junction temperature, as current crowding effects cause temperatures to be extremely high in small spots resulting in device degradation should the limits of Figure 16 be exceeded.

FIGURE 17 — TYPICAL CAPACITANCE

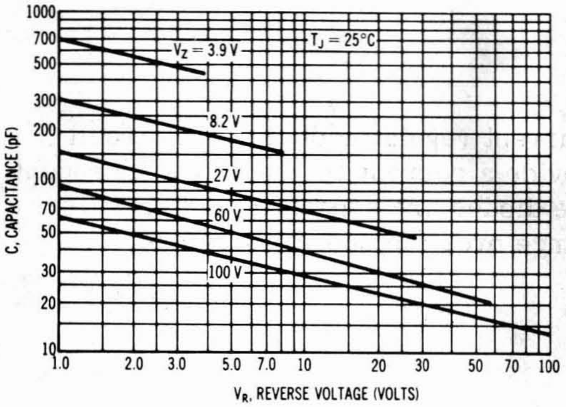


FIGURE 18 — TYPICAL FORWARD CHARACTERISTICS

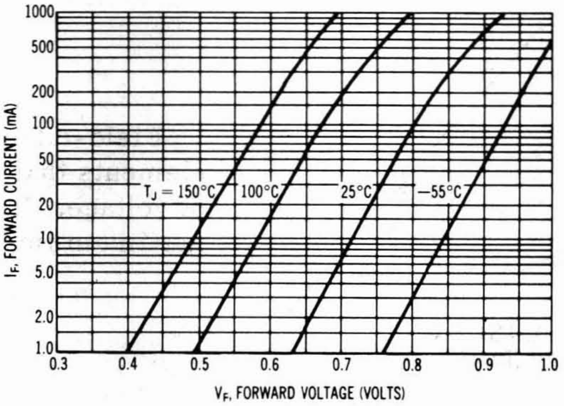


FIGURE 19 — TYPICAL NOISE DENSITY

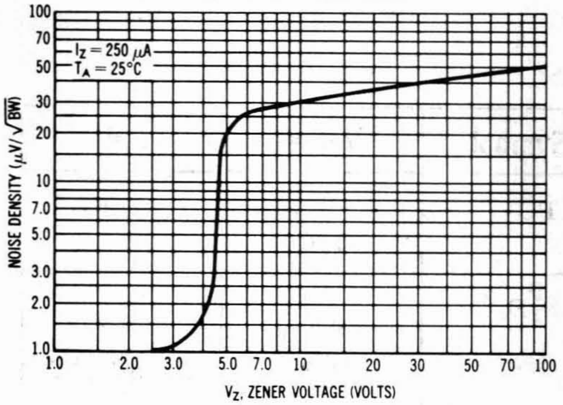
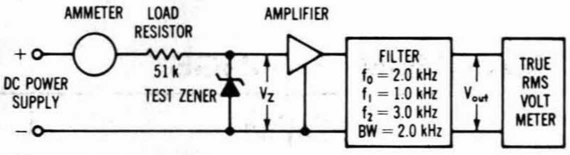


FIGURE 20 — NOISE DENSITY MEASUREMENT METHOD


AMMETER
LOAD RESISTOR
AMPLIFIER
+
DC POWER SUPPLY
−
51 k
TEST ZENER
V_Z
FILTER
f_0 = 2.0 kHz
f_1 = 1.0 kHz
f_2 = 3.0 kHz
BW = 2.0 kHz
V_{out}
TRUE RMS VOLT METER

NOISE DENSITY (VOLTS PER SQUARE ROOT BANDWIDTH) = $\frac{V_{out}}{\text{OVERALL GAIN } \sqrt{BW}}$

WHERE: BW = FILTER BANDWIDTH (Hz)
V_{out} = OUTPUT NOISE (VOLTS RMS)

The input voltage and load resistance are high so that the zener diode is driven from a constant current source. The amplifier is low noise so that the amplifier noise is negligible compared to that of the test zener. The filter bandpass is known so that the noise density can be calculated from the formula shown. The data of Figure 19 and the formula can also be used to find noise for any system bandwidth.

1N5283 thru 1N5314

CASE 51
(DO-7)

Field-effect current regulator diodes are circuit elements that provide a current essentially independent of voltage. These diodes are especially designed for maximum impedance over the operating range.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Peak Operating Voltage (T_J = -55°C to +200°C)	POV	100	Volts
Steady State Power Dissipation @ T_L = 75°C	P_D	600	mW
Derate above T_L = 75°C Lead Length = 3/8" (Forward or Reverse Bias)		4.8	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +200	°C

1N5283 thru 1N5314 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

	Regulator Current I_P (mA) @ V_T = 25 V			Minimum Dynamic Impedance @V_T = 25 V Z_T (MΩ)	Minimum Knee Impedance @V_K = 6.0 V Z_K (MΩ)	Maximum Limiting Voltage @I_L = 0.8 I_P (min) V_L (Volts)
Type No.	nom	min	max			
1N5283	0.22	0.198	0.242	25.0	2.75	1.00
1N5284	0.24	0.216	0.264	19.0	2.35	1.00
1N5285	0.27	0.243	0.297	14.0	1.95	1.00
1N5286	0.30	0.270	0.330	9.0	1.60	1.00
1N5287	0.33	0.297	0.363	6.6	1.35	1.00
1N5288	0.39	0.351	0.429	4.10	1.00	1.05
1N5289	0.43	0.387	0.473	3.30	0.870	1.05
1N5290	0.47	0.423	0.517	2.70	0.750	1.05
1N5291	0.56	0.504	0.616	1.90	0.560	1.10
1N5292	0.62	0.558	0.682	1.55	0.470	1.13
1N5293	0.68	0.612	0.748	1.35	0.400	1.15
1N5294	0.75	0.675	0.825	1.15	0.335	1.20
1N5295	0.82	0.738	0.902	1.00	0.290	1.25
1N5296	0.91	0.819	1.001	0.880	0.240	1.29
1N5297	1.00	0.900	1.100	0.800	0.205	1.35
1N5298	1.10	0.990	1.210	0.700	0.180	1.40
1N5299	1.20	1.08	1.32	0.640	0.155	1.45
1N5300	1.30	1.17	1.43	0.580	0.135	1.50
1N5301	1.40	1.26	1.54	0.540	0.115	1.55
1N5302	1.50	1.35	1.65	0.510	0.105	1.60
1N5303	1.60	1.44	1.76	0.475	0.092	1.65
1N5304	1.80	1.62	1.98	0.420	0.074	1.75
1N5305	2.00	1.80	2.20	0.395	0.061	1.85
1N5306	2.20	1.98	2.42	0.370	0.052	1.95
1N5307	2.40	2.16	2.64	0.345	0.044	2.00
1N5308	2.70	2.43	2.97	0.320	0.035	2.15
1N5309	3.00	2.70	3.30	0.300	0.029	2.25
1N5310	3.30	2.97	3.63	0.280	0.024	2.35
1N5311	3.60	3.24	3.96	0.265	0.020	2.50
1N5312	3.90	3.51	4.29	0.255	0.017	2.60
1N5313	4.30	3.87	4.73	0.245	0.014	2.75
1N5314	4.70	4.23	5.17	0.235	0.012	2.90

FIGURE 1 — TYPICAL CURRENT REGULATOR CHARACTERISTICS

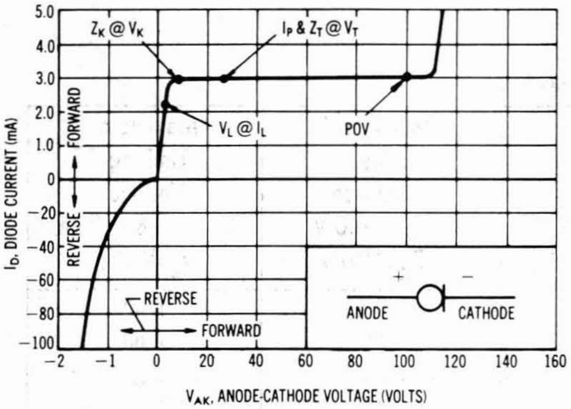
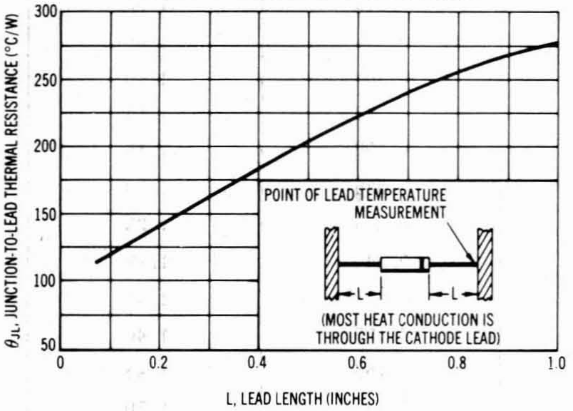


FIGURE 2 — TYPICAL THERMAL RESISTANCE



SYMBOLS AND DEFINITIONS

I_D — Diode Current.

I_L — Limiting Current: 80% of I_P minimum used to determine Limiting voltage, V_L.

I_P — Pinch-off Current: Regulator current at specified Test Voltage, V_T.

POV — Peak Operating Voltage: Maximum voltage to be applied to device.

θ_I — Current Temperature Coefficient.

V_{AK} — Anode-to-cathode Voltage.

V_K — Knee Impedance Test Voltage: Specified voltage used to establish Knee Impedance, Z_K.

V_L — Limiting Voltage: Measured at I_L. V_L, together with Knee AC Impedance, Z_K, indicates the Knee characteristics of the device.

V_T — Test Voltage: Voltage at which I_P and Z_T are specified.

Z_K — Knee AC Impedance at Test Voltage: To test for Z_K, a 90 Hz signal v_K with RMS value equal to 10% of test voltage, V_K, is superimposed on V_K:

$$Z_K = v_K / i_K$$

where i_K is the resultant ac current due to v_K

To provide the most constant current from the diode, Z_K should be as high as possible; therefore, a minimum value of Z_K is specified.

Z_T — AC Impedance at Test Voltage: Specified as a minimum value. To test for Z_T, a 90 Hz signal with RMS value equal to 10% of Test Voltage, V_T, is superimposed on V_T.

APPLICATION NOTE

As the current available from the diode is temperature dependent, it is necessary to determine junction temperature, T_J, under specific operating conditions to calculate the value of the diode current. The following procedure is recommended:

Lead Temperature, T_L, shall be determined from:

$$T_L = \theta_{LA} P_D + T_A$$

where θ_{LA} is lead-to-ambient thermal resistance
and P_D is power dissipation.

θ_{LA} is generally 30-40°C/W for the various clips and tie points in common use, and for printed circuit-board wiring.

Junction Temperature, T_J, shall be calculated from:

$$T_J = T_L + \theta_{JL} P_D$$

where θ_{JL} is taken from Figure 2.

For circuit design limits of V_{AK}, limits of P_D may be estimated and extremes of T_J may be computed. Using the information on Figures 4 and 5, changes in current may be found. To improve current regulation, keep V_{AK} low to reduce P_D and keep the leads short, especially the cathode lead, to reduce θ_{JL}.

FIGURE 3 — TYPICAL FORWARD CHARACTERISTICS

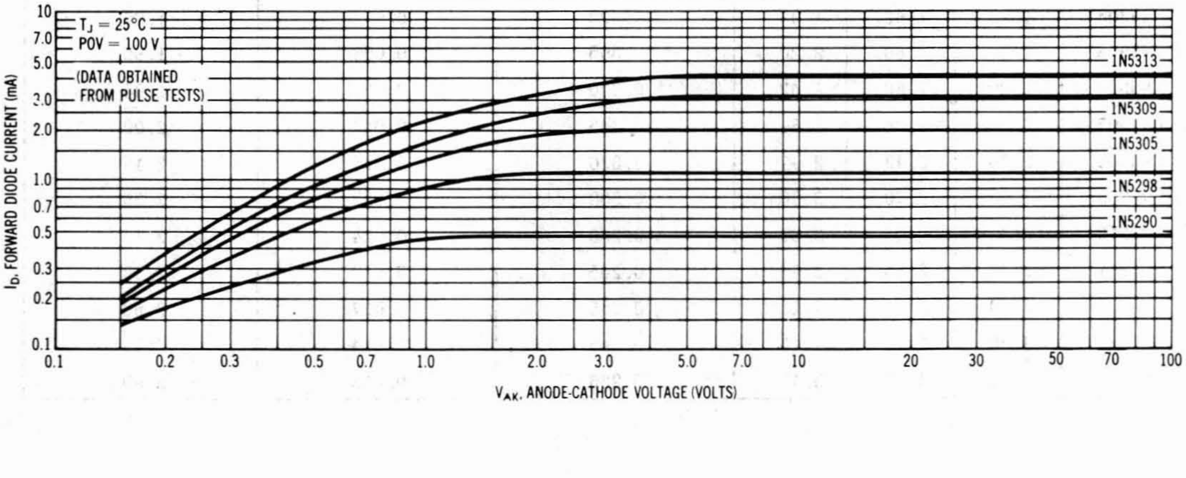


FIGURE 4 — TEMPERATURE COEFFICIENT

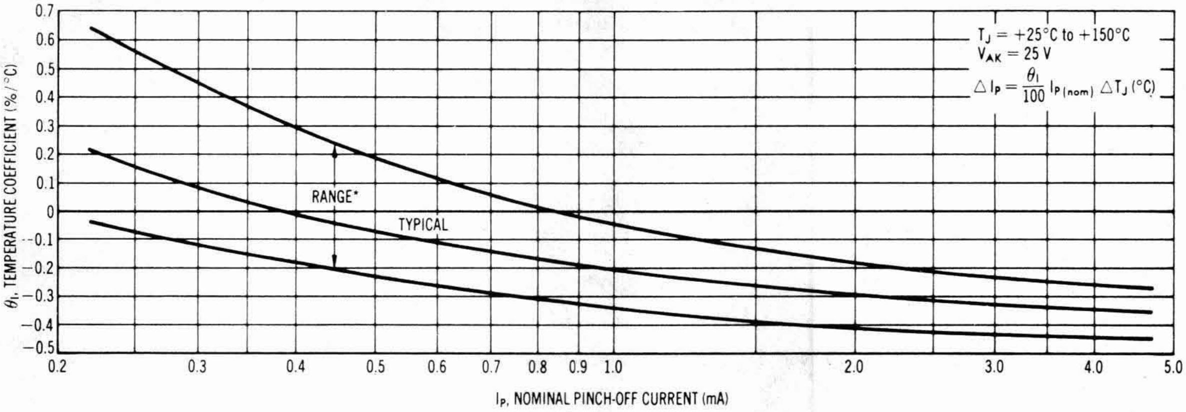


FIGURE 5 — TEMPERATURE COEFFICIENT

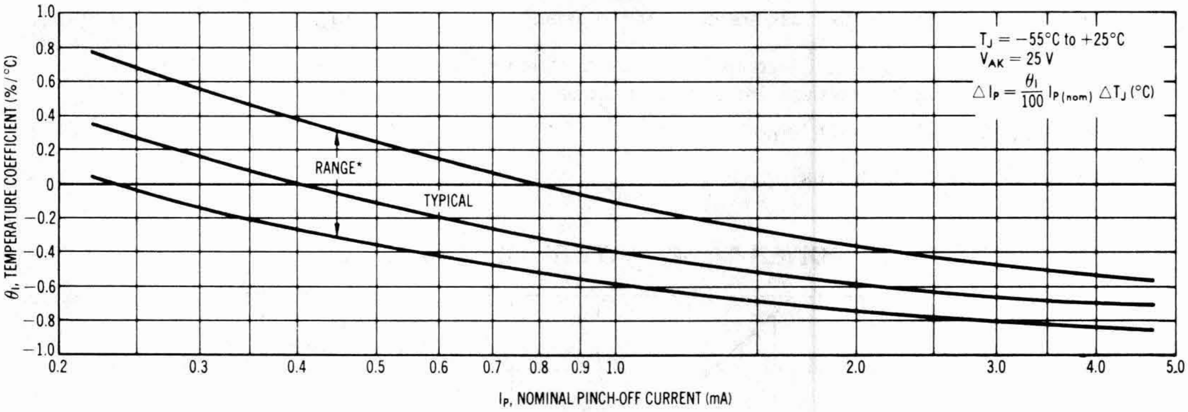
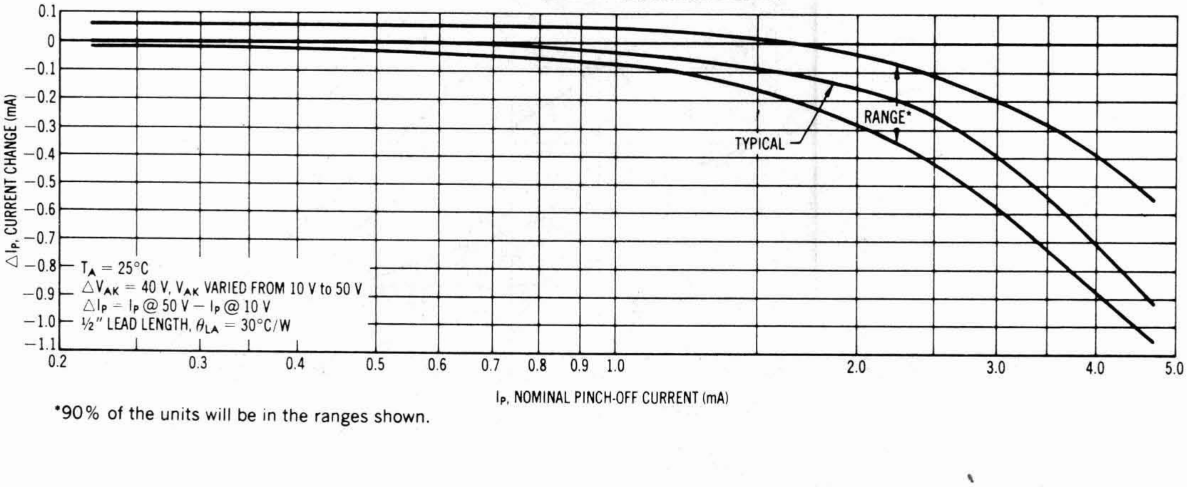


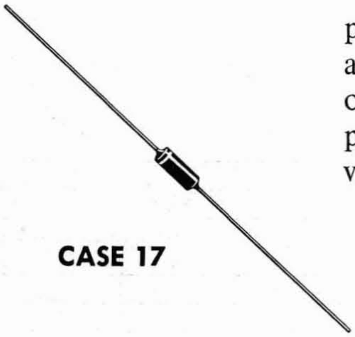
FIGURE 6 — CURRENT REGULATION FACTOR



*90% of the units will be in the ranges shown.

1N5333 (SILICON)
thru
1N5388

V_Z = 3.3 to 200 V



CASE 17

5.0 Watt surmetic 40 silicon zener diodes (silicon oxide passivated) with tight limits and better operating characteristics that reflect the superior capabilities of silicon-oxide-passivated junctions. An axial-lead, transfer-molded plastic package that offers protection in all common environmental conditions.

MAXIMUM RATINGS

Junction and Storage Temperature: -65 to +200°C

Lead Temperature not less than 1/16″ from the case for 10 seconds: 230°C

DC Power Dissipation: 5.0 W @ T_L = 75°C, Lead Length = 3/8″
(Derate 40 mW/°C above 75°C)

MECHANICAL CHARACTERISTICS

CASE: Void-free, transfer-molded, thermosetting plastic

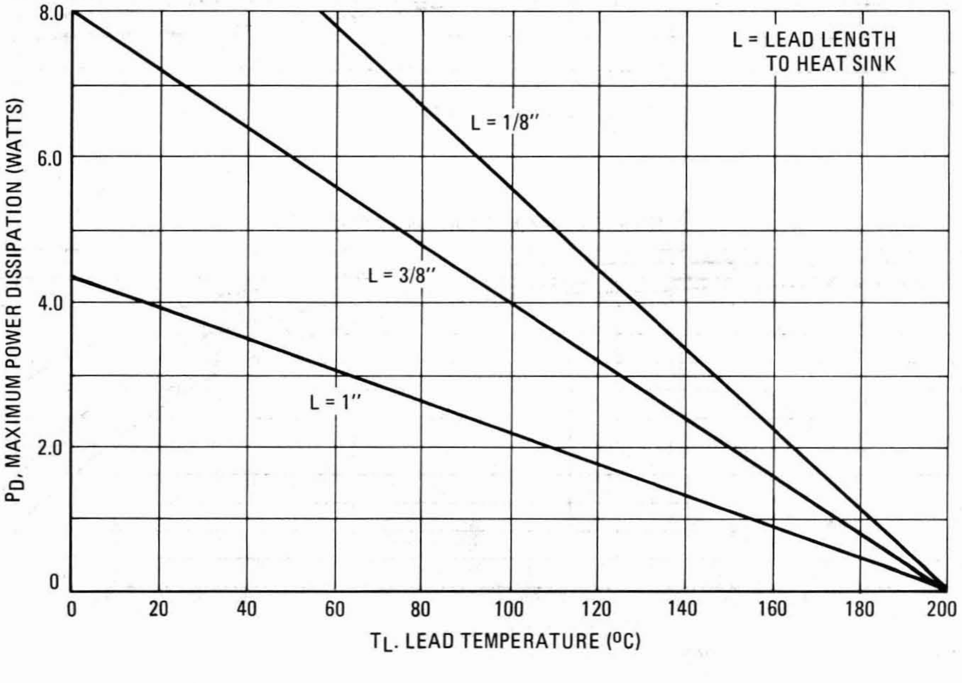
FINISH: All external surfaces are corrosion resistant. Leads are readily solderable

POLARITY: Cathode indicated by color band. When operated in zener mode, cathode will be positive with respect to anode.

MOUNTING POSITION: Any

WEIGHT: 0.7 gram (approx)

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



1N5333 thru 1N5388 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted) V_F = 1.2 Max @ I_F = 1.0 A for all types

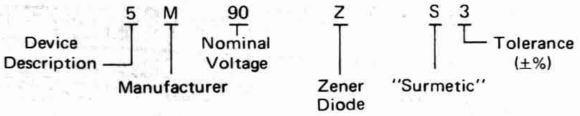
JEDEC Type No. (Note 1 & 2)	Nominal Zener Voltage V_Z @ I_{ZT} Volts (Note 3)	Test Current I_{ZT} mA	Max Zener Impedance A & B Suffix Only		Max Reverse Leakage Current			Applies to all Suffix	A & B Suffix Only	Maximum Regulator Current I_{ZM} mA (Note 6)
			Z_{ZT} @ I_{ZT} Ohms (Note 3)	Z_{ZK} @ I_{ZK} = 1.0 mA Ohms (Note 3)	I_R µA	@ V_R Volts Non & A Suffix	@ V_R Volts B-Suffix	Max Surge Current i_r,Amps (Note 4)	Max Voltage Regulation △ V_Z,Volts (Note 5)	
1N5333	3.3	380	3.0	400	300	1.0	1.0	20.0	0.85	1440
1N5334	3.6	350	2.5	500	150	1.0	1.0	18.7	0.80	1320
1N5335	3.9	320	2.0	500	50	1.0	1.0	17.6	0.54	1220
1N5336	4.3	290	2.0	500	10	1.0	1.0	16.4	0.49	1100
1N5337	4.7	260	2.0	450	5.0	1.0	1.0	15.3	0.44	1010
1N5338	5.1	240	1.5	400	1.0	1.0	1.0	14.4	0.39	930
1N5339	5.6	220	1.0	400	1.0	2.0	2.0	13.4	0.25	865
1N5340	6.0	200	1.0	300	1.0	3.0	3.0	12.7	0.19	790
1N5341	6.2	200	1.0	200	1.0	3.0	3.0	12.4	0.10	765
1N5342	6.8	175	1.0	200	10	4.9	5.2	11.5	0.15	700
1N5343	7.5	175	1.5	200	10	5.4	5.7	10.7	0.15	630
1N5344	8.2	150	1.5	200	10	5.9	6.2	10.0	0.20	580
1N5345	8.7	150	2.0	200	10	6.3	6.6	9.5	0.20	545
1N5346	9.1	150	2.0	150	7.5	6.6	6.9	9.2	0.22	520
1N5347	10	125	2.0	125	5.0	7.2	7.6	8.6	0.22	475
1N5348	11	125	2.5	125	5.0	8.0	8.4	8.0	0.25	430
1N5349	12	100	2.5	125	2.0	8.6	9.1	7.5	0.25	395
1N5350	13	100	2.5	100	1.0	9.4	9.9	7.0	0.25	365
1N5351	14	100	2.5	75	1.0	10.1	10.6	6.7	0.25	340
1N5352	15	75	2.5	75	1.0	10.8	11.5	6.3	0.25	315
1N5353	16	75	2.5	75	1.0	11.5	12.2	6.0	0.30	295
1N5354	17	70	2.5	75	0.5	12.2	12.9	5.8	0.35	280
1N5355	18	65	2.5	75	0.5	13.0	13.7	5.5	0.40	264
1N5356	19	65	3.0	75	0.5	13.7	14.4	5.3	0.40	250
1N5357	20	65	3.0	75	0.5	14.4	15.2	5.1	0.40	237
1N5358	22	50	3.5	75	0.5	15.8	16.7	4.7	0.45	216
1N5359	24	50	3.5	100	0.5	17.3	18.2	4.4	0.55	198
1N5360	25	50	4.0	110	0.5	18.0	19.0	4.3	0.55	190
1N5361	27	50	5.0	120	0.5	19.4	20.6	4.1	0.60	176
1N5362	28	50	6.0	130	0.5	20.1	21.2	3.9	0.60	170
1N5363	30	40	8.0	140	0.5	21.6	22.8	3.7	0.60	158
1N5364	33	40	10	150	0.5	23.8	25.1	3.5	0.60	144
1N5365	36	30	11	160	0.5	25.9	27.4	3.3	0.65	132
1N5366	39	30	14	170	0.5	28.1	29.7	3.1	0.65	122
1N5367	43	30	20	190	0.5	31.0	32.7	2.8	0.70	110
1N5368	47	25	25	210	0.5	33.8	35.8	2.7	0.80	100
1N5369	51	25	27	230	0.5	36.7	38.8	2.5	0.90	93.0
1N5370	56	20	35	280	0.5	40.3	42.6	2.3	1.00	86.0
1N5371	60	20	40	350	0.5	43.0	45.5	2.2	1.20	79.0
1N5372	62	20	42	400	0.5	44.6	47.1	2.1	1.35	76.0
1N5373	68	20	44	500	0.5	49.0	51.7	2.0	1.50	70.0
1N5374	75	20	45	620	0.5	54.0	56.0	1.9	1.60	63.0
1N5375	82	15	65	720	0.5	59.0	62.2	1.8	1.80	58.0
1N5376	87	15	75	760	0.5	63.0	66.0	1.7	2.00	54.5
1N5377	91	15	75	760	0.5	65.5	69.2	1.6	2.20	52.5
1N5378	100	12	90	800	0.5	72.0	76.0	1.5	2.50	47.5
1N5379	110	12	125	1000	0.5	79.2	83.6	1.4	2.50	43.0
1N5380	120	10	170	1150	0.5	86.4	91.2	1.3	2.50	39.5
1N5381	130	10	190	1250	0.5	93.6	98.8	1.2	2.50	36.6
1N5382	140	8.0	230	1500	0.5	101	106	1.2	2.50	34.0
1N5383	150	8.0	330	1500	0.5	108	114	1.1	3.00	31.6
1N5384	160	8.0	350	1650	0.5	115	122	1.1	3.00	29.4
1N5385	170	8.0	380	1750	0.5	122	129	1.0	3.00	28.0
1N5386	180	5.0	430	1750	0.5	130	137	1.0	4.00	26.4
1N5387	190	5.0	450	1850	0.5	137	144	0.9	5.00	25.0
1N5388	200	5.0	480	1850	0.5	144	152	0.9	5.00	23.6

NOTE 1 – TOLERANCE AND VOLTAGE DESIGNATION

TOLERANCE DESIGNATION – The JEDEC type numbers shown indicate a tolerance of ±20% with guaranteed limits on only V_Z, I_R, i_r, and V_F as shown in the electrical characteristics table. Units with guaranteed limits on all seven parameters are indicated by suffix "A" for ±10% tolerance and suffix "B" for ±5.0% units.

NOTE 2 – SPECIALS AVAILABLE INCLUDE:

(A) NOMINAL ZENER VOLTAGES BETWEEN THE VOLTAGES SHOWN AND TIGHTER VOLTAGE TOLERANCES: To designate units with zener voltages other than those assigned JEDEC numbers and/or tight voltage tolerances (±3%, ±2%, ±1%), the Mfg. type number should be used.

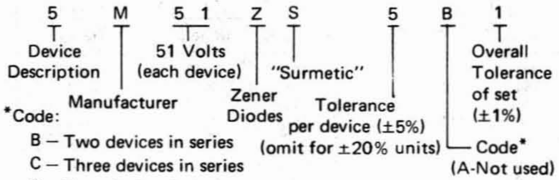


Example: **5M90ZS3**

(B) MATCHED SETS: (Standard Tolerances are ±5.0%, ±2.0%, ±1.0%).

Zener diodes can be obtained in sets consisting of two or more matched devices. The method for specifying such matched sets is similar to the one described in (A) for specifying units with a special voltage and/or tolerance except that two extra suffixes are added to the code number described.

These units are marked with code letters to identify the matched sets and, in addition, each unit in a set is marked with the same serial number, which is different for each set being ordered.



5
M
5 1
Z
S
5
B
1
Device Description
Manufacturer
51 Volts (each device)
Zener Diodes
"Surmetic"
Tolerance per device (±5%) (omit for ±20% units)
Code*
(A-Not used)
Overall Tolerance of set (±1%)

*Code:

B – Two devices in series

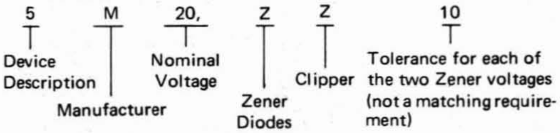
C – Three devices in series

D – Four devices in series

Example: **5M51ZS5B1**

(C) ZENER CLIPPERS: (Standard Tolerance ±10% and ±5%).

Special clipper diodes with opposing Zener junctions built into the device are available by using the following nomenclature:



5
M
20,
Z
Z
10
Device Description
Manufacturer
Nominal Voltage
Zener Diodes
Clipper
Tolerance for each of the two Zener voltages (not a matching requirement)

Example: **5M20ZZ10**

NOTE 3 – ZENER VOLTAGE (V_Z) AND IMPEDANCE (Z_{ZT} & Z_{ZK})

Test conditions for Zener voltage and impedance are as follows: I_Z is applied 40 ± 10 ms prior to reading. Mounting contacts are located 3/8" to 1/2" from the inside edge of mounting clips to the body of the diode. ($T_A = 25^oC\ ^{+8}_{-2}\ ^oC$).

NOTE 4 – SURGE CURRENT (i_r)

Surge current is specified as the maximum allowable peak, non-recurrent square-wave current with a pulse width, PW, of 8.3 ms. The data given in Figure 6 may be used to find the maximum surge current for a square wave of any pulse width between 1.0 ms and 1000 ms by plotting the applicable points on logarithmic paper. Examples of this, using the 3.3 V and 200 V zeners, are shown in Figure 7. Mounting contact located as specified in Note 3. ($T_A = 25^oC\ ^{+8}_{-2}\ ^oC$).

NOTE 5 – VOLTAGE REGULATION (ΔV_Z)

Test conditions for voltage regulation are as follows: V_Z measurements are made at 10% and then at 50% of the I_Z max value listed in the electrical characteristics table. The test currents are the same for the 5% and 10% tolerance devices. The test current time duration for each V_Z measurement is 40 ± 10 ms. (T_A = $25^\circ C\ ^{+8^\circ}_{-2}\ C$). Mounting contact located as specified in Note 3.

NOTE 6 – MAXIMUM REGULATOR CURRENT (I_{ZM})

The maximum current shown is based on the maximum voltage of a 5% type unit, therefore, it applies only to the B-suffix device. The actual I_{ZM} for any device may not exceed the value of 5.0 watts divided by the actual V_Z of the device. $T_L = 75^\circ C$ at 3/8" maximum from the device body.

TEMPERATURE COEFFICIENTS

FIGURE 2 – TEMPERATURE COEFFICIENT-RANGE FOR UNITS 3.0 TO 10 VOLTS

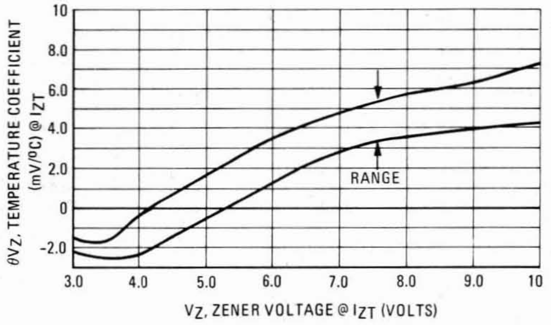


FIGURE 3 – TEMPERATURE COEFFICIENT-RANGE FOR UNITS 10 TO 220 VOLTS

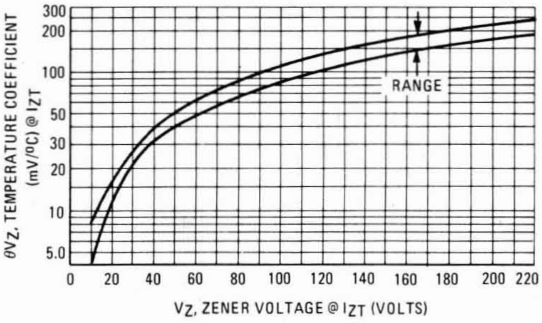


FIGURE 4 – TYPICAL THERMAL RESPONSE

L, LEAD LENGTH = 3/8 INCH

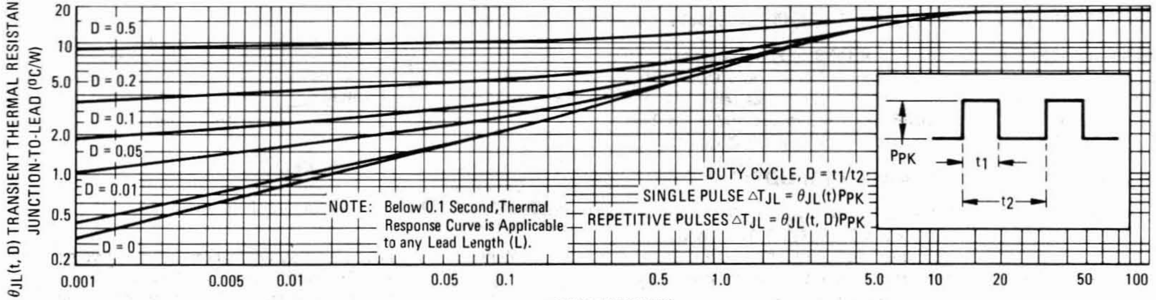


FIGURE 5 – TYPICAL THERMAL RESISTANCE

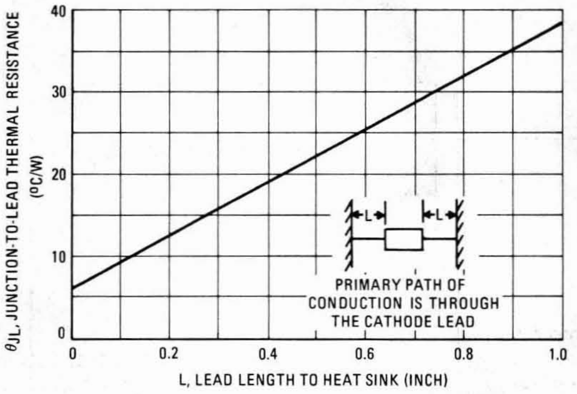


FIGURE 6 – MAXIMUM NON-REPETITIVE SURGE CURRENT versus NOMINAL ZENER VOLTAGE

(See Note 4)

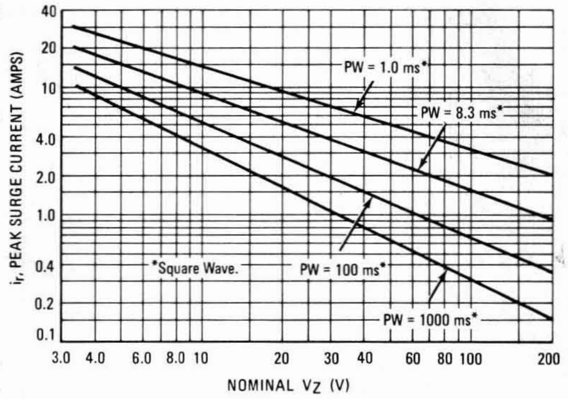
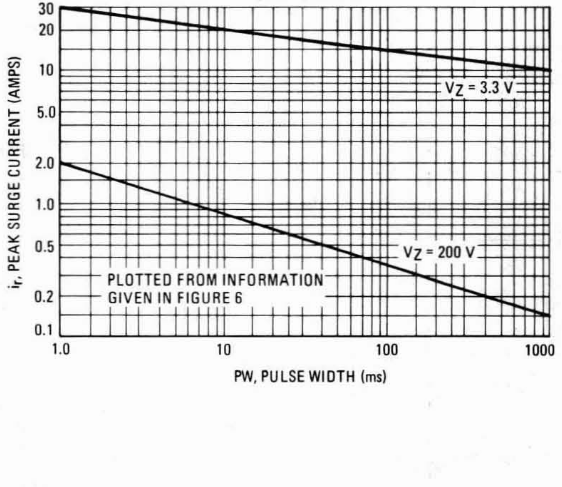


FIGURE 7 – PEAK SURGE CURRENT versus PULSE WIDTH

(See Note 4)



APPLICATION NOTE

Since the actual voltage available from a given zener diode is temperature dependent, it is necessary to determine junction temperature under any set of operating conditions, in order to calculate its value. The following procedure is recommended:

Lead Temperature, T_L, should be determined from:

$$T_L = \theta_{LA}\, P_D + T_A$$

θ_{LA} is the lead-to-ambient thermal resistance and P_D is the power dissipation.

Junction Temperature, T_J, may be found from:

$$T_J = T_L + \Delta T_{JL}$$

ΔT_{JL} is the increase in junction temperature above the lead temperature and may be found from Figure 4 for a train of power pulses or from Figure 5 for dc power.

$$\Delta T_{JL} = \theta_{JL}\, P_D$$

For worst-case design, using expected limits of I_Z, limits of P_D and the extremes of $T_J(\Delta T_J)$ may be estimated. Changes in voltage, V_Z, can then be found from:

$$\Delta V = \theta_{VZ}\, \Delta T_J$$

θ_{VZ}, the zener voltage temperature coefficient, is found from Figures 2 and 3.

Under high power-pulse operation, the zener voltage will vary with time and may also be affected significantly by the zener resistance. For best regulation, keep current excursions as low as possible.

Data of Figure 4 should not be used to compute surge capability. Surge limitations are given in Figure 6. They are lower than would be expected by considering only junction temperature, as current crowding effects cause temperatures to be extremely high in small spots resulting in device degradation should the limits of Figure 6 be exceeded.

1N5441A,B,C
thru
1N5456A,B,C

VVC

VOLTAGE-VARIABLE CAPACITANCE DIODES

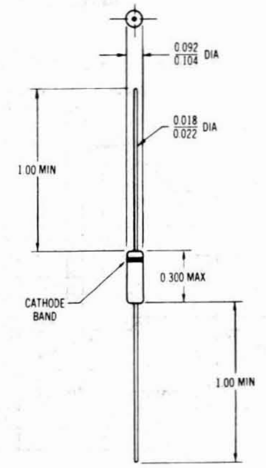
6.8 – 100 pF
30 VOLTS

SILICON EPICAP DIODES

. . . epitaxial passivated abrupt junction tuning diodes designed for electronic tuning, FM, AFC and harmonic-generation applications in AM through UHF ranges, providing solid-state reliability to replace mechanical tuning methods.

- Excellent Q Factor at High Frequencies
- Guaranteed Capacitance Change – 2.0 to 30 V
- Guaranteed Temperature Coefficient
- Capacitance Tolerance – 10%, 5.0%, and 2.0%
- Complete Typical Design Curves

DO-7 GLASS



CASE 51
DO-7

** MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	30	Volts
Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	400 2.67	mW mW/°C
Operating Junction Temperature Range	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

**Indicates JEDEC Registered Data.

** ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic—All Types	Test Conditions	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage	I_R = 10 μAdc	BV_R	30	–	–	Vdc
Reverse Voltage Leakage Current	V_R = 25 Vdc, T_A = 25°C V_R = 25 Vdc, T_A = 150°C	I_R	– –	– –	0.02 20	μAdc
Series Inductance	f = 250 MHz, lead length≈1/16″	L_S	–	4.0	10	nH
Case Capacitance	f = 1.0 MHz, lead length≈1/16″	C_C	0.1	0.17	0.25	pF
Diode Capacitance Temperature Coefficient (Note 6)	V_R = 4.0 Vdc, f = 1.0 MHz	TC_c	–	300	400	ppm/°C

Device	C_T, Diode Capacitance* V_R = 4.0 Vdc, f = 1.0 MHz pF			TR, Tuning Ratio C_2/C_{30} f = 1.0 MHz		Q, Figure of Merit V_R = 4.0 Vdc f = 50 MHz
	Min (Nom −10%)	Nom	Max (Nom +10%)	Min	Max	Min
1N5441A	6.1	6.8	7.5	2.5	3.1	450
1N5442A	7.4	8.2	9.0	2.5	3.1	450
1N5443A	9.0	10.0	11.0	2.6	3.1	400
1N5444A	10.8	12.0	13.2	2.6	3.1	400
1N5445A	13.5	15.0	16.5	2.6	3.1	400
1N5446A	16.2	18.0	19.8	2.6	3.1	350
1N5447A	18.0	20.0	22.0	2.6	3.1	350
1N5448A	19.8	22.0	24.2	2.6	3.2	350
1N5449A	24.3	27.0	29.7	2.6	3.2	350
1N5450A	29.7	33.0	36.3	2.6	3.2	350
1N5451A	35.1	39.0	42.9	2.6	3.2	300
1N5452A	42.3	47.0	51.7	2.6	3.2	250
1N5453A	50.4	56.0	61.6	2.6	3.3	200
1N5454A	61.2	68.0	74.8	2.7	3.3	175
1N5455A	73.8	82.0	90.2	2.7	3.3	175
1N5456A	90.0	100.0	110.0	2.7	3.3	175

*To order devices with C_T Nom ±5.0% or ±2.0% add Suffix B or C respectively.

**Indicates JEDEC Registered Data.

PARAMETER TEST METHODS

1. **L_S, Series Inductance**
   L_S is measured on a shorted package at 250 MHz using an impedance bridge (Boonton Radio Model 250A RX Meter or equivalent).
2. **C_C, Case Capacitance**
   C_C is measured on an open package at 1.0 MHz using a capacitance bridge (Boonton Electronics Model 75A or equivalent).
3. **C_T, Diode Capacitance**
   ($C_T = C_C + C_J$). C_T is measured at 1.0 MHz using a capacitance bridge (Boonton Electronics Model 75A or equivalent).
4. **TR, Tuning Ratio**
   TR is the ratio of C_T measured at 2.0 Vdc divided by C_T measured at 30 Vdc.
5. **Q, Figure of Merit**
   Q is calculated by taking the G and C readings of an admittance bridge at the specified frequency and substituting in the following equations:

$$Q = \frac{2\pi f C}{G}$$

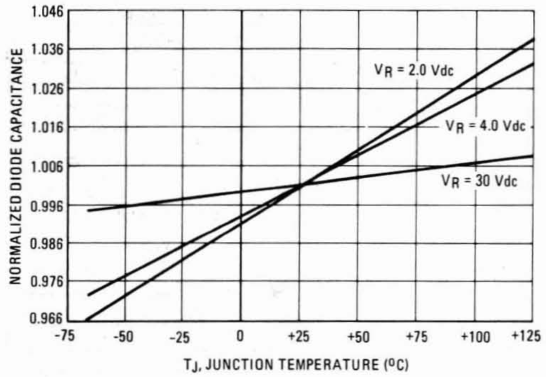
(Boonton Electronics Model 33AS8 or equivalent).

6. **TC_c, Diode Capacitance Temperature Coefficient**
   TC_c is guaranteed by comparing C_T at V_R = 4.0 Vdc, f = 1.0 MHz, T_A = −65°C with C_T at V_R = 4.0 Vdc, f = 1.0 MHz, T_A = +85°C in the following equation, which defines TC_c:

$$TC_c = \left| \frac{C_T(+85^\circ C) - C_T(-65^\circ C)}{85 + 65} \right| \frac{10^6}{C_T(25^\circ C)}$$

Accuracy limited by C_T measurement to ±0.1 pF.

FIGURE 1 — NORMALIZED DIODE CAPACITANCE versus JUNCTION TEMPERATURE



TYPICAL DEVICE PERFORMANCE

FIGURE 2 – DIODE CAPACITANCE versus REVERSE VOLTAGE

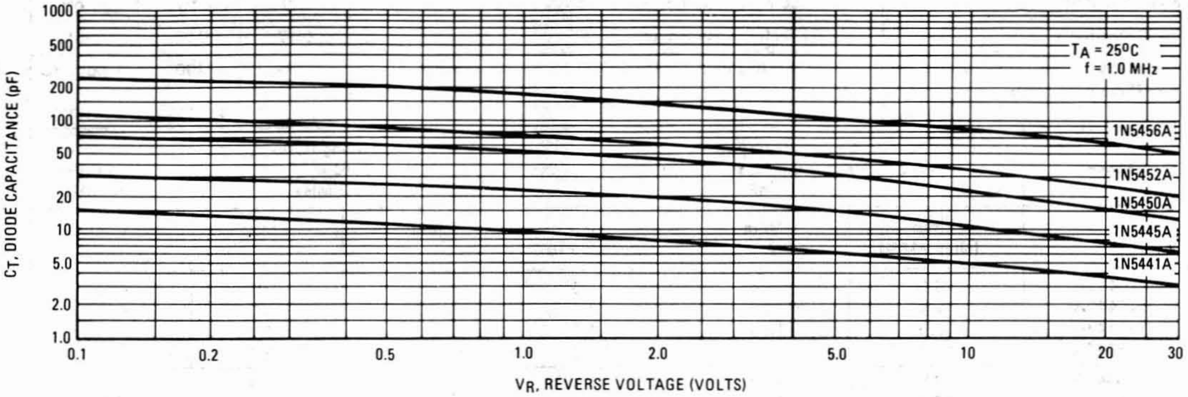


FIGURE 3 – FIGURE OF MERIT versus REVERSE VOLTAGE

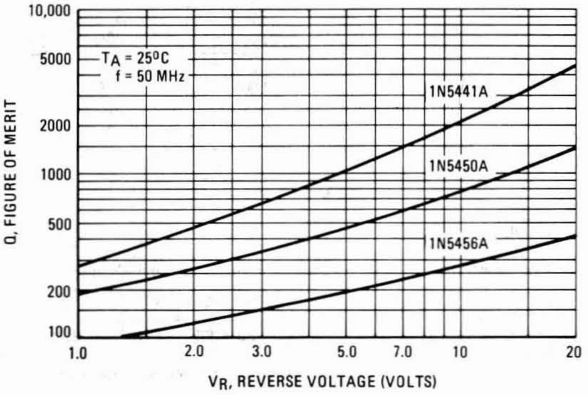


FIGURE 4 – FIGURE OF MERIT versus FREQUENCY

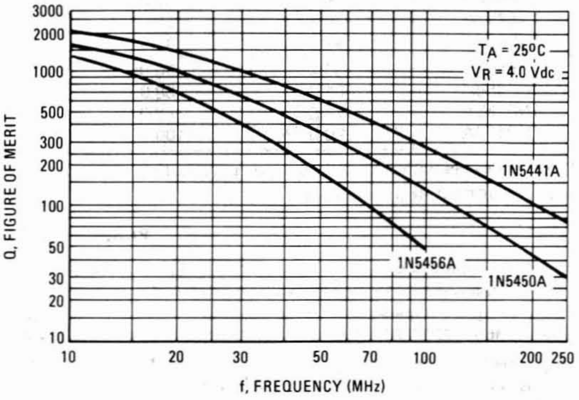


FIGURE 5 – REVERSE CURRENT versus REVERSE BIAS VOLTAGE

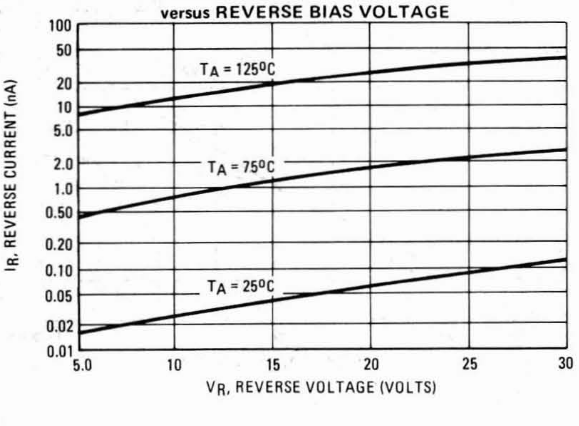
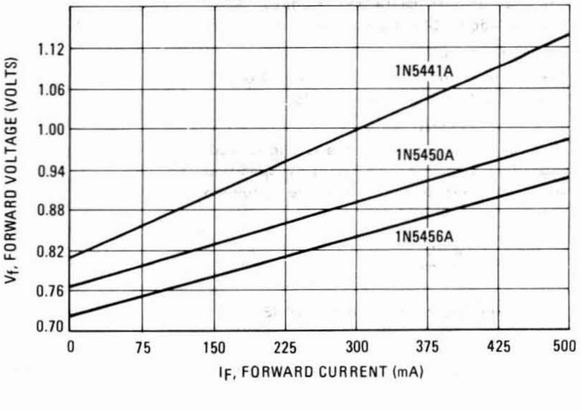


FIGURE 6 – FORWARD VOLTAGE versus FORWARD CURRENT



1N5461A,B,C
thru
1N5476A,B,C

VVC

SILICON EPICAP DIODES

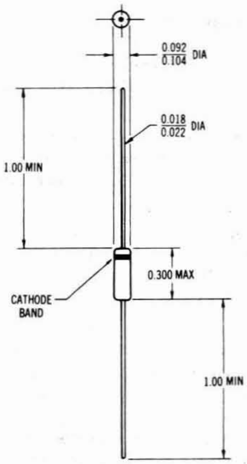
. . . a PREMIUM line of epitaxial, passivated, abrupt-junction tuning diodes for critical and sophisticated frequency control applications through the UHF range.

- High Q at High Frequencies
- Guaranteed High Capacitance Tuning Range
- Excellent Unit-to-Unit Uniformity
- Guaranteed Temperature Coefficient
- Capacitance Tolerances – 10%, 5.0%, and 2.0%
- Complete Typical Design Curves

VOLTAGE-VARIABLE CAPACITANCE DIODES

6.8 – 100 pF
30 VOLTS

DO-7 GLASS



CASE 51
DO-7

**MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	30	Volts
Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	400 2.67	mW mW/^oC
Operating Junction Temperature Range	T_J	+175	^oC
Storage Temperature Range	T_{stg}	-65 to +200	^oC

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Series Inductance	f = 250 MHz, lead length ≈1/16″	L_S	–	4.0	10	nH
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	Min (Nom −10%)	Nom	Max (Nom +10%)	Min	Max	Min
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1N5462A	7.4	8.2	9.0	2.8	3.1	600
1N5463A	9.0	10.0	11.0	2.8	3.1	550
1N5464A	10.8	12.0	13.2	2.8	3.1	550
1N5465A	13.5	15.0	16.5	2.8	3.1	550
1N5466A	16.2	18.0	19.8	2.9	3.1	500
1N5467A	18.0	20.0	22.0	2.9	3.1	500
1N5468A	19.8	22.0	24.2	2.9	3.2	500
1N5469A	24.3	27.0	29.7	2.9	3.2	500
1N5470A	29.7	33.0	36.3	2.9	3.2	500
1N5471A	35.1	39.0	42.9	2.9	3.2	450
1N5472A	42.3	47.0	51.7	2.9	3.2	400
1N5473A	50.4	56.0	61.6	2.9	3.3	300
1N5474A	61.2	68.0	74.8	2.9	3.3	250
1N5475A	73.8	82.0	90.2	2.9	3.3	225
1N5476A	90.0	100.0	110.0	2.9	3.3	200

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3. **C_T, Diode Capacitance**
   ($C_T = C_C + C_J$). C_T is measured at 1.0 MHz using a capacitance bridge (Boonton Electronics Model 75A or equivalent).
4. **TR, Tuning Ratio**
   TR is the ratio of C_T measured at 2.0 Vdc divided by C_T measured at 30 Vdc.
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(Boonton Electronics Model 33AS8 or equivalent).

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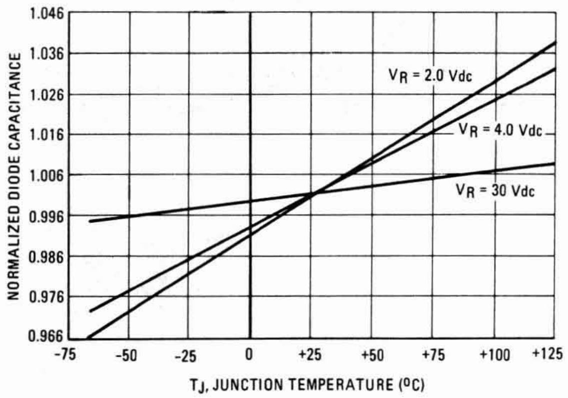
$$TC_c = \left| \frac{C_T(+85°C) - C_T(-65°C)}{85 + 65} \right| \frac{10^6}{C_T(25°C)}$$

Accuracy limited by C_T measurement to ±0.1 pF.

FIGURE 1 — NORMALIZED DIODE CAPACITANCE versus JUNCTION TEMPERATURE



TYPICAL DEVICE PERFORMANCE

FIGURE 2 – DIODE CAPACITANCE versus REVERSE VOLTAGE

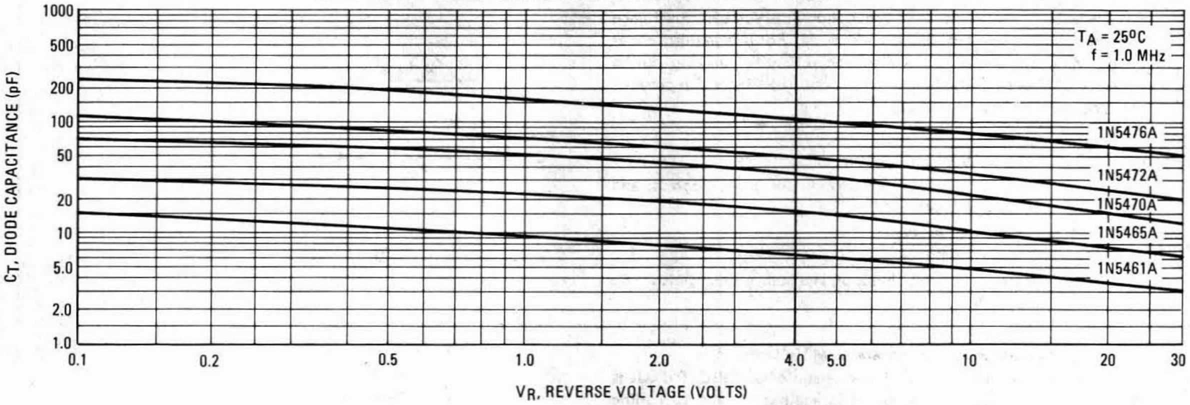


FIGURE 3 – FIGURE OF MERIT versus REVERSE VOLTAGE

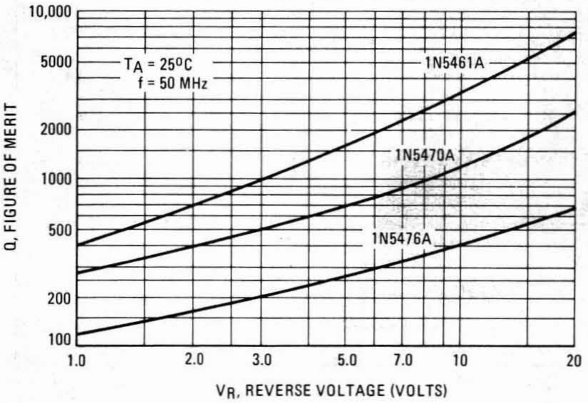


FIGURE 4 – FIGURE OF MERIT versus FREQUENCY

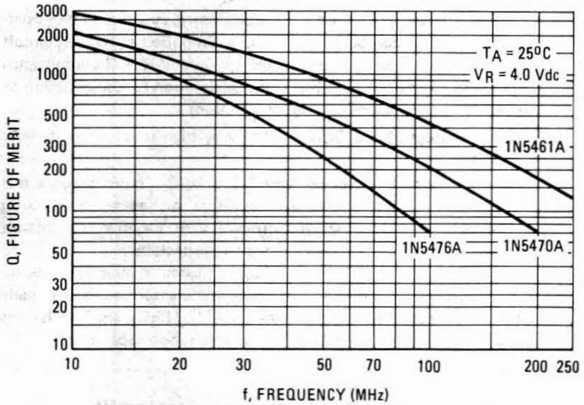


FIGURE 5 – REVERSE CURRENT versus REVERSE BIAS VOLTAGE

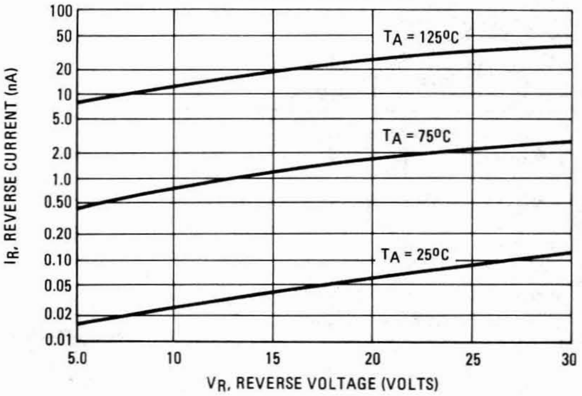
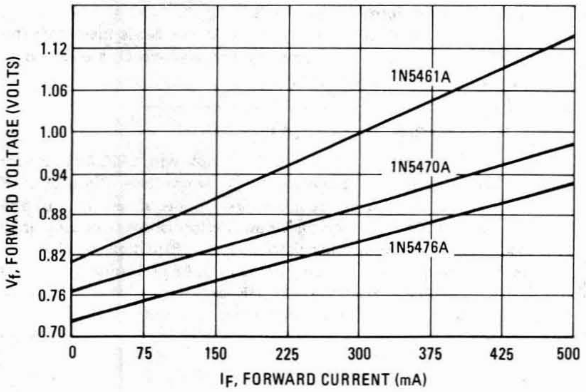


FIGURE 6 – FORWARD VOLTAGE versus FORWARD CURRENT



EPICAP VOLTAGE-VARIABLE CAPACITANCE DIODE DEVICE CONSIDERATIONS

A. Epicap Network Presentation

The equivalent circuit in Figure 7 shows the voltage capacitance and parasitic elements of an EPICAP diode. For design purposes at all but very high and very low frequencies, L_S, R_J, and C_C can be neglected. The simplified equivalent circuit of Figure 8 represents the diode under these conditions.

Definitions:

C_J – Voltage-Variable Junction Capacitance
R_S – Series Resistance (semiconductor bulk, contact, and lead resistance)
C_C – Case Capacitance
L_S – Series Inductance
R_J – Voltage-Variable Junction Resistance (negligible above 100 kHz)

FIGURE 7

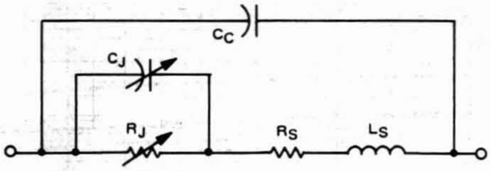
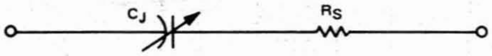


FIGURE 8



B. Epicap Capacitance versus Reverse Bias Voltage

The most important design characteristic of an EPICAP diode is the C_T versus V_R variation as shown in equations 1 and 2. Tuning Ratio, TR, between any two voltage points on curve of equation (2) is determined from equations (3) and (4).

$$C_T = C_C + C_J \qquad (1)$$

$$C_T = C_C + \frac{C_o}{\left(1 + \frac{V_R}{\phi}\right)^{\gamma}} \qquad (2)$$

C. Epicap Capacitance versus Frequency

Variations in EPICAP effective capacitance, as a function of operating frequency, can be derived from a simplified equivalent circuit similar to that of Figure 7, but neglecting R_S and R_J. The admittance expression for such a circuit is given in equation 5. Examination of equation 5 yields the following information:

At low frequencies, $C_{eq} \approx C_J$; at very high frequencies ($f \approx \infty$) $C_{eq} \approx C_C$.

As frequency is increased from 1.0 MHz, C_{eq} increases until it is maximum at $\omega^2 = 1/L_SC_J$; and as ω^2 is increased from $1/L_SC_J$ toward infinity, C_{eq} increases from a very negative capacitance (inductance) toward $C_{eq} = C_C$, a positive capacitance.

Very simple calculations for C_{eq} at higher frequencies indicate the problems encountered when capacity measurements are made above 1.0 MHz. As ω approaches $\omega_o = 1/\sqrt{L_SC_J}$, small variations in L_S cause extreme variations in measured diode capacitance.

$$\text{TR Junction} = \frac{C_{J1}}{C_{J2}} = \left(\frac{V_{R2} + \phi}{V_{R1} + \phi}\right)^{\gamma} \qquad (3)$$

$$\text{TR Diode} = \frac{C_{T1}}{C_{T2}} = \frac{C_{J1} + C_C}{C_{J2} + C_C} \qquad (4)$$

$C_o = C_J$ at $V_R = 0$
V_R = Reverse Bias (Volts)
γ, Diode Power Law, ≈ 0.44
ϕ, Contact Potential, ≈ 0.6 Volt
$C_c \approx 0.17$ pF

$$Y = j\omega C_{eq} = j\omega C_C + \frac{j\omega C_J}{1 - \omega^2 L_S C_J} \qquad (5)$$

D. EPICAP Figure of Merit (Q) and Cutoff Frequency (f_{co})

The efficiency of EPICAP response to an input frequency is related to the Figure of Merit of the device as defined in equation 6. For very low frequencies, equation 7 applies whereas at high frequencies, where R_J can be neglected, equation 6 may be rewritten into the familiar form of equation 8.

Another useful parameter for EPICAP devices is the cutoff frequency (f_{co}), and is the frequency point where Q is equal to 1. Equation 9 gives this relationship.

$$Q = \frac{X_{Seq}}{R_{Seq}} \qquad (6)$$

$$Q_{Lf} = \frac{\omega C_J R_J{}^2}{R_J + R_S(1 + \omega^2 C_J{}^2 R_J{}^2} \qquad (7)$$

$$Q_{hf} = \frac{1}{\omega R_S C_{eq}} \qquad (8)$$

$$f_{co} = Qf_{max} \quad \frac{1}{2\pi R_S C_{BVR}} \qquad (9)$$

E. Harmonic Generation Using EPICAPS

Efficient harmonic generation is possible with EPICAPS because of their high cutoff frequency and breakdown voltage. Since EPICAP junction capacitance varies inversely with the square root of the breakdown voltage, harmonic generator performance can be accurately predicted from various idealized models. Equation 10 gives the level of maximum input power for the EPICAP and equation 11 gives the relationships governing EPICAP circuit efficiency. In these equations, adequate heat sinking has been assumed.

$$P_{in(max)} = \frac{M(BV_R + \phi)^2}{R_S} \; \frac{f_{in}}{f_{co}} \qquad (10)$$

M(x2) = 0.0285; M(x3) = 0.0241; M(x4) = 0.196

$$\text{Eff} = 1 - N \; \frac{f_{out}}{f_{co}} \qquad (11)$$

N(x2) = 20.8; N(x3) = 34.8; N(x4) = 62.5

M and N are Constants

2N... & 3N... JEDEC REGISTERED DEVICE SPECIFICATIONS

TRANSISTORS
- Amplifier
- Chopper
- Light Sensitive
- Multiple Device
- Power
- Switching
- Unijunction

THYRISTORS & TRIGGERS

2N-NUMBERED DEVICES for MILITARY APPLICATIONS

The following tables list devices that comply with military specifications.

SWITCHING AND HIGH FREQUENCY TRANSISTORS

MIL-S-19500	
JAN 2N499	/72
JAN 2N499A	/72
JAN 2N501A	/62
JAN 2N502A	/112
JAN 2N502B	/112
JAN 2N559	/152
JAN 2N703	/153
JAN 2N705	/86
JAN 2N706	/120
†JAN 2N708	/312
†JAN 2N718A	/181
†JAN 2N914	/373
JAN 2N869A	/283
JAN 2N916	/271
†JAN 2N929	/253
†JAN 2N930	/253
JAN 2N962	/258
JAN 2N964	/258
JAN 2N1131	/177
JAN 2N1132	/177
†JAN 2N1613	/181
†JAN 2N2218	/251
†JAN 2N2218A	/251
†JAN 2N2219	/251
†JAN 2N2219A	/251
†JAN 2N2221	/255
†JAN 2N2221A	/255
†JAN 2N2222	/255
†JAN 2N2222A	/255
†JAN 2N2369A	/317
†JAN 2N2481	/268
JAN 2N2708	/302
†JAN 2N2857	/343
†JAN 2N2904	/290
†JAN 2N2904A	/290
†JAN 2N2905	/290
†JAN 2N2905A	/290
†JAN 2N2906	/291
†JAN 2N2906A	/291
†JAN 2N2907	/291
†JAN 2N2907A	/291
†JAN 2N3250A	/323
†JAN 2N3251A	/323
JAN 2N3253	/347
JAN 2N3444	/347
JAN 2N3449	/338
JAN 2N3467	/348
JAN 2N3468	/348
†JAN 2N3485A	/392
†JAN 2N3486A	/392
†JAN 2N3498	/366
†JAN 2N3499	/366
†JAN 2N3500	/366
†JAN 2N3501	/366
JAN 2N3506	/349
JAN 2N3507	/349
†JAN 2N3634	/357
†JAN 2N3635	/357
†JAN 2N3636	/357
†JAN 2N3637	/357

POWER TRANSISTORS

MIL-S-19500	
JAN 2N174A	/13
JAN 2N297A	/36
JAN 2N665	/58
JAN 2N1011	/67
JAN 2N1120	/68
JAN 2N1165	/178
JAN 2N1358	/122
JAN 2N1412	/76
JAN 2N1412A	/76
JAN 2N1549A	/332
JAN 2N1550A	/332
JAN 2N1551A	/332
JAN 2N1552A	/332
JAN 2N1553A	/331
JAN 2N1554A	/331
JAN 2N1555A	/331
JAN 2N1556A	/331
JAN 2N1557A	/330
JAN 2N1558A	/330
JAN 2N1559A	/330
JAN 2N1560A	/330
JAN 2N2079A	/340
JAN 2N2528	/309
JAN 2N2834	/310

MILLIWATT TRANSISTORS

MIL-S-19500	
JAN 2N331	/4
JAN 2N398A	/174
JAN 2N465	/49
JAN 2N466	/51
JAN 2N467	/49
JAN 2N526	/60
JAN 2N650A	/175
JAN 2N651A	/175
JAN 2N652A	/175
JAN 2N1008B	/196

MIL-T-19500	
JAN 2N461	/45

RF TRANSISTORS

MIL-S-19500	
JAN 2N700A	/123
†JAN 2N918	/301
JAN 2N1142	/87
JAN 2N1195	/71
JAN 2N2273	/244
JAN 2N3127	/346
†JAN 2N3375	/341
†JAN 2N3553	/341

MULTIPLE DEVICES

MIL-S-19500	
†JAN 2N2060	/270
JAN 2N3810	/336
JAN 2N3811	/336

SILICON CONTROLLED RECTIFIERS

MIL- S -19500	
JAN 2N4199	/372
JAN 2N4200	/372
JAN 2N4201	/372
JAN 2N4202	/372
JAN 2N4203	/372
JAN 2N4204	/372

UNIJUNCTION

MIL- S -19500	
†JAN 2N4948	/388
†JAN 2N4949	/388

†Recommended TX Devices.

2N173 (GERMANIUM)

For Specifications, See 2N277 Data.

2N174 (GERMANIUM)
2N1100
2N1358,A

CASE 5
(TO-36)

PNP germanium power transistors. Power dissipation and junction temperature ratings exceed those of EIA registration.

MAXIMUM RATINGS

Rating	Symbol	2N174	2N1100	2N1358	Unit
Collector-Base Voltage	V_{CB}	80	100	80	Vdc
Emitter-Base Voltage	V_{EB}	60	80	60	Vdc
Emitter Current (Continuous)	I_E	15	15	15	Amp
Base Current (Continuous)	I_B	4.0	4.0	4.0	Amp
Junction and Storage Temperature	T_J, T_{stg}	-65 to +110			°C
Thermal Resistance, Junction to Case	θ_{JC}	0.5			°C/W

2N174, 2N1100, 2N1358 (continued)

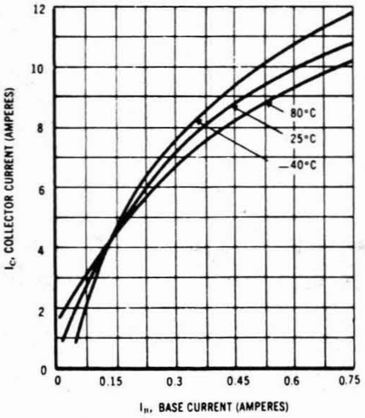
ELECTRICAL CHARACTERISTICS

Characteristic		Symbol	Minimum	Typical	Maximum	Unit
Collector-Base Cutoff Current		I_{CBO}				µA
	2N174		-	100	-	
(V_{CB} = 2 volts)	2N1100		-	100	-	
	2N1358		-	100	200	
Collector-Base Cutoff Current		I_{CBO}				mA
(V_{EB} = 1.5 volts, V_{CB} = 80 volts)	2N174		-	2.0	8.0	
100	2N1100		-	2.0	8.0	
80	2N1358		-	2.0	8.0	
Emitter-Base Cutoff Current		I_{EBO}				mA
(V_{EB} = 60 volts)	2N174		-	1.0	8.0	
80	2N1100		-	1.0	8.0	
60	2N1358		-	1.0	8.0	
Collector-Base Cutoff Current		I_{CBO}				mA
(V_{CB} = 80 volts, 71°C)	2N174		-	-	15	
100	2N1100		-	-	15	
60	2N1358		-	4.0	6.0	
Emitter-Base Cutoff Current		I_{EBO}				mA
(V_{EB} = 30 volts, 71°C)	2N1358		-	4.0	6.0	
Collector-Emitter Voltage		BV_{CES}*				Vdc
(I_C = 300 mA, V_{EB} = 0)	2N174		70	-	-	
	2N1100		80	-	-	
	2N1358		70	-	-	
Collector-Emitter Voltage		BV_{CEO}*				Vdc
(I_C = 1.0 amp, I_B = 0)	2N174		55	-	-	
1.0 amp, I_B = 0	2N1100		65	-	-	
300 mA, I_B = 0	2N1358		40	-	-	
Floating Potential		V_{EBF}				volt
(I_E = 0, V_{CB} = 80 volts)	2N174		-	-	1.0	
100	2N1100		-	-	1.0	
80	2N1358		-	0.15	1.0	
Current Gain		h_{FE}				-
(I_C = 1.2 amp, V_{CB} = 2 volts)	2N1358		40	55	80	
(I_C = 5 amp, V_{CB} = 2 volts)	2N174		25	-	50	
	2N1100		25	-	50	
	2N1358		25	35	-	
(I_C = 12 amp, V_{CB} = 2 volts)	2N174		-	20	-	
	2N1100		-	20	-	
Base-Emitter Voltage		V_{BE}				Vdc
(I_C = 1.2 amp, V_{CB} = 2 volts)	2N1358		-	0.35	0.5	
(I_C = 5 amp, V_{CB} = 2 volts)	2N174		-	0.65	0.9	
	2N1100		-	0.65	0.9	
	2N1358		-	0.65	0.9	
Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 12 amp, I_B = 2 amp)	2N174		-	0.3	0.9	
	2N1100		-	0.3	0.7	
	2N1358		-	0.3	0.7	
Common-Emitter Cutoff Frequency		$f_{\alpha e}$				kHz
(I_C = 5 amp, V_{CE} = 6 volts)	2N174		-	10	-	
	2N1100					
Common-Base Cutoff Frequency		$f_{\alpha b}$				kHz
(I_E = 1 amp, V_{CB} = 12 volts)	2N1358		100	-	-	
Rise Time ("on" I_C = 12 Adc, I_B = 2 Adc, V_{CE} = 12 volts)		t_r	-	15	-	µs
Fall Time ("off" I_C = 0, V_{EB} = -6 volts, R_{EB} = 10 ohms)		t_f	-	15	-	µs

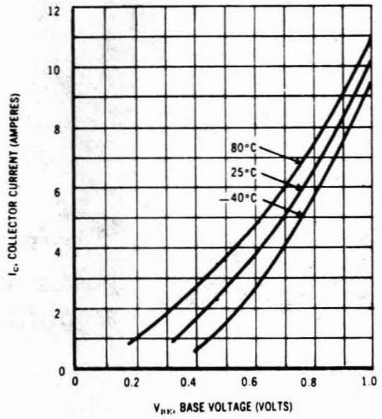
* In order to avoid excessive heating of the collector junction, perform test by the sweep method.

2N174, 2N1100, 2N1358 (continued)

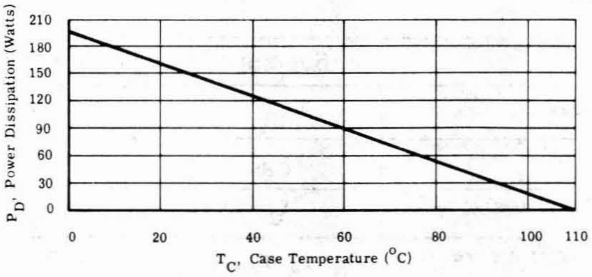
CURRENT TRANSFER CHARACTERISTICS



TRANSCONDUCTANCE CHARACTERISTICS



POWER-TEMPERATURE DERATING CURVE

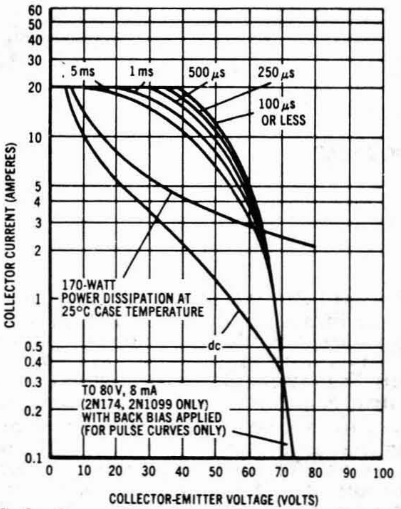


The maximum continuous power is related to maximum junction temperature by the thermal resistance factor.

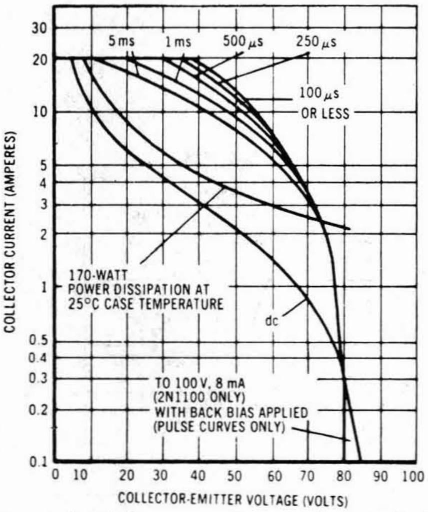
This curve has a value of 150 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that:

$$\text{allowable } P_D = \frac{110° - T_C}{0.5}$$

2N174 AND 1358

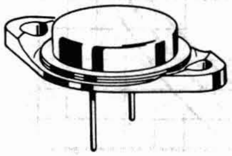


2N1100



The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N176 (GERMANIUM)
2N669



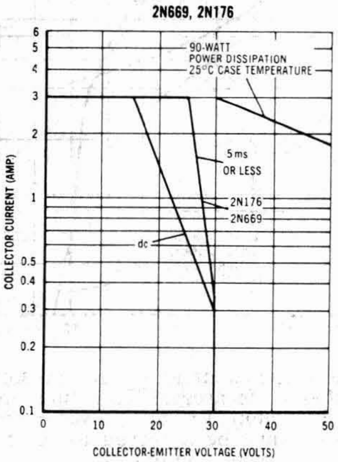
CASE 11
(TO-3)

PNP germanium power transistors for economical power switching circuits and commercial grade power amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CES}	30	Vdc
Collector Current (Continuous)	I_C	3.0	Amp
Storage and Junction Temperature	T_J, T_{stg}	−65 to +100	°C
Total Device Dissipation (At 25°C Case Temperature)	P_D	90	Watts
Thermal Resistance (Junction to Case)	θ_{JC}	0.8	°C/W

SAFE OPERATING AREAS



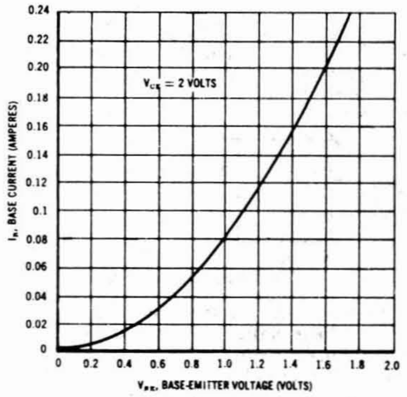
The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N176, 2N669 (continued)

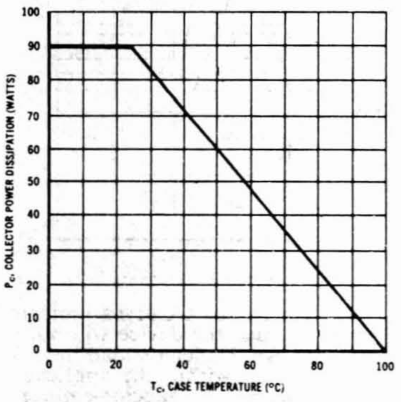
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Minimum	Typical	Maximum	Unit
Collector-Base Cutoff Current V_{CB} = 30 V, I_E = 0 V_{CB} = 2.0 V, I_E = 0 V_{CB} = 30 V, I_E = 0, T_C = 90°C	I_{CBO}	— — —	— 50 —	3.0 — 20	mA μA mA
Emitter-Base Cutoff Current V_{EB} = 10 V, I_C = 0	I_{EBO}	—	—	2.0	mA
Collector-Emitter Breakdown Voltage I_C = 330 mA, R_{BE} = 10 Ohms 2N176 2N669	BV_{CER} BV_{CES}	30 30	— —	— —	Vdc
Collector-Emitter Saturation Voltage I_C = 3 A, I_B = 300 mA	$V_{CE(SAT)}$	—	0.4	—	Vdc
DC Forward Current Transfer Ratio V_{CE} = 2.0 V, I_C = 0.5 A 2N176 2N669	h_{FE}	25 75	— —	— 250	—
Power Gain P_{out} = 2 Watts, V_{CE} = 12 V, I_C = 0.5 Amp, f = 1 kHz, R_S = 10 Ohms, R_L = 26.6 Ohms 2N176 2N669	G_{PE}	34 38	— —	37 —	dB
Total Harmonic Distortion (under same conditions of power gain)		—	—	5.0	%
Small-Signal Current Gain Cutoff Frequency V_{CE} = 12 V, I_C = 0.5 Amp, f = 1 kHz ref 2N176 2N669	$f_{\alpha e}$	4.0 3.0	7.0 5.0	— —	kHz
Small-Signal Forward-Current Transfer Ratio V_{CE} = 2.0 V, I_C = 0.5 Amp, f = 1 kHz 2N176 2N669	h_{fe}	— —	45 90	— —	—
Small-Signal Input Impedance V_{CE} = 2.0 V, I_C = 0.5 Amp, f = 1 kHz 2N176 2N669	h_{ie}	7.0 10	— —	25 50	Ohms

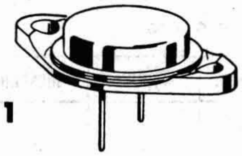
INPUT CURRENT versus EMITTER DRIVE VOLTAGE
(Both Types)



POWER-TEMPERATURE DERATING CURVE
(Both Types)



2N178 (GERMANIUM)
2N554
2N555



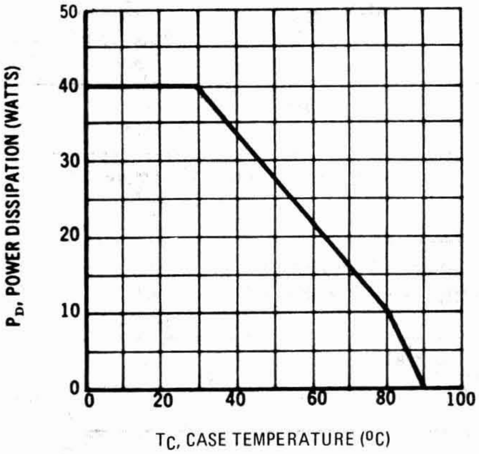
CASE 11
(TO-3)

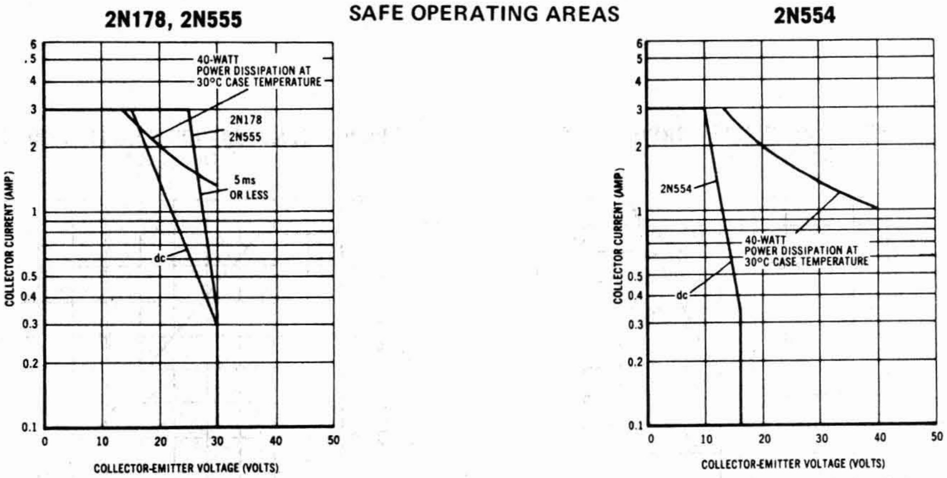
PNP germanium power transistor for non-critical power amplifier and power switching applications requiring economical components.

MAXIMUM RATINGS

Rating	Symbol	2N178	2N554	2N555	Unit
Collector-Emitter Voltage	V_{CER}	30	16	30	Vdc
Collector-Base Voltage	V_{CB}	30	15	30	Vdc
Emitter-Base Voltage	V_{EB}	20	15	15	Vdc
Collector Current	I_C	3.0			Adc
Total Device Dissipation @ T_C = 80°C	P_D	10			Watts
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-40 to +90			°C

POWER-TEMPERATURE DERATING CURVE





SAFE OPERATING AREAS

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short.

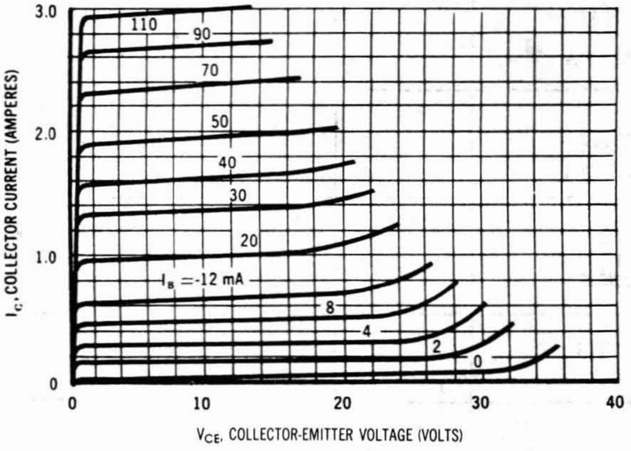
(Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N178, 2N554, 2N555 (continued)

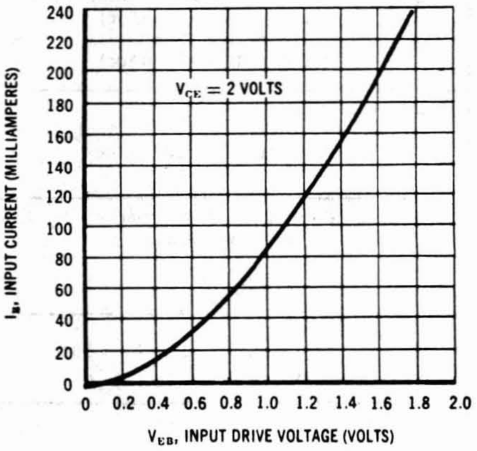
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 330 mAdc, R_{BE} = 10Ω)	2N178	BV_{CER}	30	-	-	Vdc
	2N554		16	-	-	
	2N555		30	-	-	
Collector-Base Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)	2N178	I_{CBO}	-	0.05	-	mA
(V_{VB} = 30 Vdc, I_E = 0)	2N178		-	-	3.0	
(V_{CB} = 15 Vdc, I_E = 0)	2N554		-	-	10.0	
(V_{CB} = 30 Vdc, I_E = 0)	2N555		-	-	20.0	
(V_{CB} = 30 Vdc, I_E = 0, T_C = 90°C)	2N178		-	-	20.0	
Emitter-Base Cutoff Current (V_{BE} = 10 Vdc, I_C = 0)	2N178	I_{EBO}	-	-	2.0	mA
ON CHARACTERISTICS						
DC Current Gain (I_C = 0.5 Adc, V_{CE} = 2.0 Vdc)	2N178	h_{FE}	15	-	45	-
	2N554		-	50	-	
	2N555		-	50		
Collector-Emitter Saturation Voltage (I_C = 3.0 Adc, I_B = 300 mAdc)		$V_{CE(sat)}$	-	0.6	-	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Common-Emitter Cutoff Frequency (I_C = 0.5 Adc, V_{CE} = 12 Vdc, f = 1.0 kHz ref)	2N178	$f_{\alpha e}$	5.0	-	-	kHz
	2N554		-	6.0	-	
	2N555		-	6.0	-	
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 2.0 Vdc, f = 1.0 kHz ref)	2N178	h_{fe}	-	30	-	-
	2N554		-	55	-	
	2N555		-	55	-	
Input Impedance (I_C = 0.5 Adc, V_{CE} = 2.0 Vdc, f = 1.0 kHz)	2N178	h_{ie}	8.0	25	-	Ohms
	2N554		-	25	-	
	2N555		-	25	-	
FUNCTIONAL TESTS						
Power Gain (V_{CE} = 12 Vdc, I_C = 0.5 Adc, P_{out} = 2.0 Watts, f = 1.0 kHz, R_S = 10 Ohms, R_L = 26.6 Ohms)	2N178	G_{PE}	28	-	33	dB
	2N554		20	35	-	
	2N555		25	35	-	
Total Harmonic Distortion (Under same conditions as power gain)	2N178		-	-	5.0	%

COLLECTOR CHARACTERISTICS

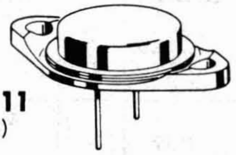


INPUT CURRENT versus INPUT DRIVE VOLTAGE



2N242 (GERMANIUM)

2N307, A



CASE 11
(TO-3)

PNP germanium power transistors for general purpose power amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N242	2N307, 307A	Unit
Collector-Base Voltage	V_{CB}	45	35	Volts
Collector-Emitter Voltage (R_{BE} = 30 Ω)	V_{CER}	45	—	Volts
Collector-Emitter Voltage	V_{CEO}	—	35	Volts
Emitter-Base Voltage	V_{EB}	—	10	Volts
Collector Current	I_C	5.0	5.0	Amp
Junction Temperature Range	T_J	-65 to + 110	-65 to +110	°C
Collector Dissipation (at T_C = 25°C)	P_D	106	106	Watts

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 2 Vdc)	2N307		—	0.5	
(V_{CB} = 25 Vdc)	2N307		—	5.0	
	2N307A		—	2.0	
(V_{CB} = 1 Vdc, I_E = 0, T_C = 85°C)	2N242		—	5.0	
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = 10 Vdc)			—	2.0	
Collector-Emitter Cutoff Current		I_{CER}			mAdc
(V_{CE} = 45 Vdc, R_{BE} = 30 Ω)	2N242		—	5.0	
(V_{CE} = 25 Vdc, R_{BE} = 30 Ω)	2N242		—	1.0	
(V_{CE} = 35 Vdc, R_{BE} = 30 Ω)	2N307		—	15	
	2N307A		—	7.0	
Base-Emitter Voltage		V_{BE}			Vdc
(V_{CE} = 1.5 Vdc, I_C = 1.0 Adc)	2N242		0.3	0.8	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 2.0 Adc, I_B = 200 mAdc)	2N242		—	0.8	
(I_C = 0.2 Adc, I_B = 20 mAdc)	2N307		—	1.0	
(I_C = 1.0 Adc, I_B = 100 mAdc)	2N307A		—	0.8	
DC Current Gain		h_{FE}			—
(V_{CE} = 12 Vdc, I_C = 500 mAdc)	2N242		30	120	
(V_{CE} = 1 Vdc, I_C = 200 mAdc)	2N307		20	—	
	2N307A		30	—	
Common Emitter Cutoff Frequency		$f_{\alpha e}$			kHz
(V_{CE} = 12 V, I_C = 0.5 A)	2N242		5.0	—	
	2N307A		3.5	—	
(V_{CE} = 6 V, I_C = 1 A)	2N307		3.0	—	
Power Gain		G_e			dB
(I_C = 0.5 A, V_{CE} = -14 V, R_L = 30 Ω, R_g = 10 Ω)	2N242		30		

2N277 (GERMANIUM)
2N278
2N173
2N1099

CASE 5
(TO-36)

PNP germanium power transistors for general purpose power amplifier and switching applications. Power and temperature ratings exceed EIA registration.

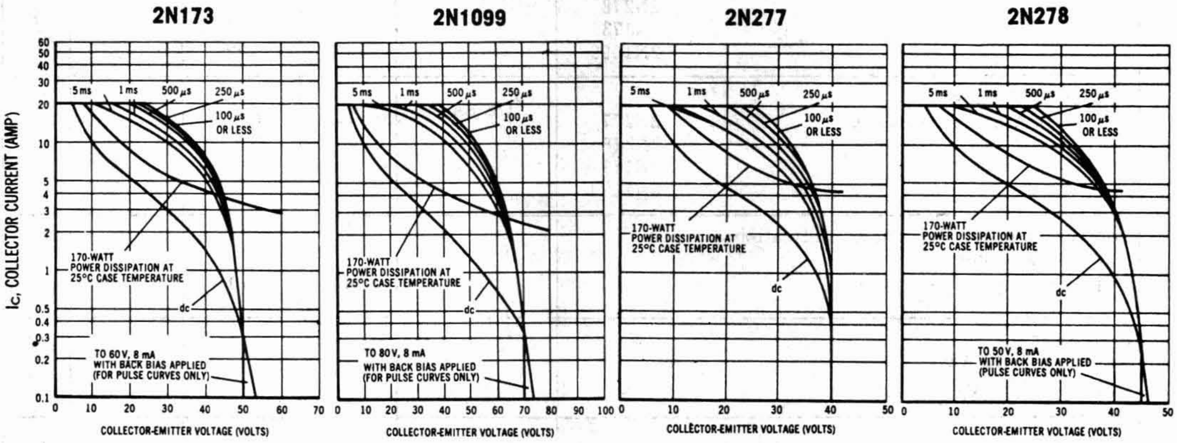
MAXIMUM RATINGS

Rating	Symbol	2N277	2N278	2N173	2N1099	Unit
Collector-Base Voltage	V_{CB}	40	50	60	80	Vdc
Emitter-Base Voltage	V_{EB}	20	30	40	40	Vdc
Emitter Current-Continuous	I_E	15				Adc
Base Current	I_B	4.0				Adc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	170 2.0				Watts $W/^oC$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110				^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.5	$^oC/W$

SAFE OPERATING AREAS



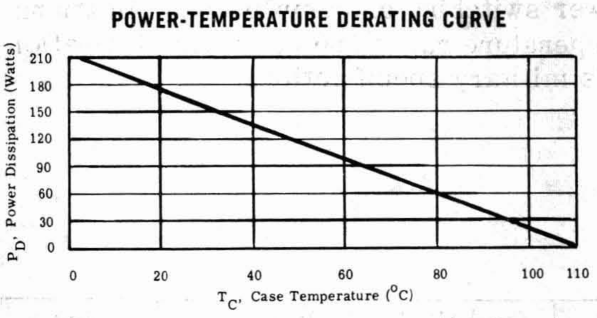
The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N277, 2N278, 2N173, 2N1099 (continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic		Symbol	Minimum	Typical	Maximum	Unit
Collector-Base Cutoff Current		I_{CBO}				μA
V_{CBO} = 2 V			—	100	—	
Collector-Base Cutoff Current		I_{CBX}				mA
V_{EB} = 1.5 V, V_{CB} = 40 V	2N277		—	2.0	8.0	
50	2N278		—	2.0	8.0	
60	2N173		—	2.0	8.0	
80	2N1099		—	2.0	8.0	
Emitter-Base Cutoff Current		I_{EBO}				mA
V_{EBO} = 20 V	2N277		—	1.0	8.0	
30	2N278		—	1.0	8.0	
40	2N173		—	1.0	8.0	
40	2N1099		—	1.0	8.0	
Collector-Base Cutoff Current		I_{CBO}				mA
V_{CBO} = 40 V, 71°C	2N277		—	—	15	
50	2N278		—	—	15	
60	2N173		—	—	15	
80	2N1099		—	—	15	
Collector-Emitter Voltage		BV_{CES}*				Vdc
I_C = 300 mA, V_{EB} = 0	2N277		40	—	—	
	2N278		45	—	—	
	2N173		50	—	—	
	2N1099		70	—	—	
Collector-Emitter Voltage		BV_{CEO}*				Vdc
I_C = 1 Amp, I_B = 0	2N277		25	—	—	
	2N278		30	—	—	
	2N173		45	—	—	
	2N1099		55	—	—	
Floating Potential		V_{fl}				volt
I_E = 0, V_{CB} = 40 V	2N277		—	0.15	1.0	
50	2N278		—	0.15	1.0	
60	2N173		—	0.15	1.0	
80	2N1099		—	0.15	1.0	
Current Gain		h_{FE}				—
I_C = 5 Amp, V_{CB} = 2 V			35	—	70	
I_C = 12 Amp, V_{CB} = 2 V			—	25	—	
Base-Emitter Voltage		V_{BE}				Vdc
I_C = 5 Amp, V_{CB} = 2 V	2N277		—	0.65	—	
	2N278		—	0.65	—	
	2N173		—	0.65	—	
	2N1099		—	0.65	0.9	
Saturation Voltage		$V_{CE(SAT)}$				Vdc
I_C = 12 Amp, I_B = 2 Amp	2N277		—	0.3	—	
	2N278		—	0.3	1.0	
	2N173		—	0.3	1.0	
	2N1099		—	0.3	0.7	
Common-Emitter Current Amplification Cutoff Frequency		$f_{\alpha e}$				kHz
I_C = 5 Amp, V_{CE} = 6 V			0.3	10	—	
Rise Time		t_r				μs
"on" I_C = 12 Adc, I_B = 2 Adc, V_{CE} = 12 V			—	15	—	
Fall Time		t_f				μs
"off" I_C = 0, V_{EB} = 6 V, R_{EB} = 10 Ohms			—	15	—	

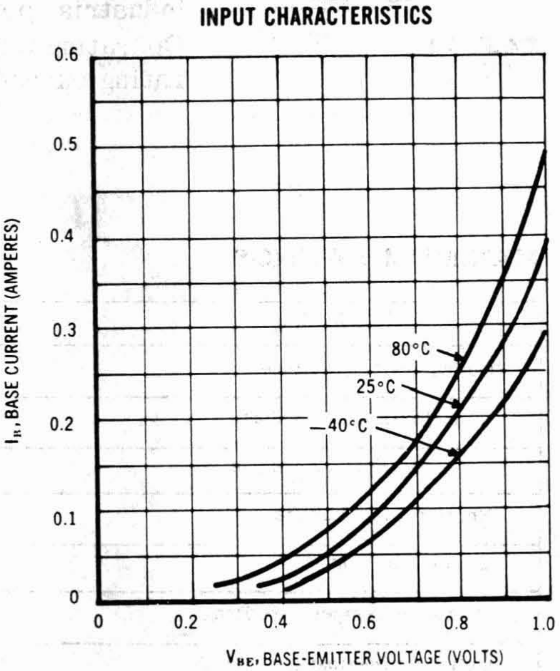
* To avoid excessive heating of the collector junction, perform these tests with the sweep method.

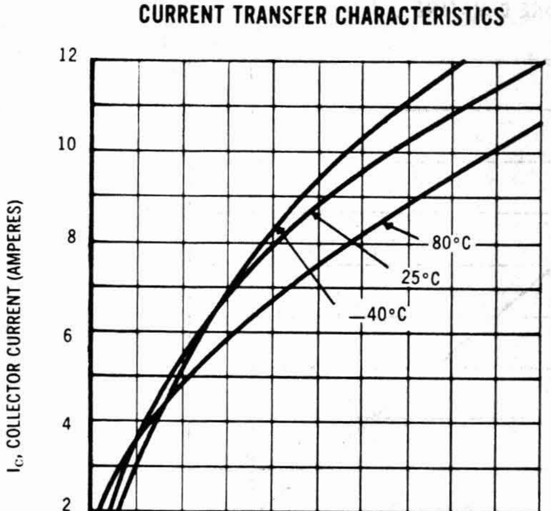

POWER-TEMPERATURE DERATING CURVE

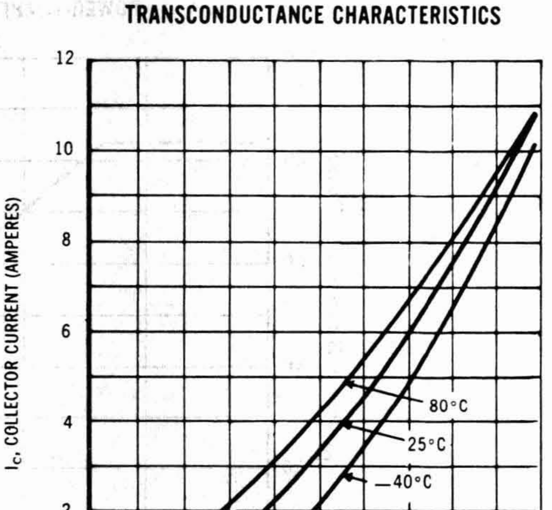
The maximum continuous power is related to maximum junction temperature by the thermal resistance factor.

This curve has a value of 150 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that:

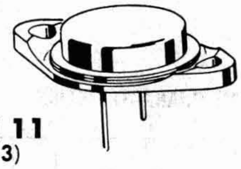
$$\text{allowable } P_D = \frac{110° - T_C}{0.5}$$


INPUT CHARACTERISTICS


CURRENT TRANSFER CHARACTERISTICS


TRANSCONDUCTANCE CHARACTERISTICS

2N297A (GERMANIUM)



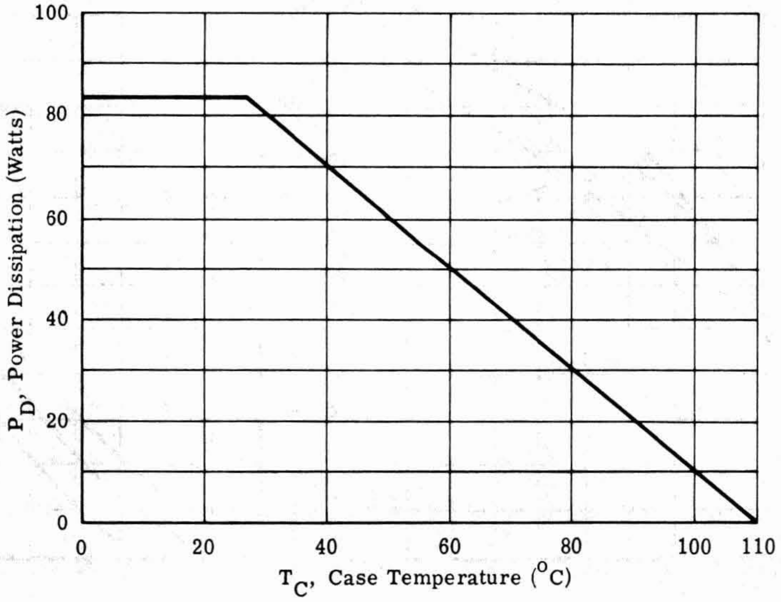
CASE 11
(TO-3)

PNP germanium power transistor for military and industrial power switching and amplifier applications. Operating temperature range and collector dissipation rating exceeds military specifications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CES}	50	Vdc
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Emitter-Base Voltage	V_{EB}	40	Vdc
Emitter Current	I_E	5.0	Amp
Operating Temperature Range	T_J	−65 to +110	°C
Collector Dissipation at 25°C Case Temperature (θ_{JC} = 1°C/W max)	P_D	85	Watts

POWER-TEMPERATURE DERATING CURVE



2N297 A (continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise specified

Characteristic	Symbol	Minimum	Maximum	Unit
DC Current Transfer Ratio V_{CE} = 2 V I_C = 0.5 Adc	h_{FE}	40	100	—
DC Current Transfer Ratio V_{CE} = 2 V I_C = 2.0 Adc	h_{FE}	20	—	—
Small-Signal Current Transfer Ratio Cutoff Frequency V_{CE} = 14 Vdc I_C = 0.5 Amp	$f_{\alpha e}$	5.0	—	kHz
Emitter-Base Cutoff Current V_{EB} = 40 Vdc I_C = 0	I_{EBO}	—	3.0	mAdc
Collector-Base Cutoff Current V_{CB} = 2 Vdc I_E = 0	I_{CBO}	—	200	μAdc
Collector-Base Cutoff Current V_{CB} = 60 Vdc I_E = 0	I_{CBO}	—	3.0	mAdc
Base Current V_{CE} = 2 Vdc I_C = 0.5 Adc	I_B	5.0	12.5	mAdc
Base Current V_{CE} = 2 Vdc I_C = 2 Adc	I_B	—	100	mAdc
Emitter-Base Voltage V_{CE} = 2 Vdc I_C = 2 Adc	V_{EB}	—	1.5	Vdc
Floating Potential V_{CB} = 60 Vdc (Voltmeter input resistance = 10 Megohm min)	V_{fl}		0.18	Vdc
Collector-Emitter Saturation Voltage I_C = 2 Adc I_B = 200 mAdc	$V_{CE(SAT)}$		1.0	Vdc
Collector-Emitter Voltage I_C = 300 mAdc I_B = 0	BV_{CEO}	40	—	Vdc
Collector-Emitter Voltage I_C = 300 mAdc V_{EB} = 0	BV_{CES}	50	—	Vdc
High-Temperature Operation T_C = +71°C min Collector Cutoff Current V_{CB} = 30 Vdc I_E = 0	I_{CBO}	—	6.0	mAdc

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2N307 (GERMANIUM)

2N307 A

For Specifications, See 2N242 Data.

2N319 thru 2N321 (Germanium)

CASE 31(1)
(TO-5)

Base connected to case

PNP germanium transistors for audio amplifier and low-frequency switching applications.

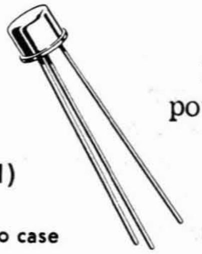
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Vdc
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	500	mAdc
Junction and Storage Temperature	T_J, T_{stg}	-65 to + 100	°C
Power Dissipation at 25°C Ambient	P_D	225	mW

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
Collector Cutoff Current V_{CB} = -25 Vdc, I_E = 0	I_{CBO}	-	16	μAdc
Emitter Cutoff Current V_{EB} = - 15 Vdc, I_C = 0	I_{EBO}	-	10	μAdc
Collector-Emitter Voltage I_C = 0.6 mAdc, R_{BE} = 10 K	BV_{CER}	20	-	Vdc
DC Current Gain I_C = 20 mAdc, V_{CE} = -1 Vdc	h_{FE}			-
2N319		25	42	
2N320		34	65	
2N321		53	121	
DC Current Gain I_C = 100 mAdc, V_{CE} = -1 Vdc	h_{FE}			-
2N319		23	-	
2N320		30	-	
2N321		47	-	
Base Input Voltage V_{CE} = -1 Vdc, I_C = 20 mAdc	V_{BE}	180	320	mVdc
Output Capacitance; Input AC Open Circuit V_{CB} = -5 Vdc, I_E = 1 mAdc, f = 1 MHz	C_{ob}	-	35	pF
Frequency Cutoff V_{CB} = -5 Vdc, I_E = 1 mAdc	$f_{\alpha b}$			MHz
2N319		1.0	-	
2N320		1.5	-	
2N321		2.0	-	

2N322 thru 2N324 (GERMANIUM)
2N508



CASE 31(1)
(TO-5)
Base connected to case

PNP germanium transistors for audio driver and low power output service in entertainment equipment.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	18	Vdc
Collector-Emitter Voltage	V_{CEO}	18	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	500	mAdc
Junction and Storage Temperature	T_J, T_{stg}	-65 to + 100	°C
Power Dissipation at 25°C Ambient	P_D	225	mW

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
Collector Cutoff Current V_{CB} = -16 Vdc, I_E = 0	I_{CBO}	—	16	μAdc
Emitter Cutoff Current V_{EB} = -3 Vdc, I_C = 0	I_{EBO}	—	16	μAdc
Collector-Emitter Voltage I_C = 0.6 mAdc, R_{BE} = 5 K	BV_{CER}	18	—	Vdc
DC Current Gain V_{CE} = -1 Vdc, I_C = 20 mAdc	h_{FE}			—
2N322		34	65	
2N323		53	121	
2N324		72	198	
2N508		99	198	
Base Input Voltage V_{CE} = -1 Vdc, I_C = 20 mAdc	V_{BE}	180	320	mVdc
Output Capacitance; Input AC Open Circuit V_{CB} = -5 Vdc, I_E = 1 mAdc, f = 1 MHz	C_{ob}	—	35	pF
Frequency Cutoff V_{CB} = -5 Vdc, I_E = 1 mAdc	$f_{\alpha b}$			MHz
2N322		1.0	—	
2N323		1.5	—	
2N324		2.0	—	
2N508		2.5	—	

2N331 (Germanium)

CASE 31(1)
(TO-5)
All leads isolated

PNP germanium transistor for audio range amplifier and switching service in military equipment. Have collector dissipation and storage temperature ratings significantly higher than those of the military specification (see maximum ratings table below).

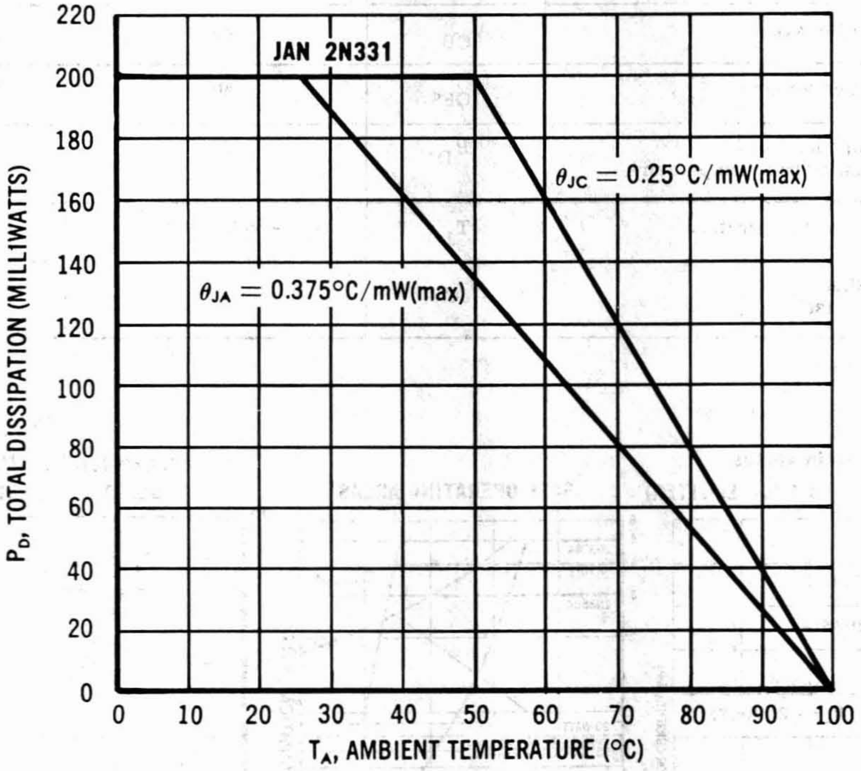
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	30	Volts
Emitter-Base Voltage	V_{EB}	12	Volts
Storage Temperature	T_{stg}	-65 to + 85	°C
Storage Temperature	T_{stg}	-65 to + 100	°C
Collector Dissipation at T_A = 25°C (MIL-S-19500/4C (Derate 1.25 mW/°C above 25°C)	P_D	75	mW
Collector Dissipation at T_A = 25°C (JAN 2N331) (Derate 2.67 mW/°C above 25°C)	P_D	200	mW

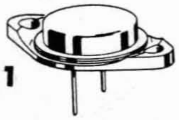
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
Emitter Cutoff Current (V_{EB} = -12 Vdc, I_C = 0)	I_{EBO}	—	10	μAdc
Collector Cutoff Current (V_{CB} = -30 Vdc, I_E = 0)	I_{CBO}	—	10	μAdc
Small-Signal Open-Circuit Output Admittance (V_{CB} = -6 Vdc, I_E = 1.0 mAdc, f = 1 kHz)	h_{ob}	—	1.0	μmho
Small-Signal Short-Circuit Input Impedance (V_{CB} = -6 Vdc, I_E = 1.0 mAdc, f = 1 kHz)	h_{ib}	—	50	Ohms
Small-Signal Short-Circuit Forward-Current Transfer Ratio (V_{CE} = -6 Vdc, I_C = 1.0 mAdc, f = 1 kHz)	h_{fe}	30	70	—
Small-Signal Short-Circuit Forward-Current Transfer Ratio Cutoff Frequency (V_{CB} = -6 Vdc, I_E = 1 mAdc)	$f_{\alpha b}$	0.4	—	MHz
Output Capacitance (V_{CB} = -6 Vdc, I_E = 1 mAdc)	C_{ob}	—	50	pF
Noise Figure (V_{CB} = -6 Vdc, I_E = 1 mAdc, R_S = 1000 ohms, f = 1 kHz , f=Δ1 Hz)	NF	—	20	dB

POWER-TEMPERATURE DERATING CURVE



2N350A (GERMANIUM)
2N351A
2N376A

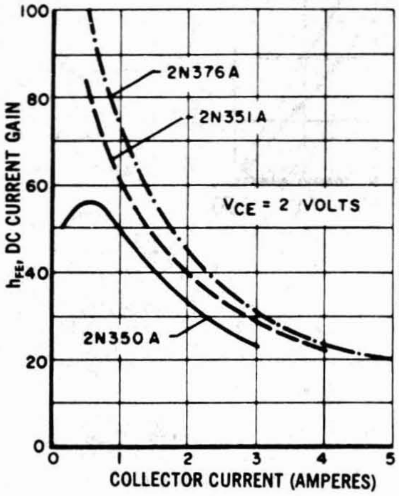


CASE 11
(TO-3)

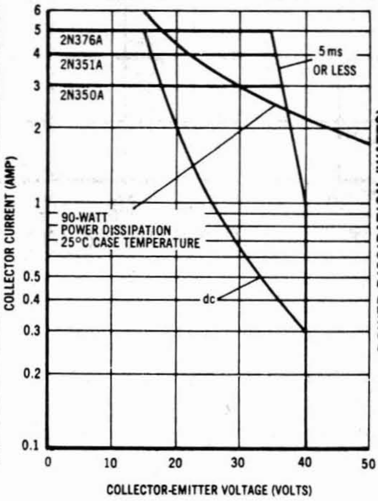
PNP germanium power transistors for economical power switching applications and for power amplifiers requiring up to 4 watts of output power at relatively low distortion.

MAXIMUM RATINGS

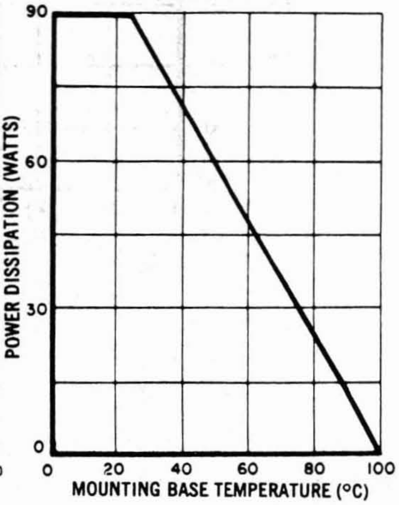
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	50	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector Dissipation at 25°C mounting base temperature	P_D	90	Watts
Collector Junction Temperature	T_J	−65 to +100	°C
Thermal Resistance (Junction to Case)	θ_{JC}	0.8	°C/W



CURRENT GAIN versus COLLECTOR CURRENT (COMMON EMITTER)



SAFE OPERATING AREAS



POWER TEMPERATURE DERATING CURVE

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N350A, 2N351A, 2N376A (continued)

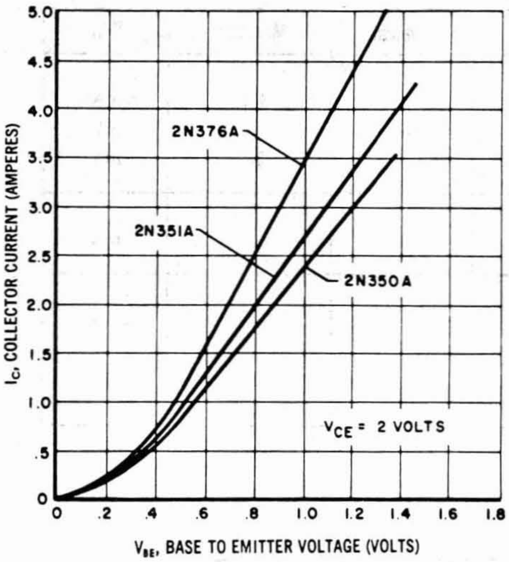
ELECTRICAL CHARACTERISTICS (at mounting base temperature 25°C ± 3°C.)

GENERAL	Symbol	Minimum	Typical	Maximum	Unit
Collector Cutoff Current $V_{CB} = 30$ V $V_{CB} = 2$ V $V_{CB} = 30$ V, $T = 100°C$	I_{CBO}	 — — —	 — 50 —	 3.0 — 30	 mA μA mA
Emitter Cutoff Current $V_{EB} = 10$ V	I_{EBO}	—	—	2.0	mA
Collector Breakdown Voltage $I_C = 1$ A ($R_{BE} = 10\,\Omega$) $I_C = 330$ mA, $R_{BE} = 0$ (This test should be made under dynamic conditions only)	BV_{CES}	40	—	—	Vdc

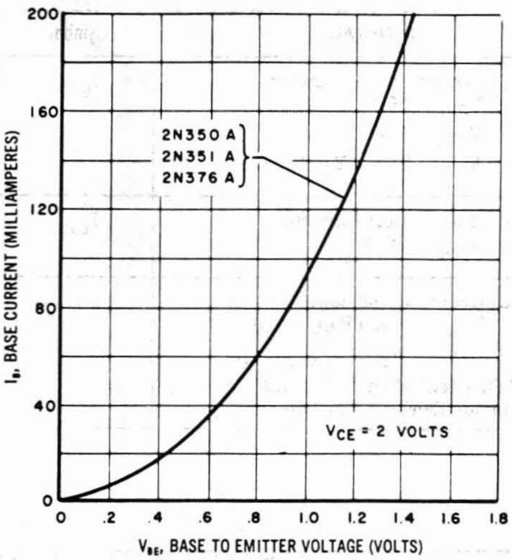
ELECTRICAL CHARACTERISTICS (at mounting base temperature 25°C ± 3°C.)

COMMON EMITTER		2N350A			2N351A			2N376A			Unit
	Sym	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Power Gain (± 0.5 db) $P_{out} = 4$ Watts, $V_{CE} = 12$ V, $I_C = 0.7$ A, f = 1 kHz	G_{PE}	30	—	33	32	—	35	34	—	37	dB
Total Harmonic Distortion under same conditions as power gain		—	—	7.0	—	—	7.0	—	—	7.0	%
DC Forward Current Gain $V_{CE} = 2$ V, $I_C = 0.7$ A	h_{FE}	20	—	60	25	—	90	35	—	120	
Current Gain Frequency Cutoff $V_{CE} = 12$ V, $I_C = 0.7$ A, f = 1 kHz ref	$f_{\alpha e}$	5.0	—	—	5.0	—	—	5.0	—	—	kHz
Small-Signal Forward Current Gain f = 1 kHz, $V_{CE} = 2$ V, $I_C = 0.7$ A	h_{fe}	—	30	—	—	45	—	—	60	—	
Small-Signal Input Impedance f = 1 kHz, $V_{CE} = 2$ V, $I_C = 0.7$ A	h_{ie}	5.0	—	17	6.0	—	20	7.0	—	25	Ohms
Collector Saturation Voltage $I_C = 3$ A, $I_B = 300$ mA	$V_{CE(SAT)}$	—	0.8	1.75	—	—	—	—	—	—	Vdc
Base-Emitter Voltage $I_C = 3$ A, $I_B = 300$ mA	V_{BE}	—	1.0	2.00	—	—	—	—	—	—	Vdc
Collector Saturation Voltage $I_C = 4$ A, $I_B = 400$ mA	$V_{CE(SAT)}$	—	—	—	—	0.8	1.75	—	—	—	Vdc
Base-Emitter Voltage $I_C = 4$ A, $I_B = 400$ mA	V_{BE}	—	—	—	—	1.0	2.00	—	—	—	Vdc
Collector Saturation Voltage $I_C = 5$ A, $I_B = 500$ mA	$V_{CE(SAT)}$	—	—	—	—	—	—	—	0.8	1.75	Vdc
Base-Emitter Voltage $I_C = 5$ A, $I_B = 500$ mA	V_{BE}	—	—	—	—	—	—	—	1.0	2.00	Vdc

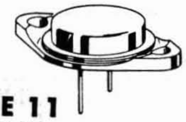
OUTPUT CURRENT versus EMITTER-DRIVE VOLTAGE



INPUT CURRENT versus EMITTER-DRIVE VOLTAGE



2N375 (GERMANIUM)
2N618
2N1359
2N1360
2N1362 thru 2N1365



CASE 11
(TO-3)

PNP germanium power transistors for general purpose switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N1359 2N1360	2N375 2N618	2N1362 2N1363	2N1364 2N1365	Unit
Collector-Emitter Voltage	V_{CES}	40	60	75	100	Vdc
Collector-Base Voltage	V_{CB}	50	80	100	120	Vdc
Emitter-Base Voltage	V_{EB}	25	40	50	60	Vdc
Collector Current-Continuous Peak	I_C	3.0 10				Adc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	106 1.25				Watts $W/^oC$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110				^oC

THERMAL CHARACTERISTICS

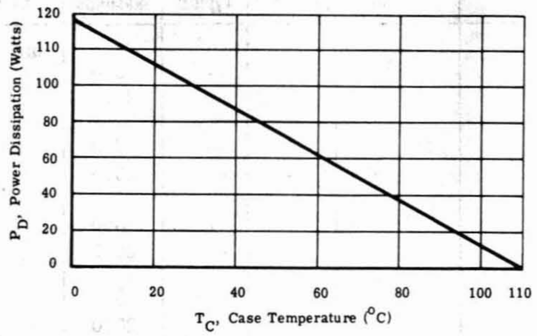
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	$^oC/W$

2N375, 2N618, 2N1359, 2N1360, 2N1362 thru 2N1365 (continued)

ELECTRICAL CHARACTERISTICS (At = 25°C unless otherwise noted)

Characteristic	Types	Symbol	Minimum	Typical	Maximum	Unit
Collector-Base Cutoff Current	2N1359, 2N1360	I_{CBO}				mA
(V_{CB} = 40 V, I_E = 0)			--	--	3.0	
(V_{CB} = 50 V, I_E = 0)			--	--	20.0	
(V_{CB} = 60 V, I_E = 0)	2N375, 2N618		--	--	3.0	
(V_{CB} = 80 V, I_E = 0)			--	--	20.0	
(V_{CB} = 75 V, I_E = 0)	2N1362, 2N1363		--	--	3.0	
(V_{CB} = 100 V, I_E = 0)			--	--	20.0	
(V_{CB} = 100 V, I_E = 0)	2N1364, 2N1365		--	--	3.0	
(V_{CB} = 120 V, I_E = 0)			--	--	20.0	
Collector-Base Cutoff Current at Tc = +90°C V_{CB} = 1/2 BV_{CES} rating		I_{CBO}	--	--	20	mA
Emitter-Base Cutoff Current (V_{EB} = 12 V, I_C = 0)		I_{EBO}	--	--	0.5	mA
(V_{EB} = 25 V, I_C = 0)	2N1359, 2N1360		--	--	20	
(V_{EB} = 50 V, I_C = 0)	2N1362, 2N1363		--	--	20	
(V_{EB} = 60 V, I_C = 0)	2N1364, 2N1365		--	--	20	
Collector-Emitter Breakdown Voltage						Vdc
I_C = 500 mA, V_{EB} = 0)	2N1359, 2N1360	BV_{CES}	40	--	--	
	2N375, 2N618		60	--	--	
	2N1362, 2N1363		75	--	--	
	2N1364, 2N1365		100	--	--	
DC Current Transfer Ratio		h_{FE}				--
(V_{CE} = 4 V, I_C = 1.0A)	2N1359, 375, 1362, 64		35	55	90	
	2N1360, 618, 1363, 65		60	90	140	
(V_{CE} = 4 V, I_C = 1.0A)	2N1359, 375, 1362, 64		15	22	--	
	2N1360, 618, 1363, 65		20	35	--	
Transconductance						mhos
(V_{CE} = 4 V, I_C = 1.0A)	2N375	g_{FE}	0.8	1.25	2.2	
	2N618		1.0	1.6	2.5	
	2N1359, 2N1362, 2N1364		0.8	1.25	--	
	2N1360, 2N1363, 2N1365		1.0	1.6	--	
Frequency Cutoff		$f_{\alpha e}$				kHz
(V_{CE} = 4 V, I_C = 1 A)	2N375		5.0	8.5	--	
(V_{CE} = 4 V, I_C = 1 A)	2N618		5.0	8.5	--	
(V_{CE} = 4 V, I_C = 3 A)	2N1359, 2N1362, 2N1364		7.0	10	--	
(V_{CE} = 4 V, I_C = 3 A)	2N1360, 2N1363, 2N1365		5.0	8.5	--	
Collector Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 2.0 A, I_B = 200mA)	2N1359, 375, 1362, 64		--	0.4	1.0	
	2N1360, 618, 1363, 65		--	0.3	0.8	
Base-Emitter Drive Voltage		V_{BE}				Vdc
(I_C = 2.0A, I_B = 200 mA)	2N1359, 375, 1362, 64		--	0.7	--	
	2N1360, 618, 1363, 65		--	0.6	--	
Collector-Emitter Punch-Through Voltage		V_{EBF}				Vdc
(V_{CB} = 50 V, I_C = 0)	2N1359, 2N1360		--	--	1.25	
(V_{CB} = 100 V, I_C = 0)	2N1362, 2N1363		--	--	1.25	
(V_{CB} = 120 V, I_C = 0)	2N1364, 2N1365		--	--	1.25	

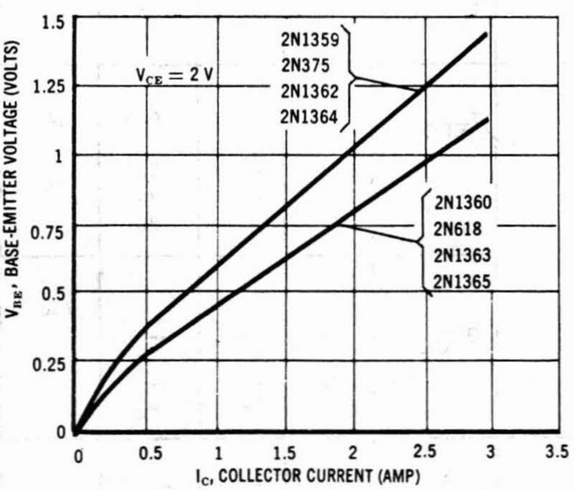
POWER-TEMPERATURE DERATING CURVE



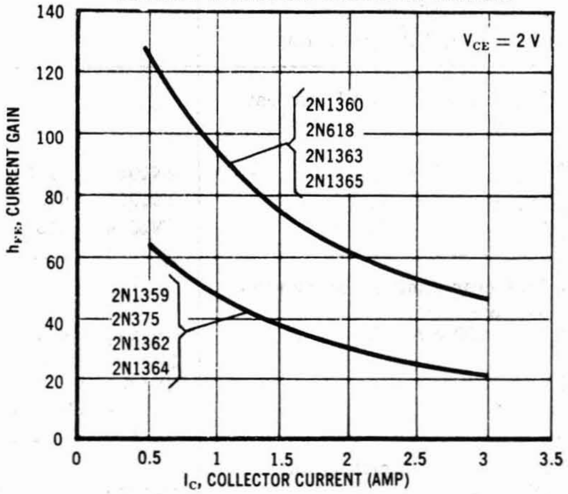
The maximum continuous power is related to maximum junction temperature, by the thermal resistance factor. For d. c. or frequencies below 25 cps the transistor must be operated within the constant $P_D = V_c \times I_c$ hyperbolic curve. This curve has a value of 106 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that

$$P_D \text{ allowable} = \frac{110^\circ - T_c}{0.8}$$

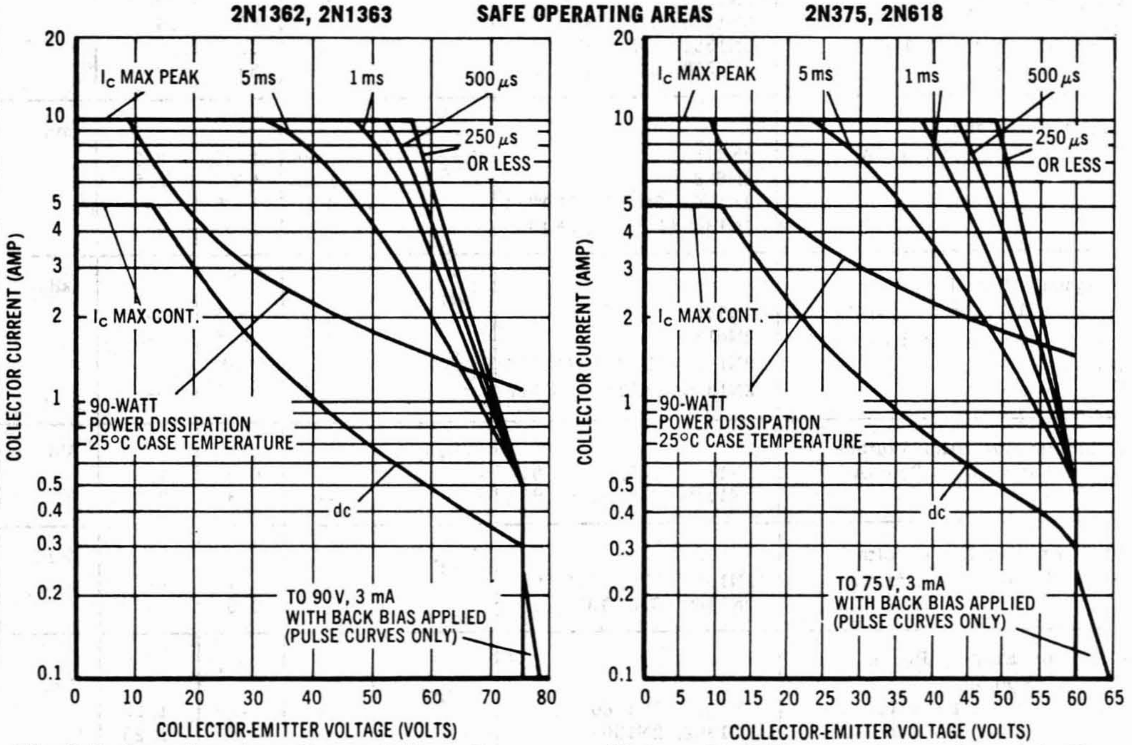
BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT



CURRENT GAIN versus COLLECTOR CURRENT



SAFE OPERATING AREAS



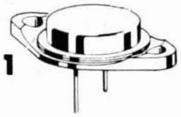
The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N376A (GERMANIUM)

For Specifications, See 2N350A Data.

2N378 thru 2N380 (GERMANIUM)

2N459,A



CASE 11
(TO-3)

PNP germanium power transistors for general purpose power amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N378	2N379	2N380	2N459	2N459A	Unit
Collector-Emitter Voltage	V_{CEO}	20	40	30	60	60	Vdc
Collector-Emitter Voltage	V_{CEX}						Vdc
(V_{BE} = 1.5 V)		40	80	60	-	-	
(V_{BE} = 1.0 V)		-	-	-	105	105	
Collector-Emitter Voltage	V_{CES}	-	-	-	70	70	Vdc
Collector-Base Voltage	V_{CB}	-	-	-	-	105	Vdc
Emitter-Base Voltage	V_{EB}	-	-	-	10	25	Vdc
Collector Current	I_C	5.0					Adc
Operating Junction Temperature Range	T_J	-65 to +110					°C
Total Device Dissipation @ T_C = 25° C	P_D	106					Watts

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc)	2N378 2N379 2N380 2N459, 2N459A	BV_{CEO}	20 40 30 60	- - - -	Vdc
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N378		-	10	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N380		-	10	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N379		-	10	
(V_{CE} = 105 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N459		-	10	
(V_{CE} = 105 Vdc, $V_{BE(off)}$ = 1.0 Vdc)	2N459A		-	10	
Collector Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 25 Vdc)			-	0.5	
(V_{CB} = 25 Vdc, T_C = 85° C)			-	7.5	
Emitter Cutoff Current		I_{EBO}			mAdc
(V_{BE} = 10 Vdc)	2N380 2N459		- -	1.5 2.0	
(V_{BE} = 25 Vdc)	2N459A		-	2.0	

2N378 thru 2N380 2N459, 2N459 A (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Max	Unit
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			-
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	2N378		40	80	
	2N379, 2N459		20	70	
	2N380		30	70	
	2N459A		40	70	
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	2N459A		20	-	
Collector-Emitter Saturation Voltage (I_C = 2.0 Adc, I_B = 0.2 Adc)	2N378-2N380, 2N459	$V_{CE(sat)}$	-	1.0	Vdc
	2N459A		-	0.3	
Base-Emitter Voltage (I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	2N378	$V_{BE(on)}$	-	1.6	Vdc
	2N379, 2N459, 2N459A		-	1.3	
	2N380		-	1.0	
DYNAMIC CHARACTERISTICS					
Common-Emitter Cutoff Frequency (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)	2N378-2N380, 2N459	$f_{\alpha e}$	5.0	-	kHz
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	2N459A		5.0	-	

2N381 thru 2N383 (GERMANIUM)
2N2171

CASE 31(1)
(TO-5)
Base connected to case

PNP germanium transistors for small-signal audio amplifiers, Class B push-pull output stages and medium-speed switching circuits.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	50	Volts
Collector-Emitter Voltage (R_{BE} = 10K)	V_{CER}	25	Volts
Emitter-Base Voltage	V_{EB}	20	Volts
Collector Current	I_C	400	mA
Junction Temperature	T_J	-65 to +100	°C
Collector Dissipation	P_D		
T_A = 25°C		225	mW
derate		3.0	mW/°C
T_C = 25°C		500	mW
derate		6.7	mW/°C

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Typical	Max	Unit
Collector-Base Cutoff Current (V_{CB} = -25 Vdc)	I_{CBO}	- - -	6.0	10	μAdc
Emitter-Base cutoff Current (V_{EB} = -20 Vdc)	I_{EBO}	- - -	5.0	10	μAdc
Collector-Emitter Voltage (I_C = 500 μAdc, R_{BE} = 10K)	BV_{CER}	25	- - -	- - -	Vdc
Collector-Emitter Voltage (I_C = 50 μAdc, V_{BE} = 1.0 Vdc) 2N381	BV_{CER}	- - -	50	- - -	Vdc
2N382, 2N383, 2N2171		- - -	45	- - -	
DC Current Gain (I_C = 20 mAdc, V_{CE} = -1.0 Vdc) 2N381	h_{FE}	35	- - -	65	- - -
2N382		60	- - -	95	
2N383		75	- - -	120	
2N2171		110	- - -	250	
(I_C = 100 mAdc, V_{CE} = -1.0 Vdc) 2N381		30	- - -	- - -	
2N382		50	- - -	- - -	
2N383		65	- - -	- - -	
2N2171		90	- - -	- - -	

ELECTRICAL CHARACTERISTICS (continued)

Characteristics		Symbol	Min	Typical	Max	Unit
Small Signal Current Gain (I_C = 10 mA, V_{CE} = -5.0 V, f = 1 kHz)		h_{fe}				---
	2N381		35	60	85	
	2N382		70	90	135	
	2N383		90	115	155	
	2N2171		120	210	310	
Voltage Feedback Ratio (I_C = 10 mA, V_{CE} = -5 V, f = 1 kHz)		h_{re}				$X10^{-3}$
	2N381		---	0.66	---	
	2N382		---	0.69	---	
	2N383		---	0.72	---	
	2N2171		---	0.75	---	
Input Impedance (I_C = 10 mA, V_{CE} = -5.0 V, f = 1 kHz)		h_{ie}				ohms
	2N381		---	300	---	
	2N382		---	450	---	
	2N382		---	550	---	
	2N2171		---	850	---	
Output Admittance (I_C = 10 mA, V_{CE} = -5.0 V, f = 1 kHz)		h_{oe}				µmhos
	2N381		---	420	---	
	2N382		---	400	---	
	2N383		---	380	---	
	2N2171		---	500	---	
Transducer Gain		G_T				dB
(R_g = 300 Ω , R_L = 500 Ω)	2N381		---	36	---	
(R_g = 450 Ω , R_L = 500 Ω)	2N382		---	38	---	
(R_g = 550 Ω , R_L = 500 Ω)	2N383		---	39.5	---	
(R_g = 785 Ω , R_L = 500 Ω)	2N2171		---	42.5	---	
Output Capacitance (I_C = 1 mA, V_{CB} = -6V)		C_{ob}	---	20	---	pF
Noise Figure (I_C = 1 mA, V_{CE} = -6V, R_g = 1 kc, f = 1 kHz)		NF				dB
	2N381		---	6.0	---	
	2N382		---	5.5	---	
	2N383		---	5.0	---	
	2N2171		---	3.5	---	
Cutoff Frequency (I_C = 1 mA, V_{CB} = -6V)		$f_{\alpha b}$				MHz
	2N381		---	3.0	---	
	2N382		---	4.0	---	
	2N383		---	5.0	---	
	2N2171		---	7.5	---	

2N398, 2N398 A (GERMANIUM)

PNP germanium transistor for high-voltage, audio-frequency applications.

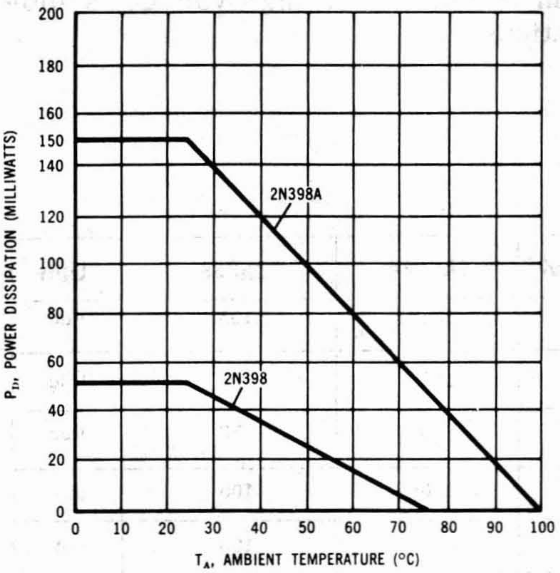
CASE 31(1)
(TO-5)
All leads isolated

MAXIMUM RATINGS

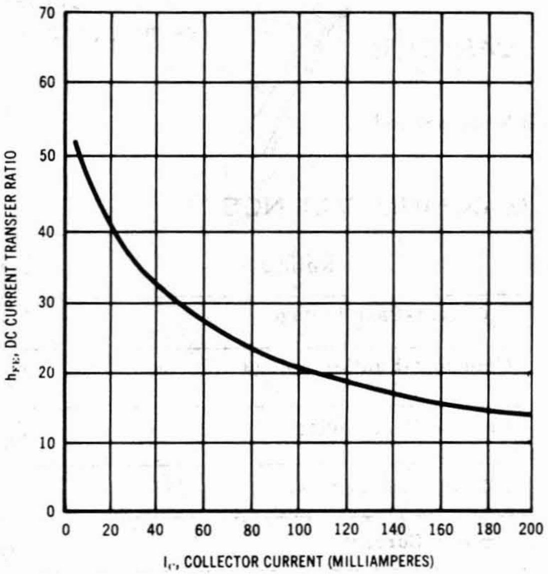
Rating	Symbol	2N398A	2N398	Unit
Collector-Base Voltage	V_{CB}	105	105	Vdc
Collector-Emitter Voltage	V_{CEO}	105	105	Vdc
Emitter-Base Voltage	V_{EB}	50	50	Vdc
DC Collector Current	I_C	200	100	mA
Emitter Current	I_E	200	100	mA
Junction Temperature	T_J	-65 to +100	-65 to +85	°C
Storage Temperature	T_{stg}	-65 to +100	-65 to +85	°C
Collector Dissipation @ 25°C	P_D	150	50	mW
Thermal Resistance, Junction to Ambient	θ_{JA} max	0. 5	1. 2	°C/mW

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Typical	Max	Unit
Collector-Base Cutoff Current (V_{CB} = 105 V, I_B = 0)	I_{CBO}	-	12. 0	50	μA
Collector-Base Cutoff Current (V_{CB} = 2. 5 V, I_B = 0)	I_{CBO}	-	5. 0	14	μA
Emitter-Base Cutoff Current (V_{EB} = 50 V, I_C = 0)	I_{EBO}	-	3. 0	50	μA
Collector-Emitter Saturation Voltage (I_C = 5 mAdc; I_B = 0. 25 mAdc)	$V_{CE\ (SAT)}$	-	0. 11	0. 35	Vdc
Base-Emitter Saturation Voltage (I_C = 5 mAdc; I_B = 0. 25 mAdc)	$V_{BE\ (SAT)}$	-	0. 22	0. 40	Vdc
DC Current Transfor Ratio (I_C = 5 mAdc; V_{CE} = 0. 35 Vdc)	h_{FE}	20	65	-	-
DC Collector-Emitter Punch-Through Voltage (V_{CB} necessary to obtain V_{EB} of -1 V max, using instrument with Z_{in} > 11 megohm to measure V_{BE})	V_{PT}	105	160	-	Vdc
Small-Signal Short-Circuit, Forward Current Transfer Ratio Cutoff Frequency (V_{CB} = 6 Vdc; I_E = 1 mAdc)	$f_{\alpha b}$	-	1. 0	-	MHz

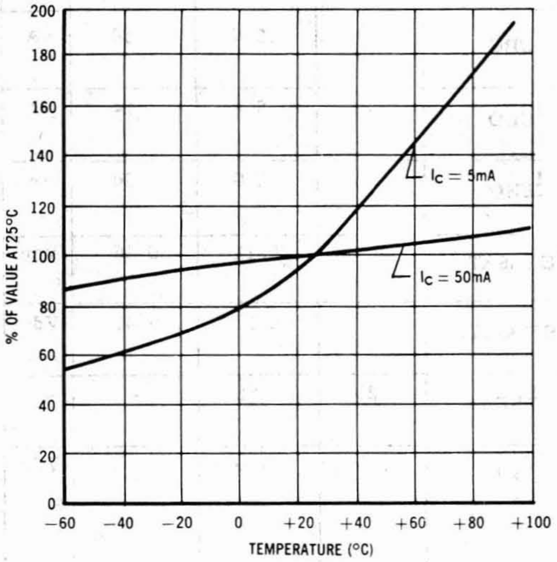


POWER — TEMPERATURE DERATING CURVE



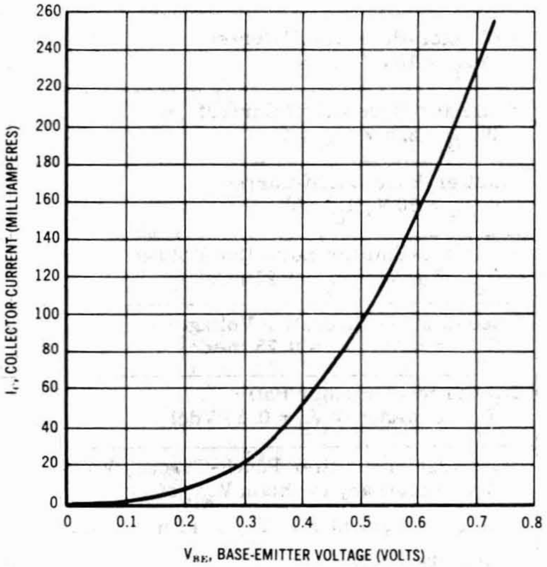
DC CURRENT TRANSFER RATIO versus COLLECTOR CURRENT

$V_{CE} = 0.35V$



LARGE SIGNAL CURRENT GAIN (H_{FE}) versus TEMPERATURE

(Normalized to 25°C Value; $V_{CE} = 0.35V$)



OUTPUT CURRENT versus BASE-DRIVE VOLTAGE

($V_{CE} = -1$ V)

2N441 (GERMANIUM)
2N442
2N443

PNP germanium power transistors for power switching and amplifier applications. Power and temperature ratings exceed EIA registration.

CASE 5
(TO-36)

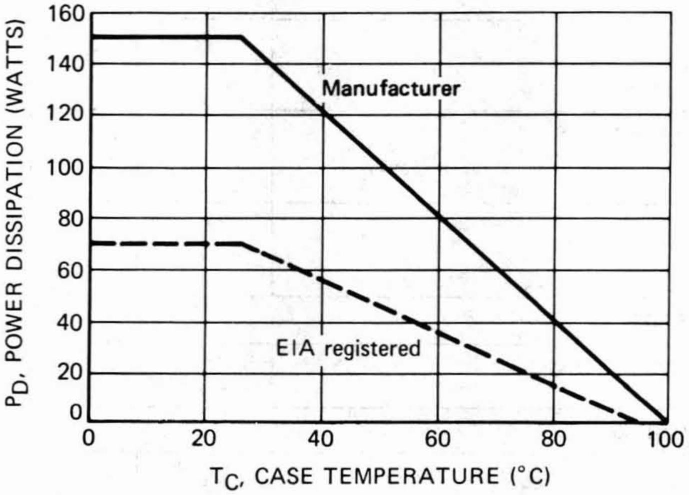
MAXIMUM RATINGS

Rating	Symbol	2N441	2N442	2N443	Unit
Collector-Emitter Voltage	V_{CES}	40	45	50	Vdc
Collector-Base Voltage	V_{CB}	40	50	60	Vdc
Emitter-Base Voltage	V_{EB}	20	30	40	Vdc
Base Current — Continuous	I_B	4.0			Adc
Emitter Current — Continuous	I_E	15			Adc
Total Device Dissipation @ T_C = 25°C	P_D	150			Watts
Operating Junction Temperature Range (EIA Registered)	T_J	-65 to +95			°C
Operating Junction Temperature Range	T_J	-65 to +100			°C

THERMAL CHARACTERISTICS

Thermal Resistance, Junction to Case (EIA Registered)	θ_{JC}	1.0	°C/W
Thermal Resistance, Junction to Case	θ_{JC}	0.5	°C/W

FIGURE 1 – POWER-TEMPERATURE DERATING CURVE



The maximum continuous power is related to maximum junction temperature, by the thermal resistance factor.

This curve has a value of 150 Watts at case temperatures of 25°C and is 0 Watts at 100°C with a linear relation between the two temperatures such that

$$P_D \text{ allowable} = \frac{100^\circ - T_C}{0.5}$$

2N441 thru 2N443 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage* (I_C = 1.0 Adc, I_B = 0)	2N441	BV_{CEO}*	25	-	-	Vdc
	2N442		30	-	-	
	2N443		45	-	-	
Collector-Emitter Breakdown Voltage* (I_C = 300 mAdc, V_{BE} = 0)	2N441	BV_{CES}*	40	-	-	Vdc
	2N442		45	-	-	
	2N443		50	-	-	
Floating Potential		V_{EBF}				Vdc
(V_{CB} = 40 Vdc, I_E = 0)	2N441		-	-	1.0	
(V_{CB} = 50 Vdc, I_E = 0)	2N442		-	-	1.0	
(V_{CB} = 60 Vdc, I_E = 0)	2N443		-	-	1.0	
Collector Cutoff Current		I_{CBO}				mAdc
(V_{CB} = 2.0 Vdc, I_E = 0)			-	0.1	-	
(V_{CB} = 40 Vdc, I_E = 0)	2N441		-	2.0	8.0	
(V_{CB} = 50 Vdc, I_E = 0)	2N442		-	2.0	8.0	
(V_{CB} = 60 Vdc, I_E = 0)	2N443		-	2.0	8.0	
(V_{CB} = 40 Vdc, I_E = 0, T_B = 71°C)	2N441		-	-	15	
(V_{CB} = 50 Vdc, I_E = 0, T_B = 71°C)	2N442		-	-	15	
(V_{CB} = 50 Vdc, I_E = 0, T_B = 71°C)	2N443		-	-	15	
Emitter Cutoff Current		I_{EBO}				mAdc
(V_{BE} = 20 Vdc, I_C = 0)	2N441		-	1.0	8.0	
(V_{BE} = 30 Vdc, I_C = 0)	2N442		-	1.0	8.0	
(V_{BE} = 40 Vdc, I_C = 0)	2N443		-	1.0	8.0	
ON CHARACTERISTICS						
DC Current Gain		h_{FE}				-
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)			20	-	40	
(I_C = 12 Adc, V_{CE} = 2.0 Vdc)			-	20	-	
Collector-Emitter Saturation Voltage (I_C = 12 Adc, I_B = 2.0 Adc)	2N441	$V_{CE(sat)}$	-	0.3	-	Vdc
	2N442		-	0.3	-	
	2N443		-	0.3	1.0	
Base-Emitter Voltage (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	2N441	V_{BE}	-	0.65	-	Vdc
	2N442		-	0.65	-	
	2N443		-	0.65	0.9	
DYNAMIC CHARACTERISTICS						
Common-Emitter Cutoff Frequency (I_C = 5.0 Adc, V_{CE} = 6.0 Vdc)		$f_{\alpha e}$	-	10	-	kHz
SWITCHING CHARACTERISTICS						
Rise Time (V_{CE} = 12 Vdc, I_C = 12 Adc, I_B = 2.0 Adc)		t_r	-	15	-	μs
Fall Time (I_C = 0, V_{BE} = 6.0 Vdc, R_{BE} = 10 ohms)		t_f	-	15	-	μs

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

TYPICAL COMMON-EMITTER CHARACTERISTICS

FIGURE 2 – OUTPUT CHARACTERISTICS

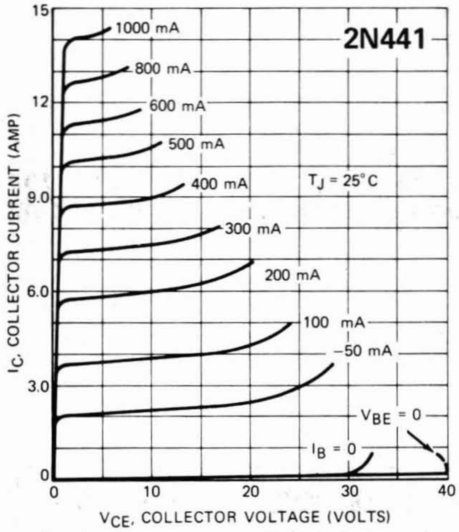


FIGURE 3 – OUTPUT CHARACTERISTICS

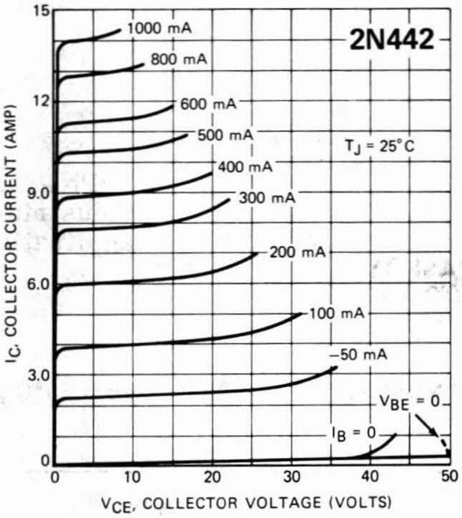


FIGURE 4 – OUTPUT CHARACTERISTICS

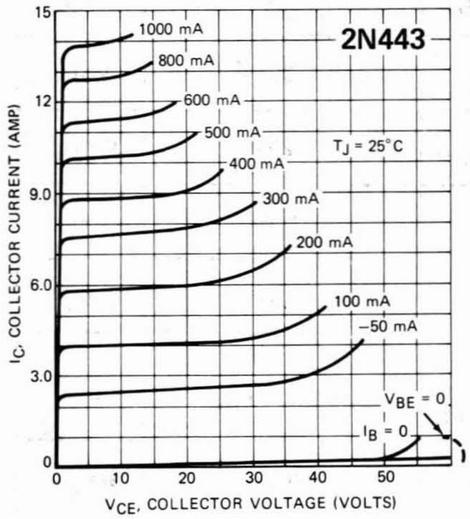


FIGURE 5 – INPUT CHARACTERISTICS

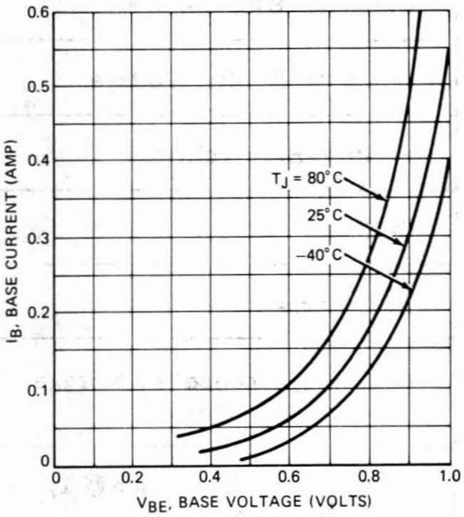


FIGURE 6 – DC CURRENT GAIN TRANSFER CHARACTERISTICS

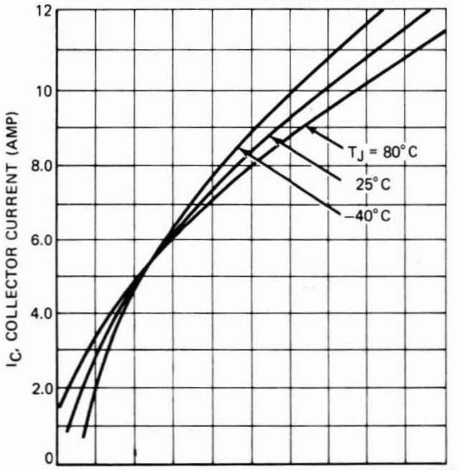
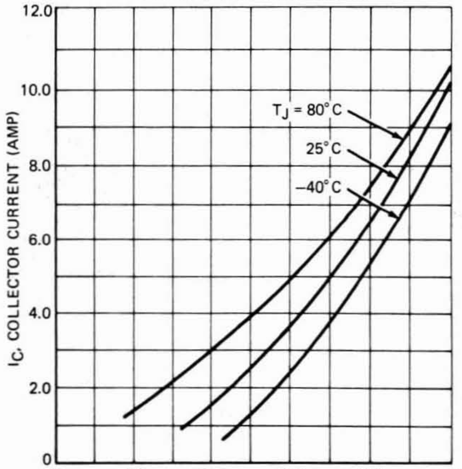
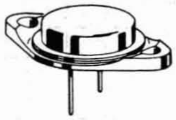


FIGURE 7 – TRANSCONDUCTANCE CHARACTERISTICS



2N456A (GERMANIUM)
2N457A
2N458A



CASE 11
(TO-3)

PNP high-current germanium power transistors for industrial and general power amplifier and switching applications.

MAXIMUM RATINGS (Tc = 25°C unless otherwise noted)

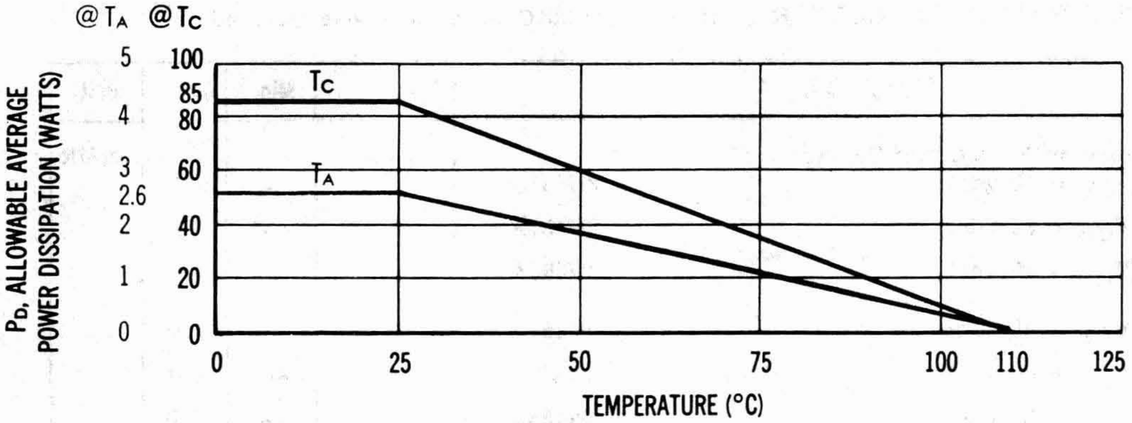
Rating	Symbol	2N456A	2N457A	2N458A	Unit
Collector-Base Voltage	V_{CB}	40	60	80	Volts
Collector-Emitter Voltage	V_{CEO}	20	30	40	Volts
Emitter-Base Voltage	V_{EB}	20			Volts
Collector Current	I_C	7.0			Amp
Base Current	I_B	3.0			Amp
Operating Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +110			°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	85 1.0			Watts W/°C

2N456A, 2N457A, 2N458A (continued)

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise specified)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 20 Vdc)	2N456A		—	0.5	
(V_{CB} = 30 Vdc)	2N457A		—	0.5	
(V_{CB} = 40 Vdc)	2N458A		—	0.5	
(V_{CB} = 40 Vdc)	2N456A		—	2.0	
(V_{CB} = 60 Vdc)	2N457A		—	2.0	
(V_{CB} = 80 Vdc)	2N458A		—	2.0	
(V_{CB} = 40 Vdc, T_C = +71°C)	2N456A		—	10	
(V_{CB} = 60 Vdc, T_C = +71°C)	2N457A		—	10	
(V_{CB} = 80 Vdc, T_C = +71°C)	2N458A		—	10	
Emitter-Base Cutoff Current (V_{EB} = 20 Vdc)		I_{EBO}	—	2.0	mAdc
Collector-Emitter Breakdown Voltage		BV_{CEO}			Vdc
(I_C = 200 mAdc)	2N456A		20	—	
	2N457A		30	—	
	2N458A		40	—	
Base-Emitter Voltage (I_C = 5 Adc, V_{CE} = 1.5 Vdc)		V_{BE}	—	1.5	Vdc
Collector-Emitter Saturation Voltage (I_C = 5 Adc, I_B = 500 mAdc)		$V_{CE(sat)}$	—	0.5	Vdc
DC Current Gain		h_{FE}			—
(I_C = 1 Adc, V_{CE} = 1.5 Vdc)			40	—	
(I_C = 3 Adc, V_{CE} = 1.5 Vdc)			35	—	
(I_C = 5 Adc, V_{CE} = 1.5 Vdc)			30	90	
(I_C = 7 Adc, V_{CE} = 1.5 Vdc)			22	—	
Current Gain-Bandwidth Product (I_C = 1 Adc, V_{CE} = 2 Vdc)		f_T	200	—	kHz
Input Impedance (I_C = 5 Adc, V_{CE} = 1.5 Vdc)		h_{ie}	—	28	ohms

POWER-TEMPERATURE DERATING CURVE



2N459,A (GERMANIUM)

For Specifications, See 2N378-380 Data.

2N460, 2N461 (GERMANIUM)

CASE 31(1)
(TO-5)
Base connected to case

PNP germanium transistor for general purpose industrial applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	45	Volts
Collector-Emitter Voltage (R_{BE} = 1 K)	V_{CER}	35	Volts
Emitter-Base Voltage	V_{EB}	10	Volts
Collector Current	I_C	400	mA
Collector Dissipation at 25° C Case Temperature Derate above 25° C at 25° C Ambient Temperature Derate above 25° C	P_D	 500 6.7 225 3.0	 mW mW/° C mW mW/° C
Junction Temperature Range	T_J	-65 to +100	° C

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Typical	Max	Unit
Collector-Base Cutoff Current (V_{CB} = 45 Vdc)	I_{CBO}	---	---	15	μAdc
Emitter-Base Cutoff Current (V_{EB} = -10 Vdc)	I_{EBO}	---	---	10	μAdc
Collector-Emitter Voltage (I_C = 1 mAdc, R_{BE} = 1 K)	BV_{CER}	35	---	---	Vdc
Small-Signal Current Gain (V_{CB} = -6 Vdc, I_E = 1 mAdc, f = 1 kHz) 2N460 2N461	h_{fb}	0.94 0.955	0.96 0.968	0.972 0.988	---
Small-Signal Current Gain (V_{CB} = -6 Vdc, I_E = 1 mAdc, f = 1 kHz) 2N460 2N461	h_{fe}	17 31	---	36 200	---
Reverse Voltage Ratio (V_{CB} = -6 Vdc, I_E = 1 mAdc, f = 1 kHz) 2N460 2N461	h_{rb}	--- ---	2.0 3.0	15 15	X10^{-4}
Input Resistance (V_{CB} - -6 Vdc, I_E = 1 mAdc, f = 1 kHz) 2N460 2N461	h_{ib}	25 25	30 ---	40 40	Ohms
Output Admittance (V_{CB} = -6 Vdc, I_E = 1 mAdc, f = 1 kHz) 2N460 2N461	h_{ob}	--- ---	0.8 0.5	1.5 1.5	μmho
Frequency Cutoff (V_{CE} = -5 Vdc, I_E = 1 mAdc) 2N460 2N461	$f_{\alpha b}$	--- ---	1.2 4.0	--- ---	MHz
Output Capacitance (V_{CB} = -10 Vdc, I_E = 1 mAdc, f = 1 MHz)	C_{ob}	---	20	---	pF
Noise Figure (V_{CE} = -4.5 Vdc, I_E = 0.5 mAdc, R_g = 1 K, f = 1 kHz) 2N460 2N461	NF	--- ---	5.0 4.0	--- ---	dB

2N464 thru 2N467 (GERMANIUM)

CASE 31(1)
(TO-5)
All leads isolated

PNP germanium transistor for general purpose applications in the audio-frequency range.

MAXIMUM RATINGS

Rating	Symbol	2N464	2N465	2N466	2N467	Unit
Collector-Base Voltage	V_{CB}	45	45	35	35	Volts
Collector-Emitter Voltage	V_{CER}	40	30	20	15	Volts
Emitter-Base Voltage	V_{EB}	12				Volts
DC Collector Current	I_C	500				mA
Max. Junction & Storage Temperature	T_J and T_{stg}	100				°C
Collector Dissipation, Ambient	P_D	200				mW
Derate above 25°C		2.67				mW/°C
Thermal Resistance, Junction to Ambient	θ_{JA}	0.375				°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

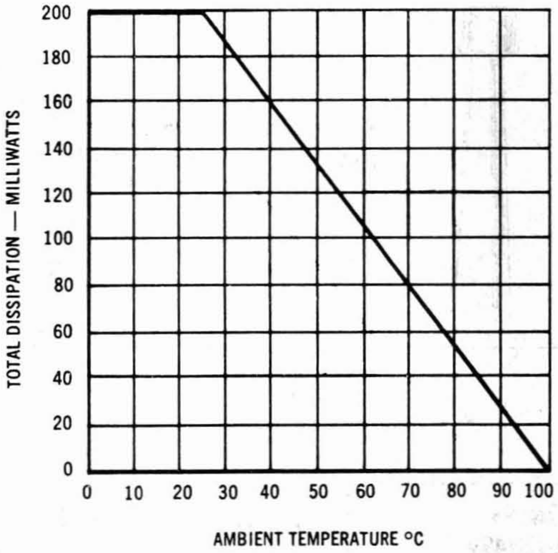
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage ($I_C = 0.6$ mAdc, $R_{BE} = 10$ K ohms)	2N464	BV_{CER}	40	–	–	Vdc
	2N465		30	–	–	
	2N466		20	–	–	
	2N467		15	–	–	
Collector-Base Cutoff Current ($V_{CB} = 20$ Vdc)		I_{CBO}	–	6.0	15	μAdc
Small Signal Current Gain Cutoff Frequency ($V_{CB} = 6$ Vdc, $I_E = 1$ mAdc)	2N464	$f_{\alpha b}$	–	0.7	–	MHz
	2N465		–	0.8	–	
	2N466		–	1.0	–	
	2N467		–	1.2	–	
Small Signal Current Gain ($V_{CE} = 6$ Vdc, $I_E = 1.0$ mAdc, f = 1 kHz)	2N464	h_{fe}	14	26	–	–
	2N465		27	45	–	
	2N466		56	90	–	
	2N467		112	180	–	

2N464 thru 2N467 (continued)

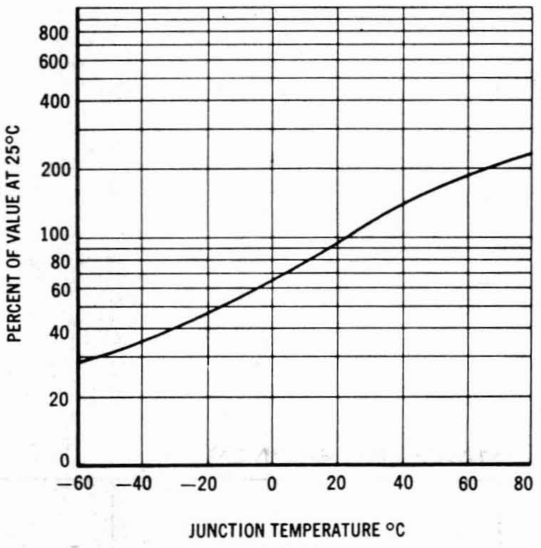
ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Typ	Max	Unit
Small Signal Input Impedance (V_{CE} = 6 Vdc, I_E = 1.0 mAdc, f = 1 kHz)	2N464 2N465 2N466 2N467	h_{ie}	– – – –	900 1400 3000 5500	– – – –	Ohms
Small Signal Power Gain (V_{CE} = 6 Vdc, I_E = 1.0 mAdc, f = 1 kHz, matched)	2N464 2N465 2N466 2N467	G_e	– – – –	40 42 44 45	– – – –	dB
Noise Figure (V_{CE} = 2.5 Vdc, I_E = 0.5 mAdc, f = 1 kHz, R_S = 10 Kohms, Δf = 1 Hz		NF	–	–	22	dB

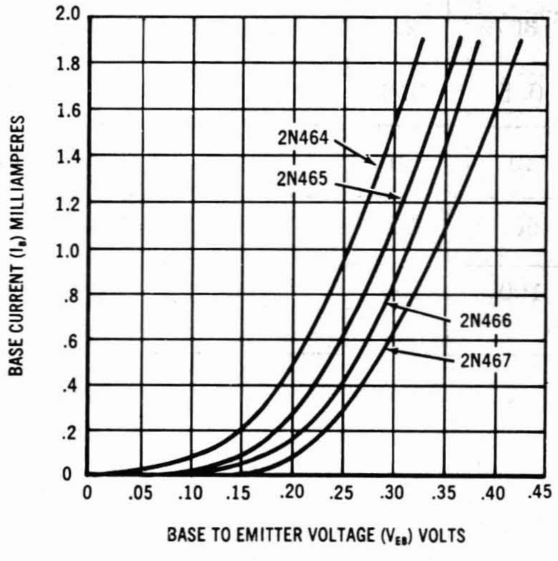
POWER-TEMPERATURE DERATING CURVE



SMALL SIGNAL CURRENT GAIN versus TEMPERATURE

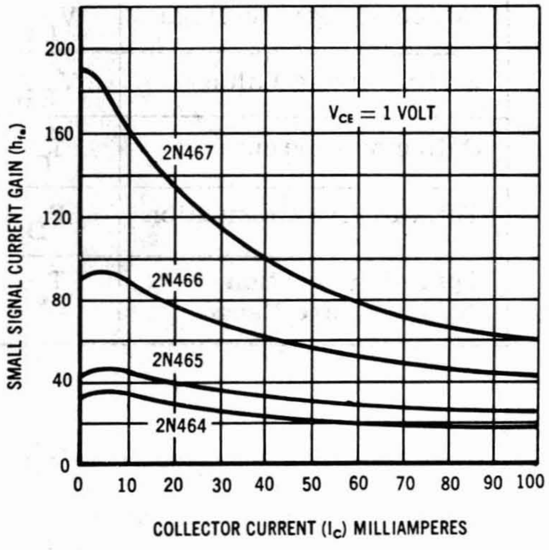


Input Current versus Emitter-Drive Voltage



Small Signal Current Gain versus Collector Current

(common emitter 1 kHz)



2N499
(JAN2N499 AVAILABLE)

2N499A
(JAN2N499A AVAILABLE)

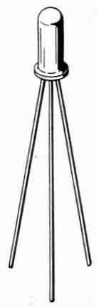
2N502

2N502A
(JAN2N502A AVAILABLE)

2N502B
(JAN2N502B AVAILABLE)

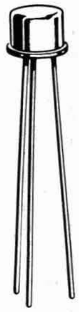
2N1742

Germanium PNP high frequency transistors designed for driver applications, small-signal amplification, wide band video amplifiers, and VHF/UHF oscillators.



CASE 149
(TO-1)

2N499, 2N499A
JAN2N499, JAN2N499A



CASE 31
(TO-5)

2N502,A,B,
JAN2N502A,B,
2N1742

MAXIMUM RATINGS

Rating	Symbol	2N499 JAN2N499 2N499A JAN2N499A	2N502	2N502A, B JAN2N502A JAN2N502B	2N1742	Unit
Collector-Base Voltage	V_{CB}	30	20	30	20	Vdc
Emitter-Base Voltage	V_{EB}	0.5	0.5	0.5	0.5	Vdc
Collector Current	I_C	50	50	50	50	mAdc
Total Device Dissipation	P_D	60	60	75	60	mW
Operating Junction Temperature Range	T_J	100	100	100	125	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 10 Vdc, I_E = 0)	2N502, A, B		-	5.0	
	JAN2N502A, B		-	4.0	
	2N1742		-	10	
(V_{CB} = 15 Vdc, I_E = 0)	2N499, A, JAN2N499, A		-	10	
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product		f_T			MHz
(I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N499, A, JAN2N499, A		120	-	
(I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	JAN2N502A, B		150	600	
Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, I_E = 0, f = 4.0 MHz)	2N499, A, JAN2N499, A		-	2.5	
	2N502		-	2.0	
	2N502A, B		-	1.6	
	JAN2N502A, B		-	1.6	
Small-Signal Current Gain		h_{fe}			-
(I_C = 1.0 mAdc, V_{CE} = 9.0 Vdc, f = 1.0 kHz)	2N499, A, JAN2N499, A		20	80	
(I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N502		9.0	-	
	2N502A		15	-	
	2N502B		20	80	
	JAN2N502A		15	200	
	JAN2N502B		25	80	
Collector-Base Time Constant		$r_b'C_c$			ps
(I_E = 2.0 mAdc, V_{CB} = 10 Vdc, f = 46 MHz)	JAN2N499, A		5.0	50	
	2N499		-	250	
	2N499A		5.0	250	
	2N502		-	120	
	2N502A, B		5.0	50	
	JAN2N502A, B		5.0	25	
Noise Figure		NF			dB
(V_{CB} = 10 Vdc, I_E = 2.0 mAdc, f = 200 MHz)	2N502A, JAN2N502A		-	7.0	
	2N502B, JAN2N502B		-	7.0	
(V_{CC} = 12 Vdc, I_E = 2.5 mAdc, f = 200 MHz)	2N1742		-	5.5	
FUNCTIONAL TESTS					
Power Gain		P_G			dB
(V_{CB} = 10 Vdc, I_E = 2.0 mAdc, f = 100 MHz)	2N499, A, JAN2N499, A		7.5	-	
(V_{CB} = 10 Vdc, I_E = 2.0 mAdc, f = 200 MHz)	2N502		8.0	-	
	2N502A		10	-	
	2N502B		10	-	
	JAN2N502A, B		10	20	
(V_{CB} = 12 Vdc, I_E = 2.5 mAdc, f = 200 MHz)	2N1742		14	19	

2N508 (GERMANIUM)

FOR SPECIFICATIONS, SEE 2N322 DATA.

2N508A (GERMANIUM)

CASE 31 (1)
(TO-5)
Base connected to case

PNP Germanium Milliwatt transistor designed for low noise audio and switching applications.

- Small-Signal Current Gain – h_{fe} = 180 (Max) @ I_E = 1.0 mAdc
- Low Noise Figure Applications – NF = 5.0 dB (Max) @ I_C = 1.0 mAdc

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
*Collector-Emitter Voltage (R_{BE} = 10 kohms)	V_{CER}	25	Vdc
*Collector-Emitter Voltage	V_{CES}	30	Vdc
*Collector-Base Voltage	V_{CB}	30	Vdc
*Emitter-Base Voltage	V_{EB}	10	Vdc
*Collector Current	I_C	200	mAdc
*Total Device Dissipation @ T_A = 25° C Derate above 25° C	P_D	200 2.67	mW mW/° C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	° C

*Indicates JEDEC Registered Data

2N508A (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
*Collector-Emitter Breakdown Voltage (I_C = 600 μAdc, R_{BE} = 10 k ohms)	BV_{CER}	25	-	Vdc
*Collector Cutoff Current (V_{CB} = 25 Vdc, I_E = 0)	I_{CBO}	-	7.0	μAdc
*Emitter Cutoff Current (V_{BE} = 10 Vdc, I_C = 0)	I_{EBO}	-	7.0	μAdc
ON CHARACTERISTICS				
*DC Current Gain (I_C = 20 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	100	200	-
*Base-Emitter Voltage (I_C = 20 mAdc, V_{CE} = 1.0 Vdc)	V_{BE}	0.18	0.32	Vdc
SMALL-SIGNAL CHARACTERISTICS				
*Cutoff Frequency (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	$f_{\alpha b}$	2.5	-	MHz
*Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 1.0 mAdc, f = 1.0 MHz)	C_{ob}	-	35	pF
*Input Impedance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	26	31	Ohms
*Voltage Feedback Ratio (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	1×10^{-4}	17×10^{-4}	-
*Small-Signal Current Gain (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	75	180	-
*Output Admittance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	0.1	0.9	μmhos
Noise Figure (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, R_S = 500 ohms, f = 1.0 kHz, Δf = 1.0 Hz)	NF	-	5.0	dB

*Indicates JEDEC Registered Data.

2N524 thru 2N527 (GERMANIUM)

CASE 31(1)
(TO-5)

Base connected to case

PNP germanium transistor for switching and amplifier applications in the audio-frequency range. Available for military and high-reliability industrial purposes.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	45	Vdc
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Emitter-Base Voltage	V_{EB}	15	Vdc
Collector Current	I_C	500	mAdc
Storage and Operating Temperature	T_{stg}, T_J	-65 to +100	°C
Collector Dissipation @ 25°C Ambient	P_D	225	mW
Thermal Resistance Junction to Ambient	θ_{JA}	0.333	°C/mW
Thermal Resistance (infinite heat sink)	θ_{JC}	0.15	°C/mW

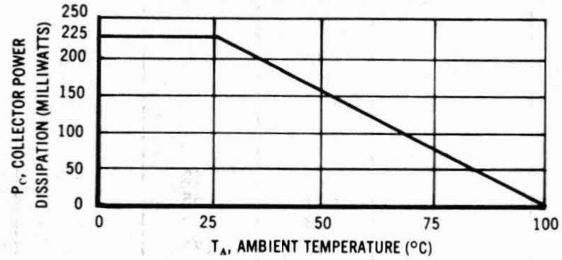
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristics		Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)		I_{CBO}	-	10	µAdc
Emitter Cutoff Current (V_{EB} = 15 Vdc, I_C = 0)		I_{EBO}	-	10	µAdc
Collector-Emitter Breakdown Voltage (I_C = 0.6 mAdc, R_{BE} = 10K)		BV_{CER}	30	-	µVdc
Collector-Emitter Reach Through (Punch-Thru) Voltage (V_{EB} = 1 Vdc, VTVM Z ≥ 1 Megohm)		V_{RT}	30	-	µVdc
Static Forward-Current Transfer Ratio		h_{FE}			
(V_{CE} = 1 Vdc, I_C = 20 mAdc)	2N524		25	42	-
	2N525		34	65	-
	2N526		53	90	-
	2N527		72	121	-
Small-Signal Short-Circuit Forward Current Transfer Ratio Frequency Cutoff		$f_{\alpha b}$			
(V_{CB} = 5 Vdc, I_E = 1 mAdc)	2N524		0.8	5.0	MHz
	2N525		1.0	5.5	
	2N526		1.3	6.5	
	2N527		1.5	7.0	
Output Capacitance (V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 MHz)		C_{ob}	5.0	40	pF
Small-Signal Open Circuit Output Admittance		h_{ob}			
(V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N524		0.10	1.3	µmho
	2N525		0.10	1.2	
	2N526		0.10	1.0	
	2N527		0.10	0.9	
Small-Signal Open Circuit Reverse Transfer Voltage Ratio		h_{rb}			
(V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N524		1.0	10	$X10^{-4}$
	2N525		1.0	11	
	2N526		1.0	12	
	2N527		1.0	14	
Small-Signal Short Circuit Input Impedance		h_{ib}			
(V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N524		26	36	ohms
	2N525		26	35	
	2N526		26	33	
	2N527		26	31	
Collector-Emitter Saturation Voltage		$V_{CE\ (sat)}$			
(I_B = 2 mAdc, I_C = **20 mAdc**)	2N524				
(I_B = 1.33 mAdc, I_C = **20 mAdc**)	2N525		-	130	mVdc
(I_B = 1.0 mAdc, I_C = **20 mAdc**)	2N526		-	130	
(I_B = 0.67 mAdc, I_C = **20 mAdc**)	2N527		-	130	
			-	130	
Base Input Voltage		V_{BE}			
(V_{CE} = 1 Vdc, I_C = 20 mAdc)	2N524		220	320	mVdc
	2N525		200	300	
	2N526		190	280	
	2N527		180	260	

2N524 thru 2N527 (continued)

ELECTRICAL CHARACTERISTICS (continued)

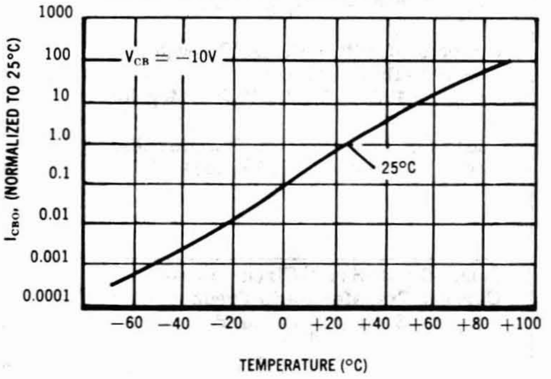
Characteristics		Symbol	Min	Max	Unit
Noise Figure (V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz, BW = 1 Hz		NF	-	15	dB
Small-Signal Short-Circuit Forward-Current Transfer Ratio (V_{CE} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N524	h_{fe}	18	41	-
	2N525		30	64	
	2N526		44	88	
	2N527		60	120	

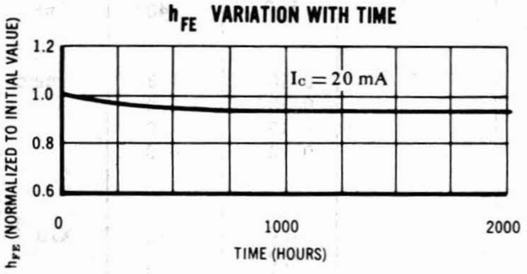

POWER-TEMPERATURE DERATING CURVE

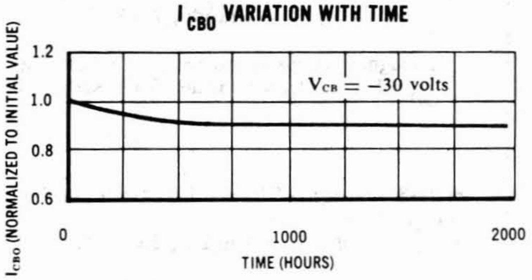
The maximum continuous power is related to maximum junction temperature by the thermal resistance factor.

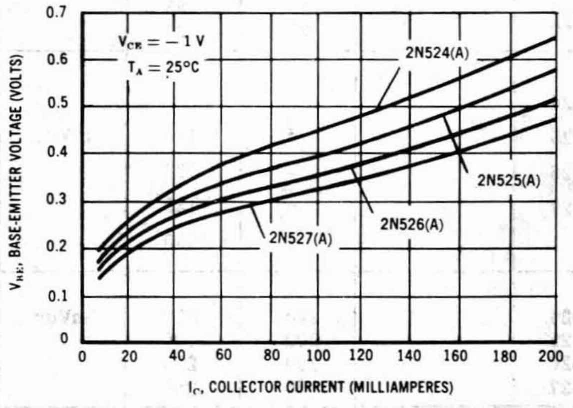
This curve has a value of 225mW at case temperatures of 25°C and is 0 mW at 100°C with a linear relation between the two temperatures such that:

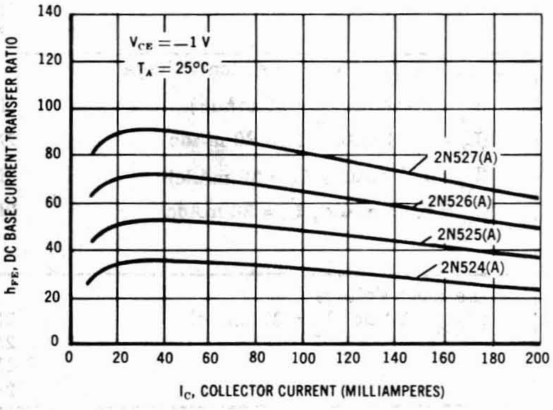
$$\text{allowable } P_D = \frac{100° - T_A}{0.333}$$


COLLECTOR CUTOFF CURRENT versus TEMPERATURE


h_{FE} VARIATION WITH TIME


I_{CBO} VARIATION WITH TIME


COMMON EMITTER INPUT VOLTAGE versus COLLECTOR CURRENT


D-C BASE CURRENT GAIN versus COLLECTOR CURRENT

2N554 (GERMANIUM)
2N555

For Specifications, See 2N178 Data.

JAN 2N559-1 (GERMANIUM)
JAN 2N559-2
JAN 2N559-3*

PNP germanium mesa transistors designed for military and industrial high-reliability, high-speed switching applications.

CASE 22
(TO-18)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CES}	15	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current	I_C	50	mAdc
Base Current	I_B	50	mAdc
Emitter Current	I_E	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	150 2.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	300 4.0	mW mW/°C
Operating Junction Temperature Range	T_J	-65 to +100	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

* Level 3 reliability data shown for information only. Qualification tests will be initiated upon established customer requirements.

JAN 2N559-1, -2, -3 (Continued)

RELIABILITY RATINGS†

Reliability Level Indicator	QUALITY LEVELS (LTPD)				RELIABILITY LEVELS Maximum failure rate (λ) during first 1000 hours with 90% confidence.						Est. Max Failure Rate in Conservatively Designed Equipment %/1000 Hrs
					Operation Life		Storage Life				
	Group A Subgroups		Group B Subgroups		$P_D = 150$ mW $I_E = 50$ mA $T_A = 25°C$		$T_A = 100°C$		$T_A = 150°C$		
	Major Defect	Minor Defect	Major Defect	Minor Defect	Major Defect	Minor Defect	Major Defect	Minor Defect	Major Defect	Minor Defect	
(1)	3.0	5.0	10	20	10	20	10	20	20	—	0.1
(2)	1.5	3.0	5	15	5	15	1.5	3	7	20	0.01
(3)*	1.0	2.0	3	7	2	5	0.2	0.5	1	3	0.001

† This table relates the statistical sampling requirements in the specification to the reliability levels for the transistor.

* Level 3 reliability data shown for information only. Qualification tests will be initiated upon established customer requirements.

TABLE I – GROUP A INSPECTION

Examination or Test	MIL-STD-750 Method	LTPD for Respective Reliability Level						Symbol	Limit				Unit
		Total ①			Major				Requirement Limit		Defect Classification		
		(1)	(2)	(3)	(1)	(2)	(3)		Min	Max	Minor	Major	
SUBGROUP 1													
Visual and Mechanical Examination	2071	10	7	5	7	5	3	—	—	—	—	—	—
SUBGROUP 2		5	3	2	3	1.5	1.0						
Emitter-Base Cutoff Current (V_{EB} = -1 Vdc)	3061 Condition D							I_{EBO}	—	5	>5 to 10	>10	μAdc
Collector-Base Cutoff Current (V_{CB} = -5 Vdc)	3036 Condition D							I_{CBO}	—	3	>3 to 5	> 5	μAdc
Emitter-Base Breakdown Voltage (I_E = -200 μAdc)	3026 Condition D							BV_{EBO}	5	—	3.5 to <5	< 3.5	Vdc
Collector-Emitter Breakdown Voltage (I_C = -100 μAdc)	3011 Condition C							BV_{CES}	15	—	12 to <15	<12	Vdc
SUBGROUP 3		5	3	2	3	1.5	1.0						
Collector-Emitter Saturation Voltage (I_C = -50 mAdc, I_B = -1.5 mAdc)	3071							$V_{CE(sat)}$	—	1	>1.0 to 1.2	>1.2	Vdc
(I_C = -10 mAdc, I_B = -0.4 mAdc)									—	0.3	>0.3 to 0.35	> 0.35	
Base-Emitter Saturation Voltage (I_C = -10 mAdc, I_B = -0.4 mAdc)	3066 Condition A							$V_{BE(sat)}$	0.32	0.44	0.30 to <0.32 and 0.44 to 0.50	< 0.30 and > 0.50	Vdc
DC Current Gain (I_C = -10 mAdc, V_{CE} = -0.5 Vdc)	3076							h_{FE}	25	150	20 to <25 and >150 to 200	< 20 and >200	—
SUBGROUP 4		5	3	2	3	1.5	1.0						
Rise Time (V_{CC} = -3.5 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_{B1} = -0.55 mAdc, R_C = 300 ohms, C_{CE} = 150 pF, $C_{CB} = 2^{+0.5}_{-0}$ pF)	3251 Condition A							t_r	—	95	> 95 to 115	>115	ns
Storage Time (V_{CC} = -3.5 Vdc, I_{B1} = -1 mAdc, I_{B2} = 0.25 mAdc, R_C = 300 ohms)	3251 Condition A							t_s	—	95	> 95 to 115	>115	ns
Fall Time (V_{CC} = -3.5 Vdc, I_{B1} = -1 mAdc, I_{B2} = 0.25 mAdc, R_C = 300 ohms, $C_{CB} = 2^{+0.5}_{-0}$ pF)	3251 Condition A							t_f	—	100	>100 to 120	>120	ns

NOTES:

① Total is defined as the sum of the major and minor defectives.

TABLE II – GROUP B INSPECTION

Examination or Test	MIL-STD-750 Method	LTPD for Respective Reliability Level						Symbol	Limit				Unit
		Total ①			Major				Requirement Limit		Defect Classification		
		(1)	(2)	(3)	(1)	(2)	(3)		Min	Max	Minor	Major	
SUBGROUP 1													
Physical Dimensions	2066	20	15	7	—	—	—	—	—	—	—	—	—
SUBGROUP 2		5	3	2	3	1.5	1						
Moisture Resistance (No initial conditioning; one cycle; only steps 1 to 6)	1021							—	—	—	—	—	—
End-Point Tests:													
Emitter-Base Cutoff Current (V_{EB} = -1 Vdc)	3061 Condition D							I_{EBO}	—	10	>10 to 20	>20	µAdc
Collector-Base Cutoff Current (V_{CB} = -5 Vdc)	3036 Condition D							I_{CBO}	—	5	>5 to 10	>10	µAdc
DC Current Gain (I_C = -10 mAdc, V_{CE} = -0.5 Vdc)	3076							h_{FE}	20	200	15 to <20 and >200 to 250	<15 and >250	—
SUBGROUP 3		20	15	7	10	5	3						
Tension	2036 Condition A							—	—	—	—	—	—
Solderability	2026							—	—	—	—	—	—
Temperature Cycling (5 cycles) $T_{(high)} = 100 {}^{+5}_{-0}$ °C 2N559 (1) $T_{(high)} = 150 \pm 5$ °C 2N559 (2), 2N559 (3)	1051 Condition B							—	—	—	—	—	—
Thermal Shock (Glass Strain)	1056 Condition A							—	—	—	—	—	—
Moisture Resistance	1021							—	—	—	—	—	—
End-Point Tests: Same as Subgroup 2													
SUBGROUP 4		20	15	7	10	5	3						
Shock (Non-operating; 5 blows: 1500 G in Orientations X_1, Y_1, Y_2, and Z_1 (total = 20 blows)	2016							—	—	—	—	—	—
Constant Acceleration (20,000 G, Orientations X_1, Y_1, Y_2, and Z_1)	2006							—	—	—	—	—	—
Vibration Fatigue (No bias applied)	2046							—	—	—	—	—	—
Vibration, Variable Frequency (1 cycle each in Orientations X_1, Y_1, and Z_1)	2056							—	—	—	—	—	—
End-Point Tests: Same as Subgroup 2													
SUBGROUP 5		20	15	7	10	5	3						
Terminal Strength - Lead Fatigue ②	2036 Condition E							—	—	—	—	—	—
SUBGROUP 6		20	—	—	10	—	—						
High-Temperature Life (Non-operating) ($T_{stg} = 100 {}^{+0}_{-5}$ °C 2N559 (1) ONLY	1031							—	—	—	—	—	—
End-Point Tests: Same as Subgroup 2													
SUBGROUP 7		—	20	3	—	7	1						
High-Temperature Life (Non-operating) ($T_{stg} = 150 {}^{+0}_{-5}$ °C) 2N559 (2), 2N559 (3)	1031							—	—	—	—	—	—
End-Point Tests: Same as Subgroup 2													
SUBGROUP 8		20	15	5	10	5	2						
Steady-State Operation Life ($I_E = 50 {}^{+0}_{-5}$ mAdc, $P_D = 150 {}^{+0}_{-15}$ mW, $T_A = 25 \pm 3$°C)	1026							—	—	—	—	—	—
End-Point Tests: Same as Subgroup 2													

NOTES: ① Total is defined as the sum of the major and minor defectives.

② Rejects from prior electrical-test samples from the same lot may be used for this test.

TABLE III – GROUP C INSPECTION*

Examination or Test	MIL-STD-750 Method	LTPD for Respective Reliability Level						Symbol	Limit				Unit
		Total ①			Major				Requirement Limit		Defect Classification		
		(1)	(2)	(3)	(1)	(2)	(3)		Min	Max	Minor	Major	
SUBGROUP 1		10	7	5	5	3	2						
Output Capacitance (V_{CB} = -5 Vdc, I_E = 0, f = 100 kHz)	3236							C_{ob}	—	6	>6 to 10	>10	pF
Current-Gain — Bandwidth Product (I_E = 10 mAdc, V_C = -1 Vdc, f = 100 MHz)	3261							f_T	300	1000	250 to <300 and >1000	<250	MHz
Delay Plus Rise Time (V_{CC} = -3.5 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_{B1} = -1 mAdc, R_C = 300 ohms, $C_{CB} = 2^{+0.5}_{-0}$ pF, C_{BE} = 2 ± 0.5 pF	3251 Condition A							$t_d + t_r$	—	50	>50 to 75	>75	ns
SUBGROUP 2		10	7	5	5	3	2						
Collector-Emitter Cutoff Current (V_{CE} = 5 Vdc, T_A = + 55°C)	3041 Condition C							I_{CES}	—	40	>40 to 50	>50	μAdc
DC Current Gain (I_C = -10 mAdc, V_{CE} = -0.5 Vdc, T_A = -55°C)	3076							h_{FE}	10	—	8 to <10	<8	—
SUBGROUP 3		20	15	7	10	5	3						
Salt Atmosphere (Corrosion) End-Point Tests: Same as Group B, Subgroup 2	1041							—	—	—	—	—	—
SUBGROUP 4		—	20	10	—	10	5						
High-Temperature Life (Non-operating) ($T_{stg} = 100^{+0}_{-5}$ °C)	1031							—	—	—	—	—	—
End-Point Tests:													
Emitter-Base Breakdown Voltage (I_E = -300 μAdc)	3026 Condition D							BV_{EBO}	5	—	3.5 to <5	<3.5	Vdc
Collector-Emitter Breakdown Voltage (I_C = -100 μAdc)	3011 Condition C							BV_{CES}	12	—	8 to <12	<8	Vdc
Collector-Emitter Saturation Voltage (I_C = -10 mAdc, I_B = -0.5 mAdc)	3071							$V_{CE(sat)}$	—	0.3	>0.3 to 0.6	>0.6	Vdc
Base-Emitter Saturation Voltage (I_C = -10 mAdc, I_B = -0.4 mAdc)	3066 Condition A							$V_{BE(sat)}$	0.31	0.47	0.25 to <0.31 and >0.47 to 0.55	<0.25 and >0.55	Vdc
Delay Time (V_{CC} = -3.5 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_{B1} = -0.55 mAdc, R_C = 300 ohms, C_{CE} = 150 pF, $C_{CB} = 2^{+0.5}_{-0}$ pF, C_{BE} = 2 ± 0.5 pF)	3251 Condition A							t_d	10	35	<10 and >35 to 45	>45	ns
Rise Time (V_{CC} = -3.5 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_{B1} = -0.55 mAdc, R_C = 300 ohms, C_{CE} = 150 pF, $C_{CB} = 2^{+0.5}_{-0}$ pF)	3251 Condition A							t_r	15	105	<15 and >105 to 125	>125	ns
Storage Time (V_{CC} = -3.5 Vdc, I_{B1} = -1 mAdc, I_{B2} = 0.25 mAdc, R_C = 300 ohms)	3251 Condition A							t_s	15	105	<15 and >105 to 125	>125	ns

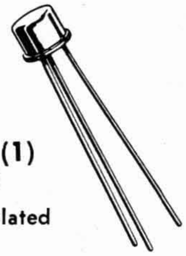
* Group C is to be performed on the first lot and every 6 months thereafter.

NOTE: ① Total is defined as the sum of the major and minor defectives.

2N618 (GERMANIUM)

For Specifications, See 2N375 Data.

2N650,A thru 2N652,A (GERMANIUM)



CASE 31(1)
(TO-5)
All leads isolated

PNP germanium transistor for switching and amplifier applications in the audio-frequency range. Available for military and high-reliability industrial purposes.

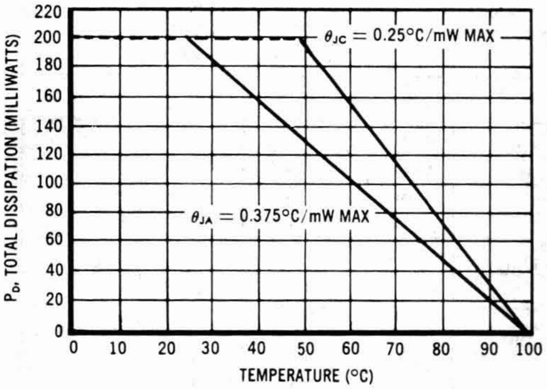
MAXIMUM RATINGS

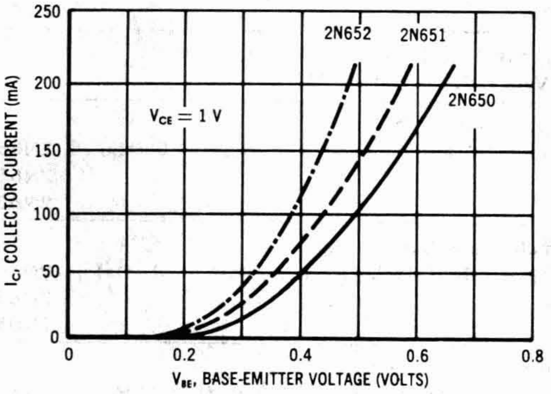
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CER}	30	Vdc
Collector-Base Voltage	V_{CB}	45	Vdc
Emitter-Base Voltage	V_{EB}	30	Vdc
Collector Current — Continuous	I_C	500*	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	200 2.67	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	°C

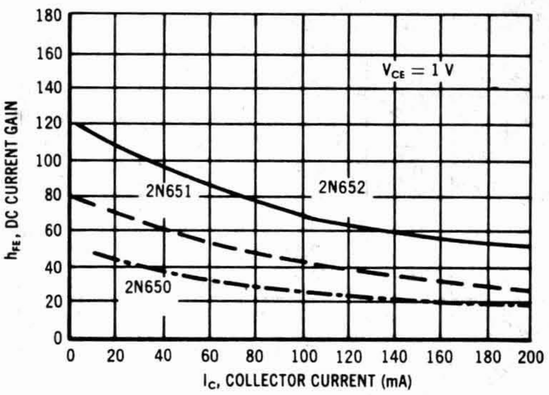
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.250	°C/mW
Thermal Resistance, Junction to Ambient	θ_{JA}	0.375	°C/mW

*Limited by power dissipation.


POWER-TEMPERATURE DERATING CURVE


COLLECTOR OUTPUT CURRENT versus BASE DRIVE VOLTAGE


h_{FE} versus COLLECTOR CURRENT

2N650 thru 2N652 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Punch-Thru Voltage (V_{CF} = 1.0 Vdc)		V_{pt}	45	–	–	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, R_{BE} = 10 k ohms)		I_{CER}	–	–	600	µAdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)		I_{CBO}	–	3.0	10	µAdc
(V_{CB} = 45 Vdc, I_E = 0)			–	–	50	
(V_{CB} = 10 Vdc, I_E = 0, T_A = +71°C			–	55	100	
Emitter Cutoff Current (V_{EB} = 30 Vdc, I_C = 0)		I_{EBO}	–	3.0	10	µAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N650	h_{FE}	33	44	–	–
	2N650A		33	44	90	
	2N651		45	75	–	
	2N651A		45	75	150	
	2N652		80	115	–	
	2N652A		80	115	250	
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 2.5 mAdc)	2N650	$V_{CE(sat)}$	–	0.175	0.250	Vdc
(I_C = 50 mAdc, I_B = 1.67 mAdc)	2N651		–	0.175	0.250	
(I_C = 50 mAdc, I_B = 1.25 mAdc)	2N652		–	0.175	0.250	
(I_C = 100 mAdc, I_B = 5.0 mAdc)	2N650		–	0.250	0.500	
(I_C = 100 mAdc, I_B = 3.33 mAdc)	2N651		–	0.250	0.500	
(I_C = 100 mAdc, I_B = 2.5 mAdc)	2N652		–	0.250	0.500	
Base-Emitter Voltage (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N650	V_{BE}	–	0.245	0.270	Vdc
	2N651		–	0.235	0.260	
	2N652		–	0.225	0.250	
SMALL-SIGNAL CHARACTERISTICS						
Common-Base Cutoff Frequency (I_E = 1.0 mAdc, V_{CB} = 6.0 Vdc)	2N650	f_{ab}	0.75	1.5	–	MHz
	2N651		1.0	2.0	–	
	2N652		1.25	2.5	–	
Output Capacitance (V_{CB} = 6.0 Vdc, I_E = 0)		C_{ob}	–	10	25	pF
Input Impedance (I_E = 1.0 mAdc, V_{CB} = 6.0 Vdc, f = 1.0 kHz)	2N650	h_{ib}	27	31	37	Ohms
	2N651		27	34	37	
	2N652		27	35	37	
Small-Signal Current Gain (I_E = 1.0 mAdc, V_{CE} = 6.0 Vdc, f = 1.0 kHz)	2N650	h_{fe}	30	49	70	–
	2N651		50	80	120	
	2N652		100	130	225	
Output Admittance (I_E = 1.0 mAdc, V_{CB} = 6.0 Vdc, f = 1.0 kHz)	2N650	h_{ob}	–	0.65	1.0	µmhos
	2N650A		0.3	0.65	1.0	
	2N651		–	0.60	0.9	
	2N651A		0.3	0.60	0.9	
	2N652		–	0.55	0.8	
	2N652A		0.3	0.55	0.8	
Noise Figure (I_E = 0.5 mAdc, V_{CE} = 4.5 Vdc, R_S = 1.0 k ohms, f = 1.0 kHz, Δf = 1.0 Hz)		NF	–	5.0	15	dB

2N653 thru 2N655 (GERMANIUM)

CASE 31(1)
(TO-5)

All leads isolated

PNP germanium transistor, for high-gain amplifier and switching service in the audio frequency range.

MAXIMUM RATINGS

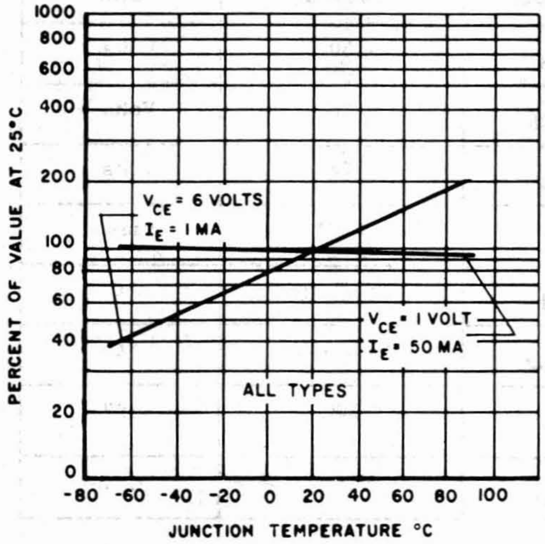
Rating	Symbol	Value	Unit
Collector to Base Voltage	V_{CB}	30	Volts
Collector to Emitter Voltage	V_{CER}	25	Volts
Emitter to Base Voltage	V_{EB}	25	Volts
Collector D. C. Current *	I_C	250*	mA
Junction Temperature Limits	T_J	-65 to +100	°C
Storage Temperature Limits	T_{stg}	-65 to +100	°C
Collector Dissipation in, Ambient Derate 2.67 mW/°C above 25°C	P_D	200	mW
Thermal Resistance, Junction to Ambient	θ_{JA}	0.375	°C/mW

*Limited by power dissipation.

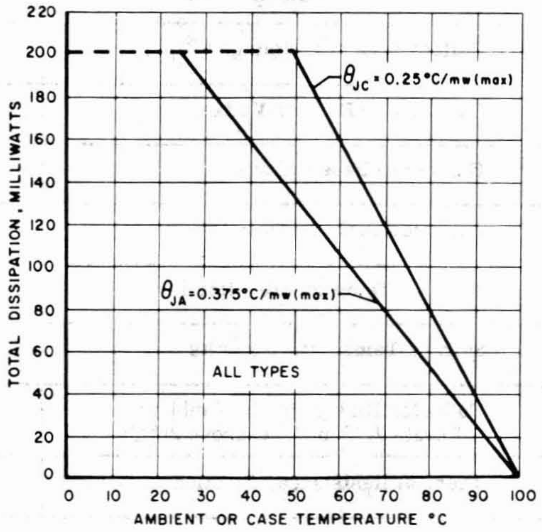
ELECTRICAL CHARACTERISTICS (TA = 25°C unless otherwise noted)

Characteristics	Symbol	2N653			2N654			2N655			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Small Signal Current Gain V_{CE} = 6 V, I_E = 1.0 mA, f = 1 kHz	h_{fe}	30	49	70	50	80	125	100	130	250	-
Small Signal Input Impedance V_{CE} = 6 V, I_E = 1.0 mA, f = 1 kHz	h_{ie}	750	-	2900	1500	-	4700	3000	-	8500	ohms
Small Signal Current Gain Cutoff Frequency V_{CB} = 6 V, I_E = 1.0 mA	$f_{\alpha b}$		1.5			2.0			2.5		MHz
Output Capacity V_{CB} = 6 V, I_E = 0 mA, f = 1 MHz	C_{ob}		10			10			10		pF
Noise Figure V_{CE} = 4.5 V, I_E = 0.5 mA, Rs = 1, f = kHz Δf = 1 Hz	NF		10			10			10		dB
Collector Reverse Current V_{CB} = 25 V, I_E = 0	I_{CBO}		5.0	15		5.0	15		5.0	15	μA
Emitter Reverse Current V_{EB} = 25 V, I_C = 0	I_{EBO}		5.0	15		5.0	15		5.0	15	μA
Collector-Emitter Reverse Current V_{CE} = 25 V, R_{BE} = 10 k	I_{CER}			600			600			600	μA
Base-Emitter Input Voltage V_{CE} = 6 V, I_C = 1.0 mA	V_{BE}			0.3			0.3			0.3	Vdc

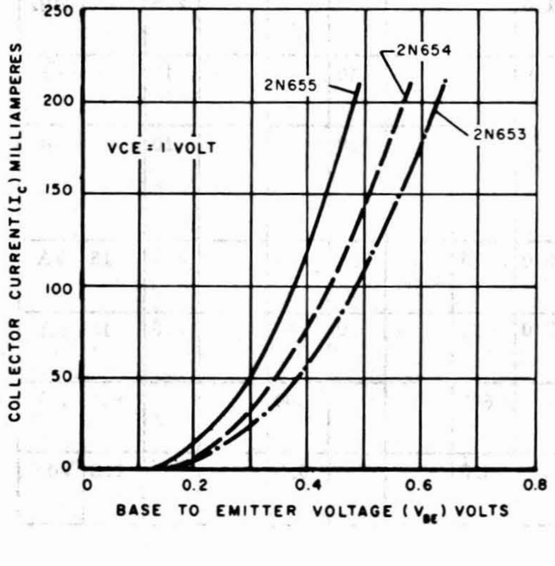
SMALL SIGNAL CURRENT GAIN (h_{fe}) versus TEMPERATURE



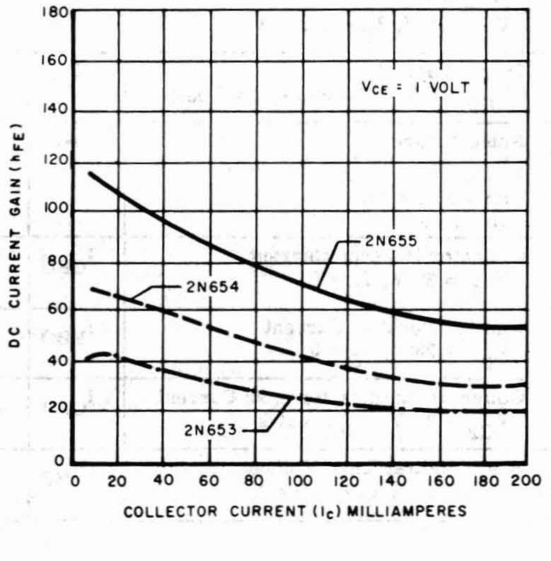
POWER-TEMPERATURE DERATING CURVE



OUTPUT CURRENT versus BASE DRIVE VOLTAGE



LARGE SIGNAL CURRENT GAIN versus COLLECTOR CURRENT BASE TO EMITTER VOLTAGE (V_{BE}) VOLTS



2N656 (SILICON)
2N657

CASE 31
(TO-5)

NPN silicon annular transistors designed for small-signal amplifier and general purpose switching applications.

MAXIMUM RATINGS

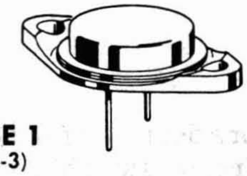
Rating	Symbol	2N656	2N657	Unit
Collector-Emitter Voltage	V_{CEO}	60	100	Vdc
Collector-Base Voltage	V_{CB}	60	100	Vdc
Emitter-Base Voltage	V_{EB}	8.0		Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	1.0 5.7		Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	4.0 22.8		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 250\ \mu Adc$, $I_B = 0$) 2N656 2N657	BV_{CEO}	60 100	- -	Vdc
Collector-Base Breakdown Voltage ($I_C = 100\ \mu Adc$, $I_E = 0$) 2N656 2N657	BV_{CBO}	60 100	- -	Vdc
Emitter-Base Breakdown Voltage ($I_E = 250\ \mu Adc$, $I_C = 0$)	BV_{EBO}	8.0	-	Vdc
Collector Cutoff Current ($V_{CB} = 30$ Vdc, $I_E = 0$)	I_{CBO}	-	10	μAdc
ON CHARACTERISTICS				
DC Current Gain* ($I_C = 200$ mAdc, $V_{CE} = 10$ Vdc)	h_{FE}*	30	90	-
Collector-Emitter Saturation Voltage* ($I_C = 200$ mAdc, $I_B = 40$ mAdc)	$V_{CE(sat)}$*	-	4.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Input Impedance* ($I_B = 8.0$ mAdc, $V_{CE} = 10$ Vdc)	h_{ie}*	-	0.5	k ohm

* Pulse Test: Pulse Length = 300 μs, Duty Cycle ≦ 2.0%.

2N665 (GERMANIUM)



CASE 1
(TO-3)

PNP germanium power transistor for driver and power output amplifier and power switching applications in military and industrial equipment.

MAXIMUM RATINGS

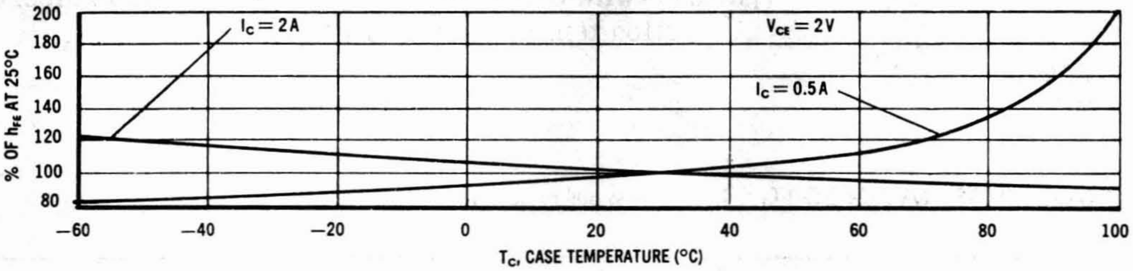
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	**80**	**Vdc**
Emitter-Base Voltage	V_{EB}	**40**	**Vdc**
DC Collector Current	I_C	3.0	**Amp**
DC Emitter Current	I_E	5.0	**Amp**
Collector Junction Temperature	T_J	**-65 to +95**	**°C**
Collector Dissipation **Derate above 25°C**	P_D	**35** **0.5**	**Watts** **W/°C**

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Emitter Cutoff Current (V_{EBO} = -40 Vdc, I_C = 0)	I_{EBO}	—	2.0	mAdc
Collector Cutoff Current (V_{CBO} = -2 Vdc, I_E = 0) (V_{CBO} = -60 Vdc, I_E = 0) (V_{CBO} = -80 Vdc, I_E = 0)	I_{CBO}	— — —	0.05 2.0 10	mAdc
DC Current Gain (V_{CE} = -2 Vdc, I_C = -0.5 Adc) (V_{CE} = -2 Vdc, I_C = -2 Adc)	h_{FE}	40 20	80 —	—
Emitter-Base Voltage (V_{CE} = -2 Vdc, I_C = -2 Adc)	V_{EB}	—	1.5	Vdc
Floating Potential (V_{CB} = -80 Vdc, voltmeter input resistance = 10 megohms min, t ≈ 1 sec)	V_{EBF}	—	1.0	Vdc
Collector-Emitter Saturation Voltage (I_C = -3 Adc, I_B = -220 mAdc)	$V_{CE\,(sat)}$	—	-0.9	Vdc
Collector-Emitter Voltage (I_C = -300 mAdc, I_B = 0)	V_{CEO}	40	—	Vdc
Small-Signal Short-Circuit Forward-Current Transfer-Ratio Cutoff Frequency (V_{CE} = -14 Vdc, I_C = -2 Adc)	$f_{\alpha e}$	20	—	kHz
Emitter Cutoff Current (V_{EBO} = -30 Vdc, I_C = 0, T_C = +71°C min)	I_{EBO}	—	2.0	mAdc
Collector Cutoff Current (V_{CBO} = -30 Vdc, I_E = 0, T_C = +71°C min)	I_{CBO}	—	2.0	mAdc

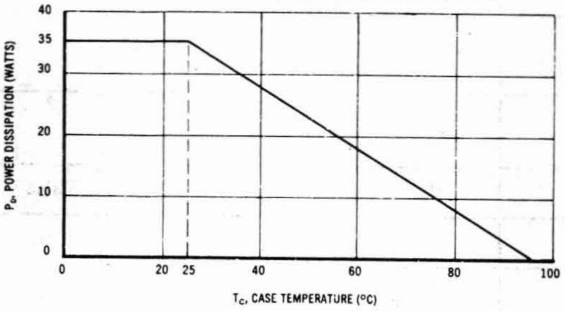
2N665 (continued)

h_{FE} versus TEMPERATURE

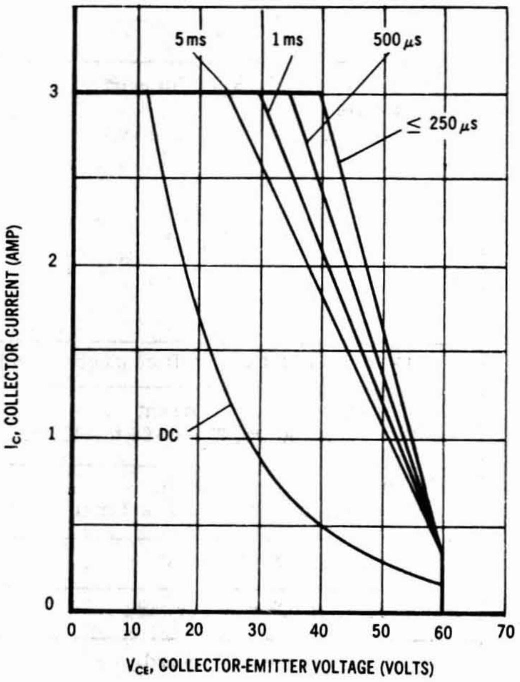


The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

POWER-TEMPERATURE DERATING CURVE



SAFE OPERATING AREA



2N669 (GERMANIUM)

For Specifications, See 2N176 Data.

2N681 thru 2N689 (SILICON)

CASE 64
(TO-48)

Industrial-type, silicon controlled rectifiers in a stud package with current handling capability to 25 amperes at junction temperatures to 125 °C.

MAXIMUM RATINGS (T_J = 125°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*†	$V_{ROM(rep)}$*†		Volts
2N681		25	
2N682		50	
2N683		100	
2N684		150	
2N685		200	
2N686		250	
2N687		300	
2N688		400	
2N689		500	
Peak Reverse Blocking Voltage* (Transient) (non-recurrent t = 5 ms max.)	$V_{ROM(non-rep)}$*		Volts
2N681		35	
2N682		75	
2N683		150	
2N684		225	
2N685		300	
2N686		350	
2N687		400	
2N688		500	
2N689		600	
Forward Current RMS (all conduction angles)	I_f	25	Amp
Peak Forward Surge Current (One cycle, 60 Hz, T_J = -65 to +125°C)	$I_{FM(surge)}$	200	Amp
Circuit Fusing Considerations (T_J = -65 to +125°C, t ≦ 8.3 ms)	I^2t	165	A^2s
Peak Gate Power-Forward	P_{GFM}	5.0	Watts
Average Gate Power-Forward	$P_{GF(AV)}$	0.5	Watt
Peak Gate Current-Forward	I_{GFM}	2.0	Amp
Peak Gate Voltage-Forward Reverse	V_{GFM} V_{GRM}	10 5.0	Volts
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C
Stud Torque	—	30	in. lb.

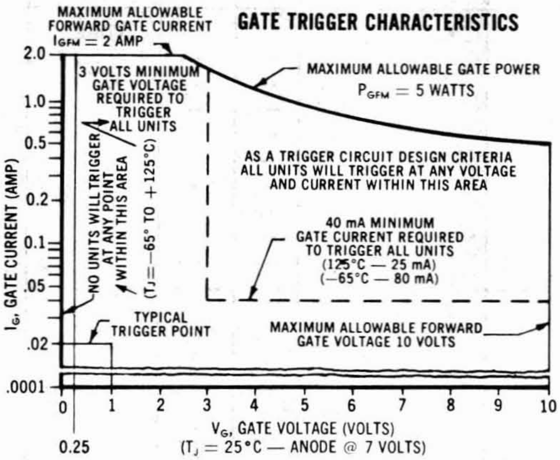
†V_{ROM} for all types can be applied on a continuous dc basis without incurring change.

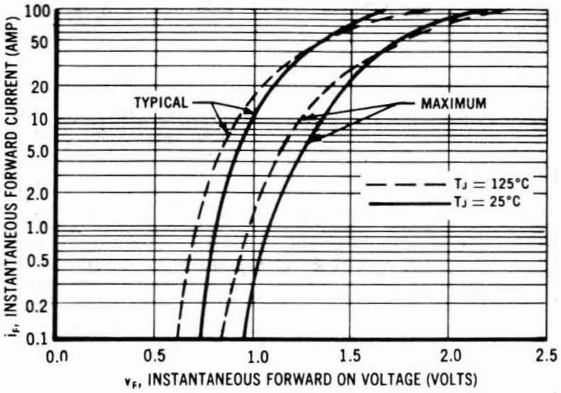
* $V_{ROM(rep)}$ ratings apply for zero or negative gate voltage.

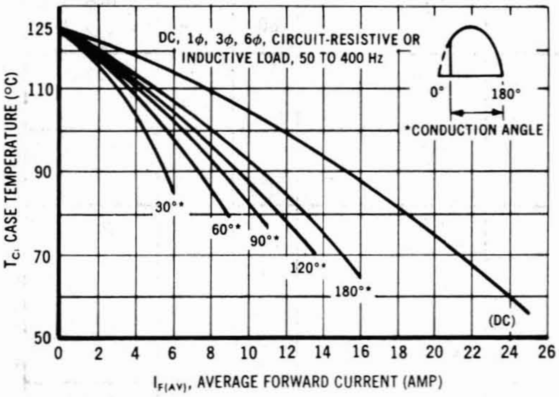
2N681 thru 2N689 (continued)

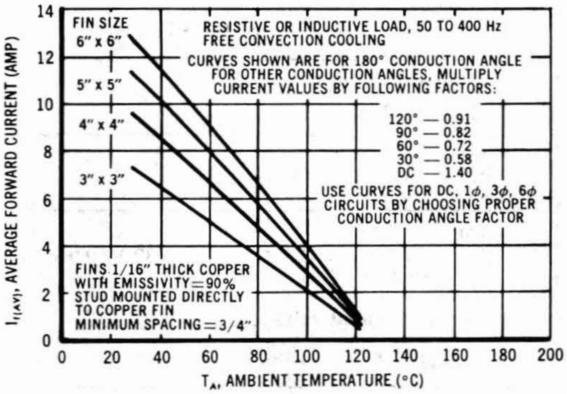
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage (T_J = 125°C)	2N681 2N682 2N683 2N684 2N685 2N686 2N687 2N688 2N689	V_{FOM}	25 50 100 150 200 250 300 400 500	— — — — — — — — —	— — — — — — — — —	Volts
Peak Forward or Reverse Blocking Current (T_J = 125°C)	2N681 - 2N684 2N685 2N686 2N687 2N688 2N689	I_{FOM} I_{ROM}	— — — — — —	— — — — — —	10.0 10.0 10.0 10.0 8.0 6.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50 Ω)		I_{GT}	—	10	25	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50 Ω)		V_{GT}	0.25	—	3.0	Volts
Holding Current (Anode Voltage = 7 Vdc, Gate Open)		I_{HO}	—	20	—	mA
Forward On Voltage (I_F = 20 Adc)		V_F	—	1.1	1.5	Volts
Turn-On Time (I_F = 10A, I_G = 200 mA)		t_{on}	—	1.0	—	μs
Turn-Off Time (I_F = 10 A; I_R = 10 A, dv/dt = 30 V/μs min, T_J = 125°C) (V_{FXM} = rated voltage) (V_{RXM} = rated voltage)		t_{off}	—	30	—	μs
Forward Voltage Application Rate (Gate open, T_J = 125°C)		dv/dt	—	30	—	V/μs
Thermal Resistance (Junction to Case)		θ_{JC}	—	1.0	2.0	°C/W


GATE TRIGGER CHARACTERISTICS


FORWARD CONDUCTING CHARACTERISTICS


CURRENT DERATING


SUGGESTED FIN SIZES

2N696 (SILICON)
2N697

CASE 31
(TO-5)

NPN silicon annular transistors designed for small-signal amplifier and general purpose switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CER}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.6 13.3	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	2.0 13.3	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 100 mAdc, R_{BE} = 10 ohms)		BV_{CER}*	40		Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	60		Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	5.0		Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)		I_{CBO}	- -	1.0 100	μAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N696 2N697	h_{FE}*	20 40	60 120	-
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE(sat)}$*	-	1.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{BE(sat)}$*	-	1.3	Vdc
DYNAMIC CHARACTERISTICS					
Current Gain–Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N696 2N697	f_T	40 50	- -	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)		C_{ob}	-	35	pF

* Pulse Test: Pulse Length $\leqq$ 12 ms, Duty Cycle $\leqq$ 2.0%.

2N699 (SILICON)

CASE 79
(TO-39)

NPN silicon annular transistor designed for medium-current switching and amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CER}	80	Vdc
Collector-Base Voltage	V_{CB}	120	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation $T_A = 25°C$ Derate above 25°C	P_D	0.6 4.0	Watt mW/°C
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	2.0 13.3	Watts mW/°C
Operating Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	75	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	250	°C/W

2N699 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* ($I_C = 100$ mAdc, $R_{BE} \leq 10$ ohms)	BV_{CER}*	80	-	Vdc
Collector Cutoff Current ($V_{CB} = 60$ Vdc, $I_E = 0$) ($V_{CB} = 60$ Vdc, $I_E = 0$, $T_A = 150°C$)	I_{CBO}	- -	2.0 200	μAdc
Emitter Cutoff Current ($V_{EB} = 2.0$ Vdc, $I_C = 0$)	I_{EBO}	-	100	μAdc
ON CHARACTERISTICS				
DC Current Gain* ($I_C = 150$ mAdc, $V_{CE} = 10$ Vdc)	h_{FE}*	40	120	-
Collector-Emitter Saturation Voltage* ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{CE(sat)}$*	-	5.0	Vdc
Base-Emitter Saturation Voltage* ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{BE(sat)}$*	-	1.3	Vdc
SMALL SIGNAL CHARACTERISTICS				
Current-Gain — Bandwidth Product ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc, f = 20 MHz)	f_T	50	-	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 100 kHz)	C_{ob}	-	20	pF
Input Impedance ($I_C = 1.0$ mAdc, $V_{CB} = 5.0$ Vdc, f = 1.0 kHz) ($I_C = 5.0$ mAdc, $V_{CB} = 10$ Vdc, f = 1.0 kHz)	h_{ib}	20 -	30 10	ohms
Voltage Feedback Ratio ($I_C = 1.0$ mAdc, $V_{CB} = 5.0$ Vdc, f = 1.0 kHz) ($I_C = 5.0$ mAdc, $V_{CB} = 10$ Vdc, f = 1.0 kHz)	h_{rb}	- -	2.5 3.0	$X\ 10^{-4}$
Small-Signal Current Gain ($I_C = 1.0$ mAdc, $V_{CE} = 5.0$ Vdc, f = 1.0 kHz) ($I_C = 5.0$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)	h_{fe}	35 45	100 -	-
Output Admittance ($I_C = 1.0$ mAdc, $V_{CB} = 5.0$ Vdc, f = 1.0 kHz) ($I_C = 5.0$ mAdc, $V_{CB} = 10$ Vdc, f = 1.0 kHz)	h_{ob}	0.1 -	0.5 1.0	μmhos

* Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2%.

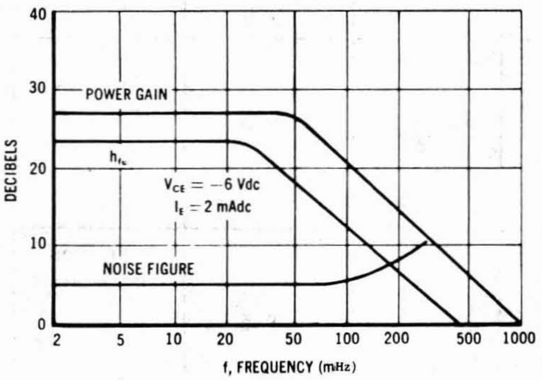
2N700, A (GERMANIUM)

CASE 21
(TO-17)

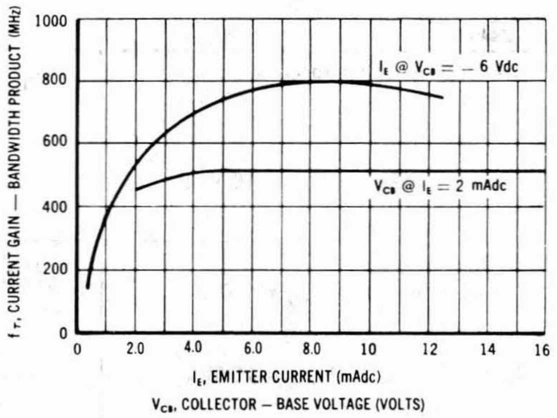
PNP germanium mesa transistors for oscillator, frequency multiplier, wide-band mixer and wide-band amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Vdc
Collector-Emitter Voltage 2N700 2N700A	V_{CEO}	 20 25	Vdc
Emitter-Base Voltage	V_{EB}	0.2	Vdc
Collector DC Current	I_C	50	mAdc
Junction Temperature	T_J	100	°C
Storage Temperature	T_{stg}	-65 to +100	°C
Total Device Dissipation at 25°C Ambient (Derate 1 mW/°C above 25°C)	P_D	75	mW



POWER GAIN, CURRENT GAIN, & NOISE FIGURE versus FREQUENCY



CURRENT-GAIN-BANDWIDTH PRODUCT versus CURRENT AND VOLTAGE

2N700,A (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Sym	Test Conditions	Types	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	I_C = 100 μAdc, I_E = 0	All Types	25	32	---	Vdc
Collector-Emitter Breakdown Voltage	BV_{CEO}	I_C = 100 μAdc, I_B = 0	2N700 2N700A	20 25	— —	— —	Vdc
Emitter-Base Breakdown Voltage	BV_{EBO}	I_E = 100 μAdc, I_C = 0	All Types	0.2	0.5	—	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 6 Vdc, I_E = 0 V_{CB} = 6 Vdc, I_E = 0, T_A = 85°C	All Types 2N700 2N700A	— — —	0.4 60 —	2 150 50	μAdc
Small Signal Forward Current Transfer Ratio	h_{fe}	I_E = 2 mAdc, V_{CE} = 6 Vdc, f = 1 kHz I_E = 5 mAdc, V_{CE} = 6 Vdc, f = 1 kHz I_E = 2 mAdc, V_{CE} = 6 Vdc, f = 200 MHz	All Types 2N700A 2N700 2N700A	4 — 2.5 5	10 — 7 —	— 50 — —	— — dB dB
Input Impedance	h_{ib}	I_E = 2 mAdc, V_{CB} = 6 Vdc, f = 1 kHz	All Types	—	17	30	Ohms
Base Resistance	r'_b	I_E = 2 mAdc, V_{CB} = 6 Vdc, f = 300 MHz	All Types	—	55	100	Ohms
Collector-Base Output Capacitance (case grounded)	C_{ob}	V_{CB} = 6 Vdc, I_E = 0, f = 100 kHz	2N700 2N700A	— —	1.1 —	1.5 1.4	pF
Power Gain	G_e	I_E = 2 mAdc, V_{CB} = 6 Vdc, f = 70 MHz (neutralized)	2N700 2N700A	20 22	23 —	— —	dB
Noise Figure	NF		All Types	—	6	10	dB
Power Gain	G_e	I_E = 2 mAdc, V_{CB} = 6 Vdc, f = 30 MHz (neutralized)	2N700A	26	—	—	

2N702 (SILICON)
2N703

NPN silicon annular transistors designed for low-level, high-speed switching applications.

CASE 22
(TO-18)

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 2.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	600 4.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 2.0 mAdc, I_B = 0)	BV_{CEO}	25	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 5.0 μAdc, I_E = 0)	BV_{CBO}	25	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, I_B = 0)	I_{CEO}	-	-	10	μAdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0) (V_{CB} = 10 Vdc, I_E = 0, T_A = +150°C)	I_{CBO}	- -	- -	0.5 50	μAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 5.0 Vdc) 2N702	h_{FE}*	20	-	60	-
2N703		40	-	100	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc, T_A = -55°C) 2N702		12	-	-	
2N703		20	-	-	
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$*	-	-	0.5	Vdc
Base-Emitter On Voltage* (I_C = 10 mAdc, V_{CE} = 5.0 Vdc)	$V_{BE(on)}$*	0.7	-	0.95	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain – Bandwidth Product (I_E = 10 mAdc, V_{CE} = 5.0 Vdc, f = 100 MHz)	f_T	70	150		MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	3.0	6.0	pF

*Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2.0%.

2N705 (GERMANIUM)

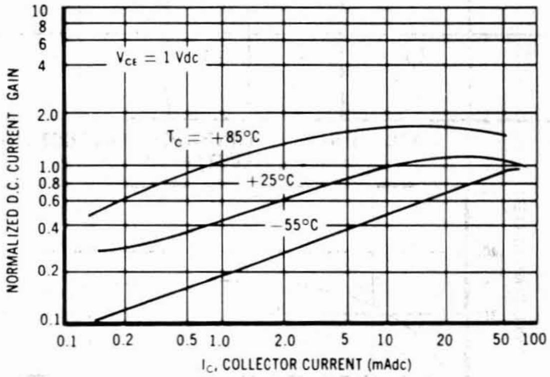
CASE 22
(TO-18)

PNP germanium mesa transistor for high-speed switching applications.

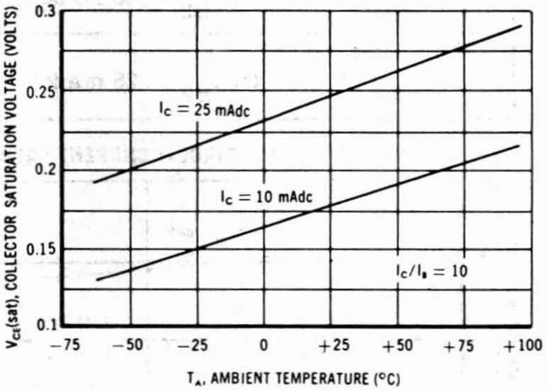
Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	15	Vdc
Collector-Emitter Voltage	V_{CES}	15	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector Current	I_C	50	mAdc
Emitter Current	I_E	50	mAdc
Junction Temperature	T_J	100	°C
Storage Temperature	T_{stg}	-65°C to +100	°C
Collector Dissipation @ T_C = 25°C Derate above 25°C	P_C	300 4.0	mW mW/°C
Collector Dissipation in Free Air	P_C	150	mW



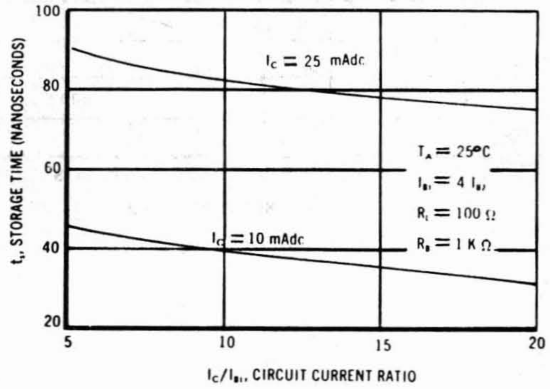
NORMALIZED D.C. CURRENT GAIN
versus COLLECTOR CURRENT

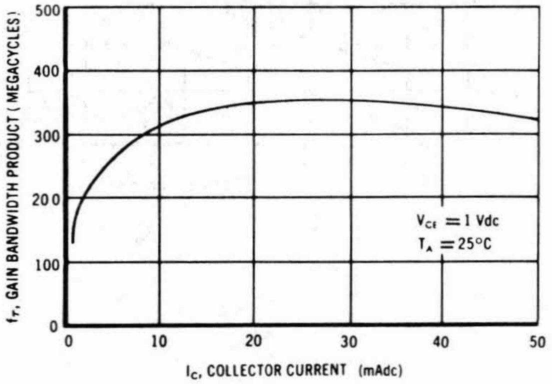


COLLECTOR SATURATION VOLTAGE
versus AMBIENT TEMPERATURE

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 µAdc, I_E = 0)	BV_{CBO}	15	–	–	Vdc
Collector-Emitter Breakdown Voltage (I_{CE} = 100 µAdc, V_{BE} = 0)	BV_{CES}	15	–	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 µAdc, I_C = 0)	BV_{EBO}	3.5	–	–	Vdc
Collector Cutoff Current (V_{CB} = 5 Vdc, I_E = 0)	I_{CBO}	–	0.2	3	µAdc
DC Forward Current Transfer Ratio (V_{CE} = .3 Vdc, I_C = 10 mAdc)	h_{FE}	25	40	–	–
Collector Saturation Voltage (I_B = .4 mAdc, I_C = 10 mAdc)	$V_{CE(sat)}$	–	0.18	0.3	Vdc
(I_B = 5 mAdc, I_C = 50 mAdc)		–	0.45	–	
Base-Emitter Voltage (I_B = .4 mAdc, I_C = 10 mAdc)	V_{BE}	0.34	0.39	0.44	Vdc
Small Signal Forward Current Transfer Ratio (V_{CE} = 1.0 Vdc, I_C = 10 mAdc, f = 100 MHz)	h_{fe}	–	9	–	
Collector Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	–	5.0	–	pF
Input Capacitance (V_{BE} = 2 Vdc)	C_{ib}	–	3.5	–	pF
Common Base Alpha Cutoff Frequency (V_{CB} = 5 Vdc, I_C = 10 mAdc)	$f_{\alpha b}$	–	300	–	MHz
Delay + Rise Time (I_C = 10 mAdc, I_B = 1 mAdc)	$t_d + t_r$	–	55	75	ns
Storage Time (I_{B1} = 1.0 mAdc, I_{B2} = .25 mAdc)	t_s	–	65	100	ns
Fall Time (I_{B1} = 1.0 mAdc, I_{B2} = .25 mAdc)	t_f	–	70	100	ns


STORAGE TIME versus CIRCUIT CURRENT RATIO


CURRENT GAIN — BANDWIDTH PRODUCT (f_T) versus COLLECTOR CURRENT

2N706, A, B (SILICON)
2N753

CASE 22
(TO-18)
Collector connected to case

NPN silicon annular switching transistors for high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Volts
Collector-Emitter Voltage *	V_{CER}*	20	Volts
Emitter-Base Voltage 2N706	V_{EB}	3	Volts
2N706A		5	
2N706B		5	
2N753		5	
Junction Temperature	T_J	175	°C
Storage Temperature	T_{stg}	-65 to +175	°C
Total Device Dissipation at 25° C Case Temperature (Derate 6.67 mW/°C above 25°C)	P_D	1.0	Watt
Total Device Dissipation at 25° C Ambient Temperature (Derate 2 mW/°C above 25°C)	P_D	0.3	Watt
Total Device Dissipation at 100°C Case Temperature (Derate 6.67 mW/°C above 100°C)	P_D	0.5	Watt

**Refers to collector breakdown voltage in the high current region when* $R_{be} = 10\Omega$

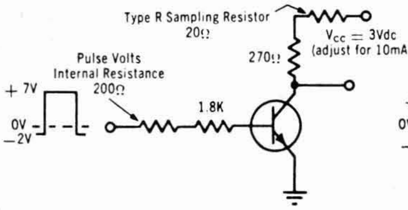
ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Type	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current (V_{CB} = 15Vdc, I_E = 0) (V_{CB} = 15Vdc, I_E = 0, T_A = 150 °C) (V_{CB} = 25Vdc, I_E = 0)	All Types All Types 2N706A, 2N706B, 2N753	I_{CBO}	- - -	0.005 3 -	0.5 30 10	μAdc
Collector-Emitter Cutoff Current (V_{CE} = 20Vdc, R_{be} = 100k)	2N706A, 2N706B, 2N753	I_{CER}	-	-	10	μAdc
Emitter Cutoff Current (V_{EB} = 3Vdc, I_c = 0) (V_{EB} = 5Vdc, I_c = 0)	2N706 2N706A, 2N706B, 2N753	I_{EBO}	- -	- -	10 10	μAdc
Collector-Emitter Breakdown Voltage * (I_C = 10mAdc, I_B = 0)		BV_{CEO}*	15		-	Vdc
Collector-Emitter Breakdown Voltage* (R = 10 ohms, I_c = 10mAdc)		BV_{CER}*	20		-	Vdc
Forward-Current Transfer Ratio* (I_c = 10mAdc, V_{CE} = 1Vdc)	2N706 2N706A, 2N706B, 2N753	h_{FE} *	20 20 40	40 40 -	- 60 120	
Base-Emitter Voltage* (I_c = 10mAdc, I_B = 1mAdc)	2N706 2N706A, 2N706B, 2N753	V_{BE} (sat)*	- 0.7	0.75 0.75	0.9 0.9	Vdc
Collector Saturation Voltage* (I_c = 10mAdc, I_B = 1mAdc) (I_c = 50mAdc, I_B = 5mAdc)	2N706, 2N706A 2N706B 2N753 2N753	V_{CE} (sat)*	- - - -	0.3 0.3 0.18 0.3	0.6 0.4 0.6 -	Vdc
Collector Capacitance (V_{CB} = 5Vdc, I_E = 0 (V_{CB} = 10Vdc, I_E = 0)	2N706A, 2N706B, 2N753 2N706	C_{ob}	- -	4.5 5	5 6	pF
Small-Signal Forward Current Transfer Ratio (V_{CE} = 15Vdc, I_E = 10mAdc, f = 100MHz)		h_{fe}	2	4	-	-
Current Gain-Bandwidth Product (V_{CE} = 15Vdc, I_E = 10mAdc, f = 100 MHz)		f_T	-	400	-	MHz
Base Resistance (V_{CE} = 15Vdc, I_E = 10mAdc, f = 300 MHz)		r_b'	-	39	50	ohms
Charge Storage Time Constant	2N706 2N706A 2N753	τ_s**	- - -	16 16 19	60 25 35	ns
Storage Time	2N706B	t_s	-	19	25	ns
Turn-On Time		t_{on}**	-	30	40	ns
Turn-Off Time		t_{off}**	-	50	75	ns

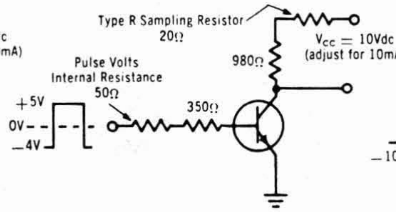
* Pulse Test: PW ≤ 12 ms, Duty Cycle ≤ 2%

** Switching Times Measured with Tektronix Type R Plug-In (50Ω Internal Impedance) and Circuits Shown Below.

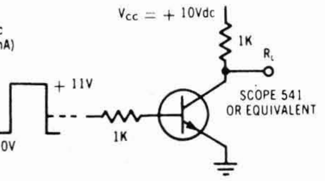
SWITCHING TIME TEST CIRCUIT


Type R Sampling Resistor
20Ω
Pulse Volts
Internal Resistance
200Ω
270Ω
V_{cc} = 3Vdc
(adjust for 10mA)
+ 7V
0V
−2V
1.8K

STORAGE TIME TEST CIRCUIT


Type R Sampling Resistor
20Ω
Pulse Volts
Internal Resistance
50Ω
980Ω
V_{cc} = 10Vdc
(adjust for 10mA)
+5V
0V
−4V
350Ω

MEASUREMENT CIRCUIT


V_{cc} = + 10Vdc
1K
R_L
+ 11V
−10V
1K
SCOPE 541
OR EQUIVALENT

2N707, A (SILICON)

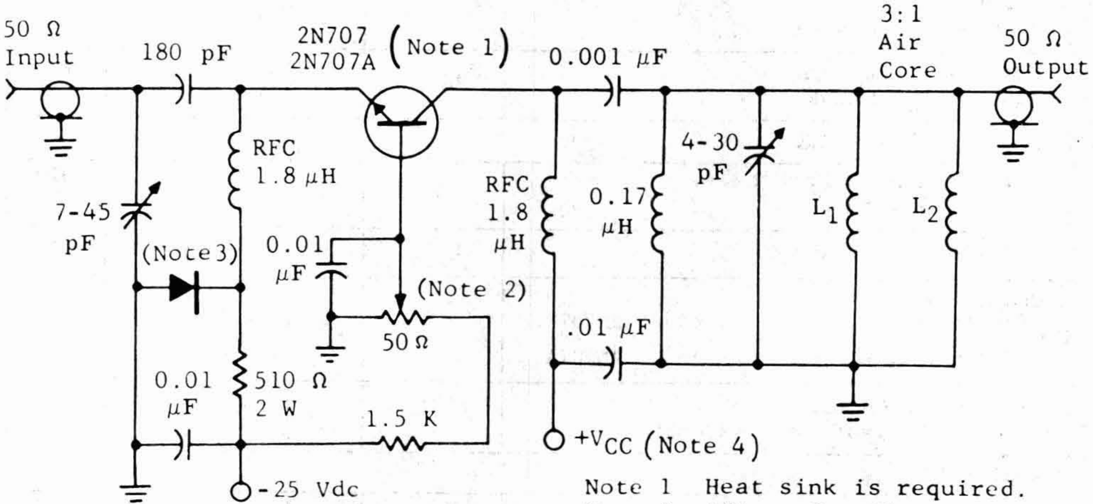
CASE 22
(TO-18)

NPN silicon epitaxial mesa transistors for VHF oscillator and class C amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N707	2N707A	Unit
Collector-Emitter Voltage	V_{CEO}	-	40	Vdc
Collector-Emitter Voltage ($R_{BE} \leq$ 10 ohms)	V_{CER}	28	-	Vdc
Collector-Base Voltage	V_{CB}	56	70	Vdc
Emitter-Base Voltage	V_{EB}	4	5	Vdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	0.3 2	0.5 3.33	Watt $mW/^oC$
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	1.0 6.67	1.2 8	Watts $mW/^oC$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175		^oC


50 Ω
Input
180 pF
2N707
2N707A
(Note 1)
0.001 μF
3:1
Air
Core
50 Ω
Output
RFC
1.8 μH
7-45
pF
(Note 3)
0.01
μF
(Note 2)
50 Ω
RFC
1.8
μH
0.17
μH
4-30
pF
L1
L2
.01 μF
0.01
μF
510 Ω
2 W
1.5 K
-25 Vdc
+VCC (Note 4)

L_1 5 turns #14 wire wound on 1/2" diameter.

L_2 2 turns #14 wire wound on L_1.

Note 1 Heat sink is required.
Note 2 Adjust for Class C operation.
Note 3 Very High conductance silicon diode.
Note 4 Adjust V_{CC} for proper V_{CE}

FIGURE 1 – 100 MHz, CLASS C, COMMON BASE AMPLIFIER

2N707,A (continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise specified)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage* (I_C = 20 mAdc, I_B = 0)	2N707A	BV_{CEO}*	40	-	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, R_{BE} = 10 ohms)	2N707	BV_{CER}	28	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N707 2N707A	BV_{CBO}	56 70	- -	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	2N707A	BV_{EBO}	5	-	-	Vdc
Collector Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 15 Vdc, I_E = 0)	2N707		-	0.005	5.0	
(V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	2N707		-	3.0	-	
(V_{CB} = 30 Vdc, I_E = 0)	2N707A		-	0.01	1.0	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	2N707A		-	5.0	100	
Emitter Cutoff Current		I_{EBO}				μAdc
(V_{BE} = 4 Vdc, I_C = 0)	2N707		-	-	10	
(V_{BE} = 5 Vdc, I_C = 0)	2N707A		-	-	100	
ON CHARACTERISTICS						
DC Current Gain (I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N707 2N707A	h_{FE}	9 9	12 -	- 50	-
Collector Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{CE(sat)}$	-	0.18	0.6	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{BE(sat)}$	-	0.75	0.9	Vdc
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_E = 15 mAdc, V_{CE} = 10 Vdc)		f_T	70	350	-	MHz
Maximum Frequency of Oscillation		f_{max}	-	600	-	MHz
Output Capacitance		C_{ob}				pF
(V_{CB} = 10 Vdc, I_E = 0)	2N707		-	4.0	10.0	
(V_{CB} = 5 Vdc, I_E = 0)	2N707A		-	4.0	6.0	
Collector-Base Time Constant (I_C = 10 mAdc, V_{CB} = 10 Vdc, f = 4 MHz)		$r'_b C_c$	-	80	-	ps
FUNCTIONAL TEST						
Power Output (Figure 1)		P_{out}				mW
(V_{CE} = 20 Vdc, P_{in} = 50 mW)	All Types		200	300	-	
(V_{CE} = 40 Vdc, P_{in} = 175 mW)	2N707A		400	-	-	
100-MHz Oscillator Efficiency (V_{CE} = 28 Vdc, I_C = 40 mAdc)		η	-	38	-	%

***Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.**

2N708 (SILICON)

NPN silicon annular transistor for high-speed switching applications.

CASE 22
(TO-18)
Collector
connected to case

***MAXIMUM RATINGS**

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ $T_A = 25^\circ C$ Derate above 25°C	P_D	360 2.0	mW mW/°C
Total Device Dissipation @ $T_C = 25^\circ C$ $T_C = 100^\circ C$ Derate above 25°C Derate above 100°C	P_D	1.2 680 6.9 6.9	Watts mW mW/°C mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	−65 to +200	°C

*Indicates JEDEC Registered Data.

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 30 mAdc, I_B = 0)	BV_{CEO}	15	-	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 30 mAdc, $R_{BE} \leq$ 10 ohms)	BV_{CER}	20	-	-	Vdc
*Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	BV_{CBO}	40	-	-	Vdc
*Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	-	Vdc
†Collector Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0.25 Vdc, T_A = +125°C)	I_{CEX}	-	-	10	μAdc
*Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.005 -	0.025 15	μAdc
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	-	0.08	μAdc
ON CHARACTERISTICS					
*DC Current Gain (I_C = 0.5 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (Note 1) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C) (Note 1)	h_{FE}	15 30 15	- - -	- 120 -	-
*Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 7.0 mAdc, I_B = 0.7 mAdc, T_A = -55°C to +125°C)	$V_{CE(sat)}$	- -	0.2 -	0.4 0.4	Vdc
*Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 7.0 mAdc, I_B = 0.7 mAdc, T_A = -55°C)	$V_{BE(sat)}$	0.72 -	- -	0.80 0.90	Vdc
DYNAMIC CHARACTERISTICS					
††Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	450	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, 100 kHz ≤ f ≤ 1.0 MHz)	C_{ob}	-	3.0	6.0	pF
*Extrinsic Base Resistance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 300 MHz)	r_b'	-	-	50	ohms
*Storage Time ($I_C = I_{B1} = I_{B2}$ = 10 mAdc)	t_s	-	15	25	ns

*Indicates JEDEC Registered Data.
†JEDEC Registration Defined as V_{CB} = 20 Vdc.
††JEDEC Registration Defined as h_{fe}.
Note 1: Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N711,A,B (GERMANIUM)

CASE 22
(TO-18)

PNP germanium mesa transistors for high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N711	2N711A	2N711B	Unit
Collector-Base Voltage	V_{CB}	12	15	18	Vdc
Collector-Emitter Voltage	V_{CES}	12	14	15	Vdc
Collector-Emitter Voltage	V_{CEO}	—	7	7	Vdc
Emitter-Base Voltage	V_{EB}	1	1.5	2	Vdc
Collector Current (Continuous)	I_C	50	100	100	mAdc
Emitter Current (Continuous)	I_E	50	100	100	mAdc
Junction Temperature	T_J	← 100 →			°C
Storage Temperature	T_{stg}	← -65 to + 100 →			°C
Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	← 300 → ← 4 →			mW mW/°C
Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	← 150 → ← 2 →			mW mW/°C

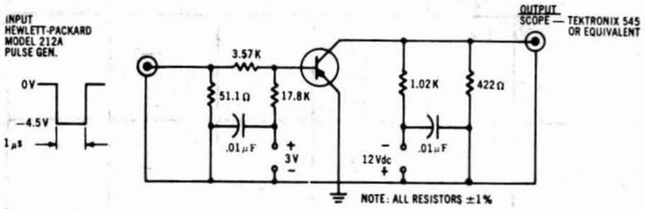
2N711,A,B (continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic		Sym	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage		BV_{CBO}				Vdc
(I_C = 100 µAdc, I_E = 0)	2N711		12	—	—	
	2N711A		15	—	—	
(I_C = 20 µAdc, I_E = 0)	2N711B		18	—	—	
Collector-Emitter Breakdown Voltage		BV_{CES}				Vdc
(I_C = 100 µAdc)	2N711		12	—	—	
	2N711A		14	—	—	
(I_C = 20 µAdc)	2N711B		15	—	—	
Collector-Emitter Breakdown Voltage		BV_{CEO}				Vdc
(I_C = 5 mAdc, I_B = 0)	2N711A, 2N711B		7	—	—	
Emitter-Base Breakdown Voltage		BV_{EBO}				Vdc
(I_E = 0.1 mAdc, I_C = 0)	2N711		1.0	—	—	
	2N711A		1.5	—	—	
	2N711B		2.0	—	—	
Collector-Base Cutoff Current		I_{CBO}				µAdc
(V_{CB} = 5 Vdc, I_E = 0)	2N711		—	0.2	3.0	
	2N711A		—	—	1.5	
(V_{CB} = 10 Vdc, I_E = 0)	2N711B		—	—	1.5	
Emitter-Base Cutoff Current		I_{EBO}				µAdc
(V_{EB} = 1 Vdc)	2N711A		—	—	100	
	2N711B		—	—	20	
DC Current Gain		h_{FE}				—
(I_C = 10 mAdc, V_{CE} = 0.5 Vdc)	2N711		20	30	—	
	2N711A		25	—	150	
	2N711B		30	—	150	
(I_C = 50 mAdc, V_{CE} = 0.7 Vdc)	2N711A, 2N711B		40	—	—	
Collector Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 10 mAdc, I_B = 0.5 mAdc)	2N711		—	0.2	0.5	
	2N711A		—	—	0.30	
(I_C = 10 mAdc, I_B = 0.4 mAdc)	2N711B		—	—	0.25	
(I_C = 50 mAdc, I_B = 2 mAdc)	2N711A		—	—	0.55	
	2N711B		—	—	0.45	
Small-Signal Current Gain		h_{fe}				—
(I_C = 10 mAdc, V_{CE} = 5 Vdc, f = 100 MHz)	2N711A, 2N711B		1.5	—	—	
(I_C = 10 mAdc, V_{CE} = 0.5 Vdc, f = 100 MHz)	2N711A		1.1	—	—	
	2N711B		1.2	—	—	
Base-Emitter Voltage		V_{BE}				Vdc
(I_C = 10 mAdc, I_B = 0.4 mAdc)	2N711, 2N711A		0.30	0.38	0.44	
	2N711B		0.30	—	0.44	
(I_C = 50 mAdc, I_B = 2 mAdc)	2N711A		0.40	—	0.65	
	2N711B		0.40	—	0.65	
Collector Output Capacitance		C_{ob}				pF
(V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)	2N711A, 2N711B		—	—	6	
(V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	2N711		—	5.0	—	
Fall Time		t_f				ns
Figure 1:	2N711A		—	—	150	
	2N711B		—	—	110	
Figure 2:	2N711A		—	—	110	
	2N711B		—	—	100	
	2N711		—	90	150	
Minority Carrier Storage Time		t_s				ns
Figure 1:	2N711A		—	—	150	
	2N711B		—	—	140	
Figure 2:	2N711A		—	—	120	
	2N711B		—	—	100	
	2N711		—	90	200	
Delay Plus Rise Time		$t_d + t_r$				ns
Figure 1:	2N711A, 2N711B		—	—	100	
Figure 2:	2N711A, 2N711B		—	—	75	
	2N711		—	70	100	

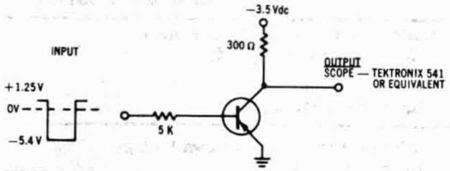
SWITCHING CIRCUITS

FIGURE 1

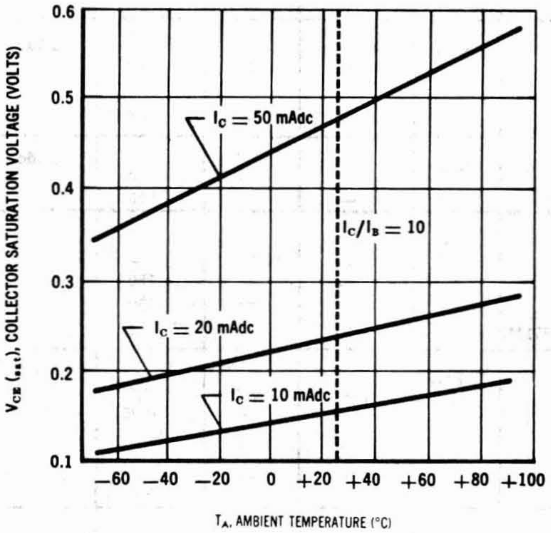

INPUT
HEWLETT-PACKARD
MODEL 212A
PULSE GEN.
0V
−4.5V
1 µs
3.57K
51.1 Ω
17.8K
.01 µF
+
3V
−
−
12Vdc
+
1.02K
.01 µF
422 Ω
OUTPUT
SCOPE — TEKTRONIX 545
OR EQUIVALENT

NOTE: ALL RESISTORS ±1%

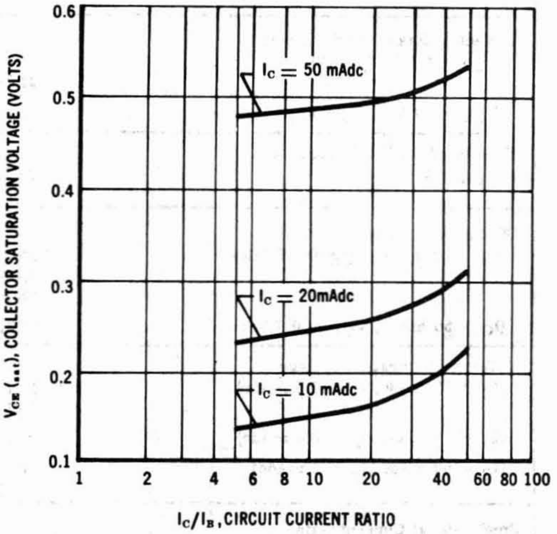
FIGURE 2


INPUT
+1.25V
0V
−5.4V
5 K
−3.5 Vdc
300 Ω
OUTPUT
SCOPE — TEKTRONIX 541
OR EQUIVALENT

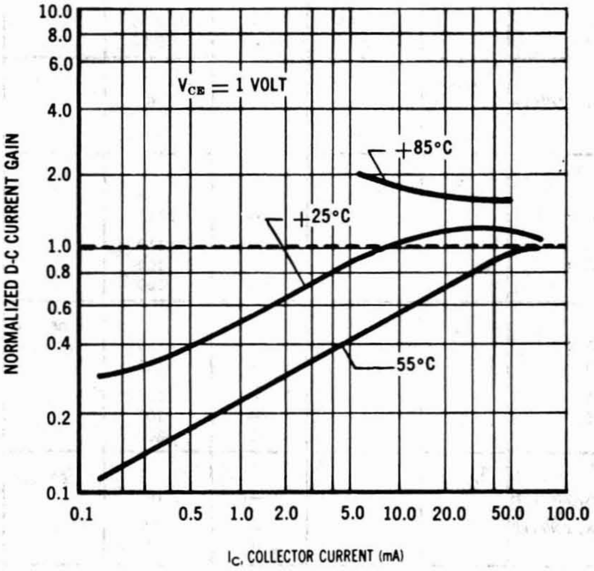
RISE AND FALL TIME < 1 ns
PULSE WIDTH 0.5 µs
SKL MOD. 503 OR EQUIVALENT



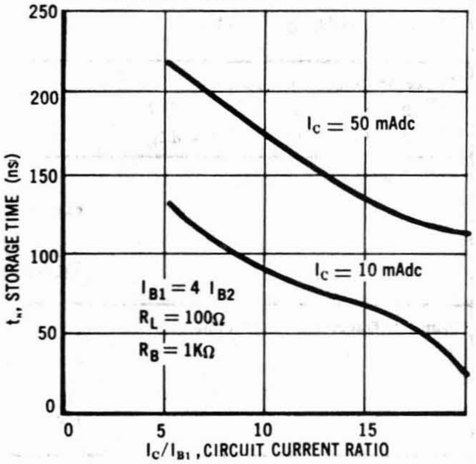
COLLECTOR SATURATION VOLTAGE versus AMBIENT TEMPERATURE



COLLECTOR SATURATION VOLTAGE STORAGE TIME versus CIRCUIT CURRENT RATIO



NORMALIZED DC CURRENT GAIN versus COLLECTOR CURRENT



STORAGE TIME versus CIRCUIT CURRENT RATIO

2N718 (SILICON)
2N1420

2N718
CASE 22
(TO-18)

2N1420
CASE 31
(TO-5)

NPN silicon annular Star transistors for medium-current switching and amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	60		Vdc
Collector-Emitter Voltage 2N718 2N1420	V_{CER}	 40 30		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
		2N1420 TO-5	2N718 TO-18	
Total Device Dissipation at 25°C Case Temperature Derating Factor Above 25°C	P_D	3 20	1.5 10	Watts mW/°C
Total Device Dissipation at 25°C Ambient Temperatures Derating Factor Above 25°C	P_D	0.6 4.0	0.4 2.66	Watts mW/°C
Junction Temperature	T_J	+ 175		°C
Storage Temperature range	T_{stg}	-65 to + 200		°C

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 – –	 .001 –	 1.0 100	μAdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	60	–	–	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, pulsed; $R_B \leq$ 10 Ohms) 2N718 2N1420	BV_{CER}	 40 30	 – –	 – –	Vdc
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}{}^*$	–	0.3	1.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}{}^*$	–	–	1.3	Vdc

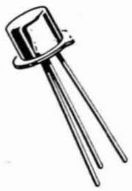
*Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2%

ELECTRICAL CHARACTERISTICS (continued)

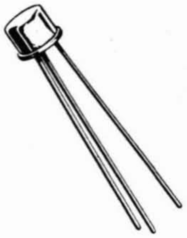
Characteristic	Symbol	Min	Typ	Max	Unit
DC Forward Current Transfer Ratio*	h_{FE} *				–
(I_C = 1 mAdc, V_{CE} = 10 Vdc)					
2N718		–	20	–	
2N1420		–	35	–	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)					
2N718		40	–	120	
2N1420		100	–	300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)					
2N718		–	20	–	
2N1420		–	35	–	
Small Signal Forward Current Transfer Ratio (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	h_{fe}	2.5	15	–	–
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)	C_{ob}	–	5	35	pF

*Pulse Test: PW ≦ 300 μs, Duty Cycle ≦ 2%

2N718A (SILICON)
2N956
2N1613
2N1711



CASE 22
(TO-18)
2N718A
2N956



CASE 31
(TO-5)
2N1613
2N1711

Collector connected to case

NPN silicon annular Star transistors for high-speed switching and DC to UHF amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N718A 2N956	2N1613 2N1711	Unit
Collector-Emitter Voltage	V_{CER}	50		Vdc
Collector-Base Voltage	V_{CB}	75		Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Total Device Dissipation @ $T_A = 25°C$	P_D	500	800	mW
Derate above 25°C		2.86	4.57	mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D	1.8	3.0	Watts
Derate above 25°C		10.3	17.1	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

2N718A, 2N956, 2N1613, 2N1711 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, pulsed; $R_{BE} \le$ 10 ohms)		BV_{CER}	50	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	75	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	7.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)		I_{CBO}	-	0.001	0.01	μAdc
(V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)			-	-	10	
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	2N718A, 2N1613	I_{EBO}	-	-	0.010	μAdc
	2N956, 2N1711		-	-	0.005	
ON CHARACTERISTICS						
DC Current Gain (I_C = 0.01 mAdc, V_{CE} = 10 Vdc)	2N956, 2N1711	h_{FE}	20	-	-	-
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N718A, 2N1613		20	-	-	
	2N956, 2N1711		35	-	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N718A, 2N1613		35	-	-	
	2N956, 2N1711		75	-	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N718A, 2N1613		20	-	-	
	2N956, 2N1711		35	-	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)*	2N718A, 2N1613		40	-	120	
	2N956, 2N1711		100	-	300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)*	2N718A, 2N1613		20	-	-	
	2N956, 2N1711		40	-	-	
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE(sat)}$*	-	0.24	1.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{BE(sat)}$*	-	1.0	1.3	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N718A, 2N1613	f_T	60	300	-	MHz
	2N956, 2N1711		70	300		
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	4.0	25	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	-	20	80	pF
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ib}	24	-	34	ohms
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)			4.0	-	8.0	
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N718A, 2N1613	h_{rb}	-	-	3.0	X 10^{-4}
	2N956, 2N1711		-	-	5.0	
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	2N718A, 2N1613		-	-	3.0	
	2N956, 2N1711		-	-	5.0	
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N718A, 2N1613	h_{fe}	30	-	100	-
	2N956, 2N1711		50	-	200	
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N718A, 2N1613		35	-	150	
	2N956, 2N1711		70	-	300	
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ob}	0.1	-	0.5	μmho
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)			0.1	-	1.0	
Noise Figure (I_C = 300 μAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N718A, 2N1613	NF	-	-	12	dB
	2N956, 2N1711		-	-	8.0	

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N720A (SILICON)

CASE 22
(TO-18)

NPN silicon annular transistor designed for small-signal amplifier and general purpose switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	80	Vdc
Collector-Emitter Voltage	V_{CER}	100	Vdc
Collector-Base Voltage	V_{CB}	120	Vdc
Emitter-Base Voltage	V_{EB}	7.0	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.5 2.86	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.8 10.3	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	97	°C/W

2N720A (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 30 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	80	-	Vdc
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, R_{BE} = 10 ohms)	$BV_{CER(sus)}$*	100	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	120	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current (V_{CB} = 90 Vdc, I_E = 0) (V_{CB} = 90 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	10 15	nAdc μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	10	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc)* (I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C) (I_C = 150 mAdc, V_{CE} = 10 Vdc)*	h_{FE}	20 35 20 40	- - - 120	-
Collector-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5.0 mAdc) (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$*	- -	1.2 5.0	Vdc
Base-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5.0 mAdc) (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$*	- -	0.9 1.3	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	50	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	15	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	85	pF
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz) (I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	h_{ib}	20 4.0	30 8.0	Ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz) (I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	h_{rb}	- -	1.25 1.50	X 10^{-4}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	30 45	100 -	-
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz) (I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	h_{ob}	- -	0.5 0.5	μmhos

* Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

2N721 (SILICON)

CASE 22
(TO-18)

PNP silicon annular transistor for high-frequency general-purpose amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	35	Vdc
Collector-Emitter Voltage	V_{CER}	50	Vdc
Collector - Base Voltage	V_{CB}	50	Vdc
Emitter - Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ T_A=25°C (Derate above 25°C)	P_D	0.40 2.67	Watts mW/°C
Total Device Dissipation @ T_C=25°C T_C=100°C (Derate above 25°C)	P_D	1.5 0.75 10	Watts mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

2N721 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	35	-	Vdc
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, R_{BE} ≦ 100 ohms)	$BV_{CER(sus)}$*	50	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	50	-	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 - -	 1.0 100	μAdc
Emitter Cutoff Current (V_{BE} = 2.0 Vdc, I_C = 0)	I_{EBO}	-	100	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 150 mAdc, V_{CE} = 10 Vdc) (I_C = 5.0 mAdc, V_{CE} = 10 Vdc)	h_{FE}*	 20 15	 45 -	-
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$	-	1.5	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	-	1.3	Vdc
SMALL SIGNAL CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	50	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	45	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0)	C_{ib}	-	100	pF
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz) (I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	h_{ib}	 25 -	 35 10	ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz) (I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	h_{rb}	 - -	 8.0 8.0	$X10^{-4}$
Small Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) (I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	 15 20	 50 -	
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz) (I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	h_{ob}	 - -	 1.0 5.0	μmhos

* Pulse Test: Pulse Width = 300 μs; Duty Cycle = 1.0%

2N722
2N1132
2N1132A
2N2303

PNP SILICON SWITCHING TRANSISTORS

CASE 22
(TO-18)
2N722

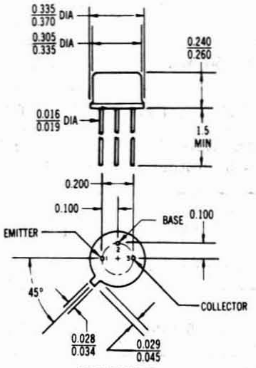
CASE 31
(TO-5)
2N1132
2N1132A
2N2303

PNP SILICON ANNULAR TRANSISTORS

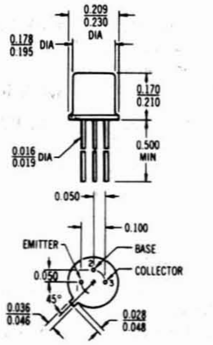
. . . designed for medium-current switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N722	2N1132	2N1132A	2N2303	Unit
Collector-Emitter Voltage	V_{CEO}	35	35	40	35	Vdc
Collector-Emitter Voltage ($R_{BE} \leq$ 10 Ohms)	V_{CER}	50	50	50	50	Vdc
Collector-Base Voltage	V_{CB}	50	50	60	50	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	5.0	5.0	Vdc
Collector Current	I_C	-	-	600	500	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	400 2.67	600 4.0	600 4.0	600 4.0	mW mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.5 10	2.0 13.3	2.0 13.3	2.0 13.3	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to +175				°C
Storage Temperature Range	T_{stg}	-65 to +300				°C


0.335/0.370 DIA
0.305/0.335 DIA
0.240/0.260
0.016/0.019 DIA
1.5 MIN
0.200
0.100
BASE
0.100
EMITTER
COLLECTOR
45°
0.028/0.034
0.029/0.045
1
2
3

TO-5 OUTLINE
(Collector internally connected to case)


0.209/0.230 DIA
0.178/0.195 DIA
0.170/0.210
0.016/0.019 DIA
0.500 MIN
0.050
0.100
EMITTER
BASE
COLLECTOR
0.050
45°
0.036/0.046
0.028/0.048
1
2
3

TO-18 OUTLINE
(Collector internally connected to case)

2N722, 2N1132, 2N1132A, 2N2303 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 100 mAdc, I_B = 0)	2N722, 2N1132, 2N2303 2N1132A	BV_{CEO}*	35 40	- -	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 100 mAdc, $R_{BE} \leq$ 10 Ohms)		BV_{CER}*	50	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N722, 2N1132, 2N2303 2N1132A	BV_{CBO}	50 60	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	2N722, 2N1132, 2N2303	BV_{EBO}	5.0	-	Vdc
(I_E = 1.0 mAdc, I_C = 0)	2N1132A		5.0	-	
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)	2N722, 2N1132, 2N2303	I_{CBO}	-	1.0	μAdc
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	2N722, 2N1132, 2N2303		-	100	
(V_{CB} = 50 Vdc, I_E = 0)	2N1132A		-	0.5	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	2N1132A		-	50	
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	2N1132A	I_{EBO}	-	100	μAdc
(V_{BE} = 2.0 Vdc, I_C = 0)	2N2303		-	100	
ON CHARACTERISTICS					
DC Current Gain (I_C = 5.0 mAdc, V_{CE} = 10 Vdc)	2N722, 2N1132, 2N1132A 2N2303	h_{FE}	25 75	- -	-
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N722, 2N1132, 2N1132A 2N2303		30 75	90 200	
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE(sat)}$	-	1.5	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{BE(sat)}$	-	1.3	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain–Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)		f_T	60	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	2N722, 2N1132, 2N2303	C_{ob}	-	45	pF
(V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	2N1132A		-	30	
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	-	80	pF
Input Resistance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ib}	25	35	Ohms
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)			-	10	
Voltage Feedback Ratio (I_C = 1.0 Adc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)		h_{rb}	-	8.0	X 10^{-4}
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)			-	8.0	
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N722, 2N1132 2N1132A 2N2303	h_{fe}	25 25 75	100 75 300	-
(I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N722, 2N1132, 2N1132A 2N2303		30 75	- -	
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)		h_{ob}	-	1.0	μmhos
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)			-	5.0	

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N731 (SILICON)

NPN silicon transistor designed primarily for large-signal, medium-power audio-frequency applications in industrial service.

CASE 22
(TO-18)

Collector electrically connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage (R_{BE} = ≦ 10 ohms)	V_{CER}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current — Continuous	I_C	1.0	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.5 3.33	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.5 10	Watts mW/°C
Operating Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 100 mAdc, R_{BE} = 10 ohms)	BV_{CER}*	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	1.0 100	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 150 mAdc, V_{CE} = 10 Vdc)	h_{FE}	40	120	-
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$*	-	1.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$*	-	1.3	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	25	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	35	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	-	80	pF

* Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2.0%.

2N735 (SILICON)
2N736
2N739
2N740

CASE 22
(TO-18)

NPN silicon annular transistors designed for small-signal amplifier and general purpose switching applications.

Collector electrically
connected to case

MAXIMUM RATINGS

Rating	Symbol	2N735 2N736	2N739 2N740	Unit
Collector-Emitter Voltage	V_{CEO}	60	80	Vdc
Collector-Base Voltage	V_{CB}	80	125	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	1.0		Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	500 2.86		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

Lead Temperature, 1/16" ± 1/32" from case for 10 s.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	2N735, 2N736 2N739, 2N740	BV_{CEO}^*	60 80	- -	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N735, 2N736 2N739, 2N740	BV_{CBO}	80 125	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0)		I_{CBO}	-	1.0	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	10	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc)	2N735, 2N739 2N736, 2N740	h_{FE}	30 60	100 200	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 2.0 mAdc)		$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 2.0 mAdc)		V_{BE}	0.35	1.5	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)		C_{ob}	-	10	pF
Input Impedance (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N735, 2N739 2N736, 2N740	h_{ie}	- -	1500 1800	Ohm
Small-Signal Current Gain (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 Hz)	2N735, 2N739 2N736, 2N740	h_{fe}	40 80	100 200	-

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N741,A (GERMANIUM)

CASE 22
(TO-18)

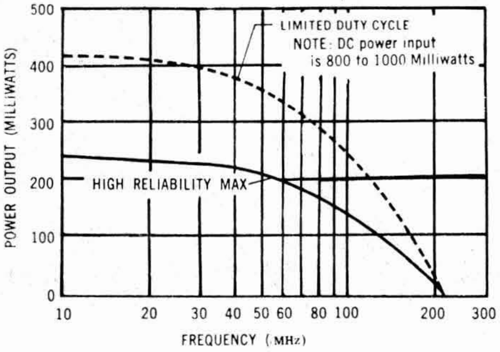
PNP germanium mesa transistors for oscillator, frequency multiplier and amplifier applications.

Collector connected to case

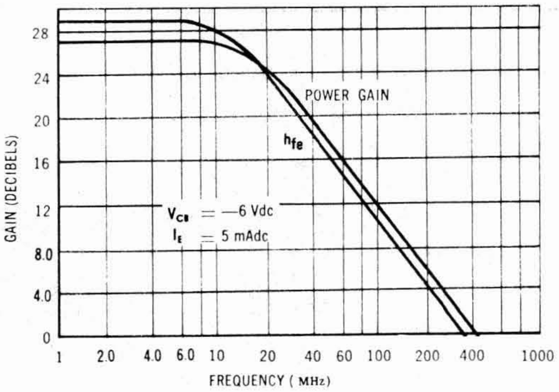
MAXIMUM RATINGS

Rating	Symbol	2N741	2N741A	Unit
Collector-Emitter Voltage	V_{CE}	15	20	Vdc
Collector-Base Voltage	V_{CB}	15	20	Vdc
Emitter-Base Voltage	V_{EB}	1.0		Vdc
Collector Current	I_C	100		mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	150 2		mW mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	300 4		mW mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100		^oC

POWER OUTPUT versus FREQUENCY, CLASS C AMPLIFIER



POWER GAIN AND COMMON EMITTER CURRENT GAIN versus FREQUENCY



2N741,A (continued)

ELECTRICAL CHARACTERISTICS (at 25°C unless otherwise specified)

Characteristic		Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS						
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N741 2N741A	BV_{CBO}	15 20	- -	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	1.0	-	-	Vdc
Collector Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0) (V_{CE} = 20 Vdc, V_{BE} = 0)	2N741 2N741A	I_{CES}	- -	- -	100 100	μAdc
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)		I_{CBO}	-	0.2	3	μAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 5 mAdc, V_{CE} = 6 Vdc)		h_{FE}	10	25	-	-
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_E = 5 mAdc, V_{CB} = 6 Vdc, f = 100 MHz)	2N741 2N741A	f_T	- 300	360 360	- -	MHz
Output Capacitance (V_{CB} = 6 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	6	10	pF
Collector Capacitance (V_{CB} = 6 Vdc, I_E = 0, f = 100 kHz)		C_c	-	3	-	pF
Small-Signal Current Gain (I_C = 5 mAdc, V_{CE} = 6 Vdc, f = 1 kHz)		h_{fe}	20	-	-	-
Output Admittance (I_E = 5 mAdc, V_{CB} = 6 Vdc, f = 1 kHz)		h_{ob}	-	45	-	μmhos
Input Impedance (I_E = 5 mAdc, V_{CB} = 6 Vdc, f = 1 kHz)		h_{ib}	-	8	15	Ohms
Base Resistance (I_E = 5 mAdc, V_{CB} = 6 Vdc, f = 300 MHz)	2N741 2N741A	r'_b	- -	75 65	- -	Ohms
Noise Figure (I_E = 5 mAdc, V_{CB} = 6 Vdc, f = 30 MHz)		NF	-	7	-	dB
Power Gain, Matched, Neutralized (V_{CB} = 6 Vdc, I_E = 5 mAdc, f = 30 MHz)		G_{pe}	16	22	-	dB
Power Output (I_C = 60 mAdc, V_{CB} = 6 Vdc, G_{pe} = 8 dB, f = 30 MHz)		P_{out}	- -	200 250	- -	mW
Power Output (I_C = 60 mAdc, V_{CB} = 6 Vdc, G_{pe} = 5 dB, f = 70 MHz)		P_{out}	-	200	-	mW

2N743 (SILICON)

CASE 22
(TO-18)

NPN silicon annular transistor designed for high-speed, low-current, saturated switching operations.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Collector-Base Voltage	V_{CB}	20	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current - Continuous	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 1.71	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

SWITCHING TEST CIRCUITS

FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT

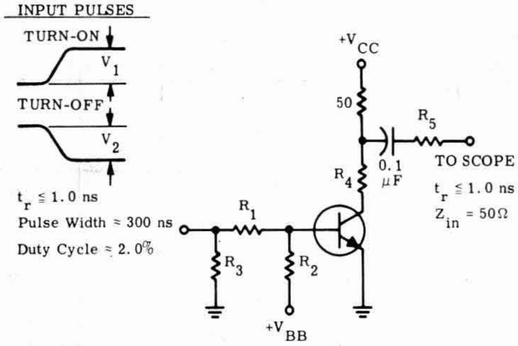
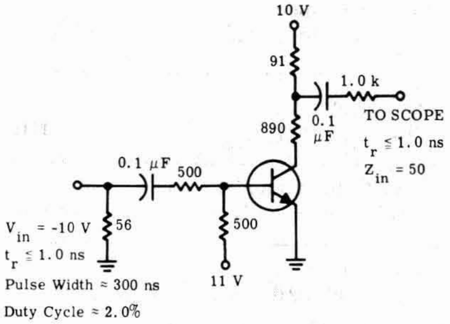

INPUT PULSES
TURN-ON
V_1
TURN-OFF
V_2
$t_r \leq 1.0$ ns
Pulse Width ≈ 300 ns
Duty Cycle ≈ 2.0%
$+V_{CC}$
50
R_5
0.1 μF
TO SCOPE
$t_r \leq 1.0$ ns
$Z_{in} = 50\Omega$
R_4
R_1
R_3
R_2
$+V_{BB}$

FIGURE 2 — CHARGE-STORAGE TIME TEST CIRCUIT


10 V
91
1.0 k
890
0.1 μF
TO SCOPE
$t_r \leq 1.0$ ns
$Z_{in} = 50$
0.1 μF
500
56
500
11 V
$V_{in} = -10$ V
$t_r \leq 1.0$ ns
Pulse Width ≈ 300 ns
Duty Cycle ≈ 2.0%

CIRCUIT CONDITIONS									
	(VOLTS)					(OHMS)			
	t_{on}		t_{off}						
Condition	V_1	V_{BB}	V_2	V_{BB}	V_{CC}	$R_1 = R_2$	R_3	R_4	R_5
1	15	-3.0	-15	+12	3.0	3.3 k	50	220	-
2	20	-4.5	-20	+15.3*	6.0	330	56	-	1.0 k

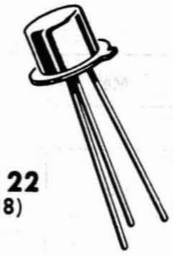
* V_{BB} is pulsed for 1.5 s at less than 10% Duty Cycle to maintain $T_C < 30°C$.

2N743 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	12	-	Vdc
Collector-Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0)	I_{CES}	-	1.0	μAdc
(V_{CE} = 20 Vdc, V_{BE} = 0, T_A = 170°C)		-	100	
Collector Cutoff Current (V_{CE} = 10 Vdc, $V_{EB(off)}$ = 0.35 Vdc, T_A = 100°C)	I_{CEX}	-	30	μAdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	-	1.0	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	10	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 1.0 mAdc, V_{CE} = 0.25 Vdc)	h_{FE}	10	-	-
(I_C = 10 mAdc, V_{CE} = 0.35 Vdc)		20	60	
(I_C = 10 mAdc, V_{CE} = 0.35 Vdc, T_A = -55°C)		10	-	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)		10	-	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = 170°C)	$V_{CE(sat)}$	-	0.35	Vdc
(I_C = 100 mAdc, I_B = 10 mAdc, T_A = 170°C)		-	1.0	
(I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = -55°C)		-	1.1	
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	0.65	0.85	Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = -55°C)		-	1.1	
(I_C = 100 mAdc, I_B = 10 mAdc)		-	1.5	
(I_C = 100 mAdc, I_B = 10 mAdc, T_A = -55°C)		-	1.6	
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	282	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	5.0	pF
Turn-On Time (V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = 1.5 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, Condition 1)	t_{on}	-	16	ns
(V_{CC} = 6.0 Vdc, $V_{BE(off)}$ = 2.4 Vdc, I_C = 100 mAdc, I_{B1} = 40 mAdc, Figure 1, Condition 2)		-	12	
Turn-Off Time (V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.5 mAdc, Condition 1)	t_{off}	-	24	ns
(V_{CC} = 6.0 Vdc, I_C = 100 mAdc, I_{B1} ≈ 40 mAdc, I_{B2} ≈ 20 mAdc, Figure 1, Condition 2)		-	40	
Storage Time (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc, V_{CC} = 10 Vdc, Figure 2)	t_s	-	14	ns

2N744 (SILICON)



CASE 22
(TO-18)

NPN silicon annular transistor for high-speed switching applications.

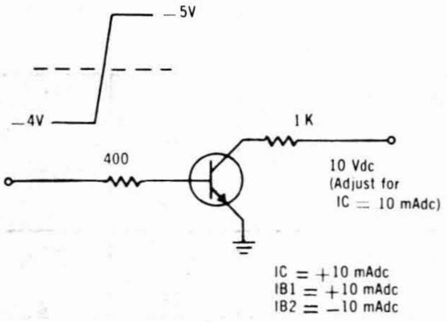
Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	20	Vdc
Collector-Emitter Voltage*	V_{CEO}	12*	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector DC Current	I_C	200	mAdc
Total Device Dissipation at 25°C Case Temperature (Derate 6.67 mW/°C above 25°C)	P_D	1.0	Watt
Total Device Dissipation at 25°C Ambient Temperature Derate above 25°C	P_D	0.3 2.0	Watt mW/°C
Junction Temperature	T_J	+200	°C
Storage Temperature	T_{stg}	-65 to +200	°C

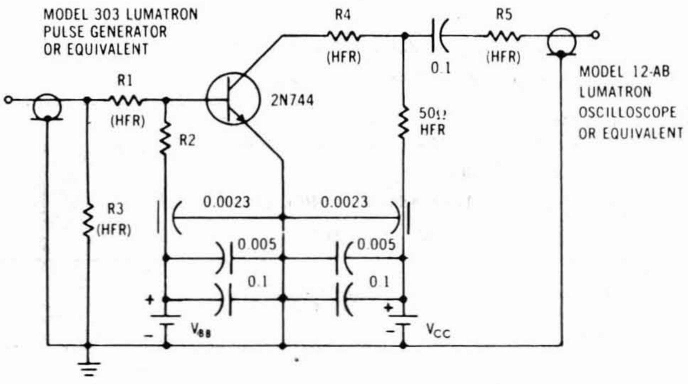
*Refers to the voltage at which the magnitude of h_{FE} approaches one when the emitter-base diode is open-circuited.

SWITCHING TIME TEST CIRCUIT



—5V
—4V
400
1 K
10 Vdc
(Adjust for
IC = 10 mAdc)
IC = +10 mAdc
IB1 = +10 mAdc
IB2 = —10 mAdc

CHARGE STORAGE TEST CIRCUIT



MODEL 303 LUMATRON
PULSE GENERATOR
OR EQUIVALENT
R1
(HFR)
R2
R3
(HFR)
2N744
R4
(HFR)
0.1
R5
(HFR)
50Ω
HFR
MODEL 12-AB
LUMATRON
OSCILLOSCOPE
OR EQUIVALENT
0.0023
0.0023
0.005
0.005
0.1
0.1
+
-
V_{BB}
+
-
V_{CC}

2N744 (continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current (V_{CE} = 20 Vdc, I_E = 0) (V_{CE} = 20 Vdc, I_B = 0, T_A = 170°C)	I_{CES}	– –	.005 –	1.0 100	μAdc
Collector Cutoff Current (V_{CE} = 10 Vdc, V_{BE} = 0.35 Vdc, T_A = 100°C)	I_{CEX}	–	–	30	μAdc
Emitter Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)	I_{EBO}	–	–	10	μAdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)*	BV_{CEO}	12	30	–	Vdc
Forward Current Transfer Ratio (I_C = 1.0 mAdc, V_{CE} = 0.25 Vdc) (I_C = 10 mAdc, V_{CE} = 0.35 Vdc) (I_C = 10 mAdc, V_{CE} = 0.35 Vdc, T_A = -55°C) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc)*	h_{FE}	20 40 20 20	– – – –	– 120 – –	–
Small Signal Forward Current Transfer Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	h_{fe}	2.8	4.5	–	–
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 10 mAdc, I_B = 1 mAdc, T_A = -55°C) (I_C = 100 mAdc, I_B = 10 mAdc)* (I_C = 100 mAdc, I_B = 10 mAdc, T_A = -55°C)*	V_{BE}	0.7 – – –	– – – –	0.85 1.1 1.5 1.6	Vdc
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc, T_A = 170°C) (I_C = 100 mAdc, I_B = 10 mAdc, T_A = 170°C)*	$V_{CE(sat)}$	– –	– –	0.35 1.0	Vdc
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0)	C_{ob}	–	3.0	5.0	pF
Turn-on Time (Condition 1) (Condition 2) (Condition 3) (Condition 4)	t_{on}	– – – –	26 10 7 6	– 16 – 12	ns
Turn-off Time (Condition 1) (Condition 2) (Condition 3) (Condition 4)	t_{off}	– – – –	30 17 18 23	– 24 – 45	ns
Charge Storage Time Constant (I_C = 10 mAdc, I_{B1} = $-I_{B2}$ = 10 mAdc)	τ_s	–	–	18	ns

* Pulse Test: Pulse width ≦ 300 μs, duty cycle ≦ 2%

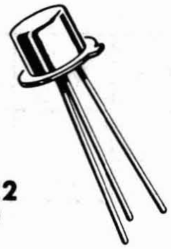
CONDITION	I_C mA	I_{B1} mA	I_{B2} mA	$V_{BE(off)}$ Vdc	V_{CC} Vdc	$R_1 = R_2$ Ω	R_3 Ω	R_4 Ω	R_5 Ω	t_{on}		t_{off}	
										V_{BB} V	V_{IN} V	V_{BB} V	V_{IN} V
1	3	1	-0.5	-0.9	3.4	6.8 K	50	1 K	0	-1.8	10.2	8.4	-10.2
2	10	3	-1.5	-1.5	3.0	3.3 K	50	220	0	-3.0	15.0	12.0	-15.0
3	50	15	-7.5	-1.8	4.0	680	50	18	1 K	-3.5	15.3	*11.7	-15.3
4	100	40	-20.0	-2.4	6.0	330	56	0	1 K	-4.5	20.0	*15.3	-20.0

*V_{BB} is pulsed for 1.5 s @ less than 10% duty cycle

2N753 (SILICON)

For Specifications, See 2N706 Data.

2N827 (GERMANIUM)



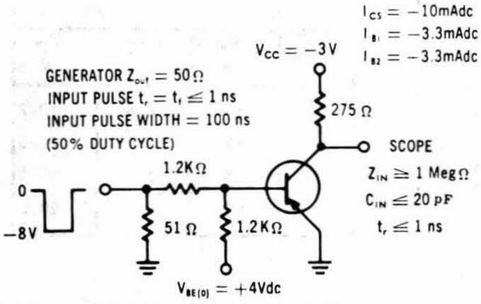
CASE 22
(TO-18)

PNP germanium mesa transistor for high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	20	Vdc
Collector-Emitter Voltage	V_{CES}	20	Vdc
Collector-Emitter Voltage	V_{CEX}	10	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector Current (Continuous)	I_C	100	mAdc
Junction Temperature	T_J	+100	°C
Storage Temperature	T_{stg}	-65 to + 100	°C
Device Dissipation @ 25°C Ambient Temperature (Derate 2mW/°C above 25°C)	P_D	150	mW


$I_{CS} = -10$mAdc
$I_{B1} = -3.3$mAdc
$I_{B2} = -3.3$mAdc
$V_{CC} = -3$V
GENERATOR $Z_{out} = 50\,\Omega$
INPUT PULSE $t_r = t_f \leq 1$ ns
INPUT PULSE WIDTH = 100 ns
(50% DUTY CYCLE)
275 Ω
SCOPE
$Z_{IN} \geq 1$ MegΩ
$C_{IN} \leq 20$ pF
$t_r \leq 1$ ns
1.2KΩ
0
−8V
51 Ω
1.2KΩ
$V_{BE(0)} = +4$Vdc

SWITCHING TIME TEST CIRCUIT

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise specified)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	20	22	---	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{EB} = 0)	BV_{CES}	20	22	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4	5	---	Vdc
Collector Latch-up Voltage	LV_{CEX}	10	---	---	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 15 Vdc, V_{EB} = 0)	I_{CES}	---	0.5	5	μAdc
Collector-Base Cutoff Current (V_{CB} = 15 Vdc)	I_{CBO}	---	0.5	5	μAdc
DC Forward Current Transfer Ratio (I_C = 10 mAdc, V_{CE} = 0.3 Vdc)	h_{FE}	100	150	---	---
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 3.3 mAdc)	$V_{CE(sat)}$	---	0.16	0.25	Vdc
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 3.3 mAdc)	V_{BE}	---	0.39	0.5	Vdc
Small-Signal Forward Current Transfer Ratio (I_C = 10 mA, V_{CE} = 1 V, f = 100 MHz)	h_{fe}	2.5	3.5	---	---
Collector Output Capacitance (V_{CB} = 10 V, I_E = 0, f = 1 MHz)	C_{ob}	---	4	9	pF
Delay Time	t_d	---	10	15	ns
Rise Time	t_r	---	10	20	ns
Storage Time	t_s	---	15	30	ns
Fall Time	t_f	---	15	30	ns

2N**828** (GERMANIUM)

CASE 22
(TO-18)

PNP germanium epitaxial mesa transistor for high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	2.5	Vdc
Collector-Current	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	150 2	mW mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	300 4	mW mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	^oC

FIGURE 1 — SWITCHING TIME TEST CIRCUIT

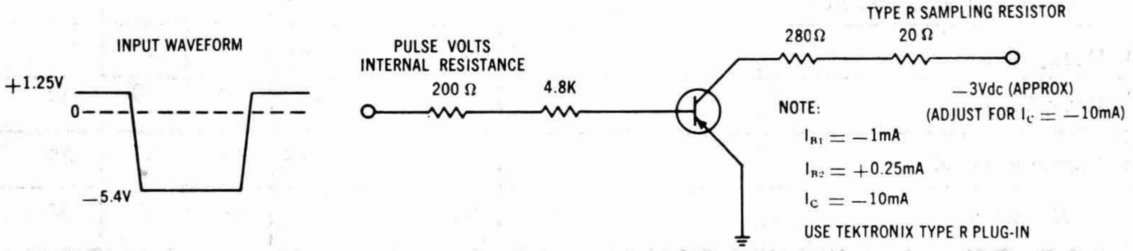

INPUT WAVEFORM
+1.25V
0
−5.4V
PULSE VOLTS
INTERNAL RESISTANCE
200 Ω
4.8K
TYPE R SAMPLING RESISTOR
280Ω
20 Ω
−3Vdc (APPROX)
(ADJUST FOR $I_C = -10mA$)
NOTE:
$I_{B1} = -1mA$
$I_{B2} = +0.25mA$
$I_C = -10mA$
USE TEKTRONIX TYPE R PLUG-IN

FIGURE 2 — CHARGE STORAGE TIME TEST CIRCUIT

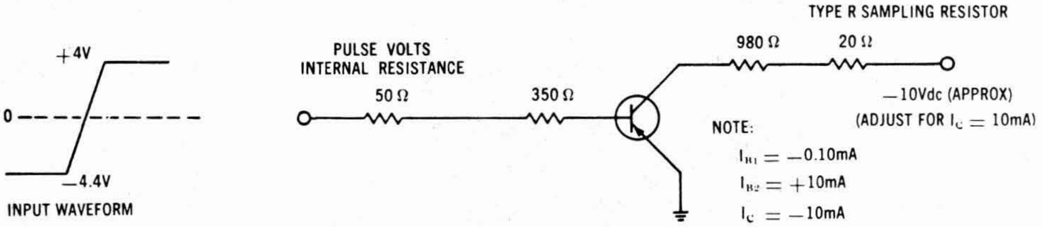

+4V
0
−4.4V
INPUT WAVEFORM
PULSE VOLTS
INTERNAL RESISTANCE
50 Ω
350 Ω
TYPE R SAMPLING RESISTOR
980 Ω
20 Ω
−10Vdc (APPROX)
(ADJUST FOR $I_C = 10mA$)
NOTE:
$I_{B1} = -0.10mA$
$I_{B2} = +10mA$
$I_C = -10mA$

FIGURE 3 — RISE TIME FACTOR

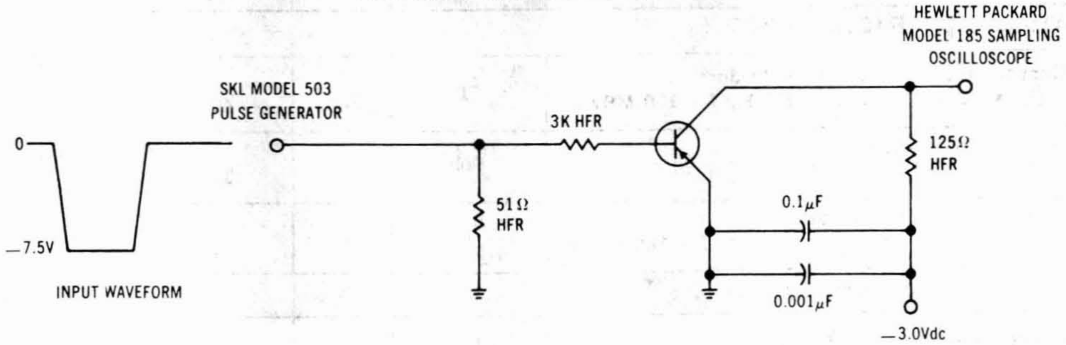
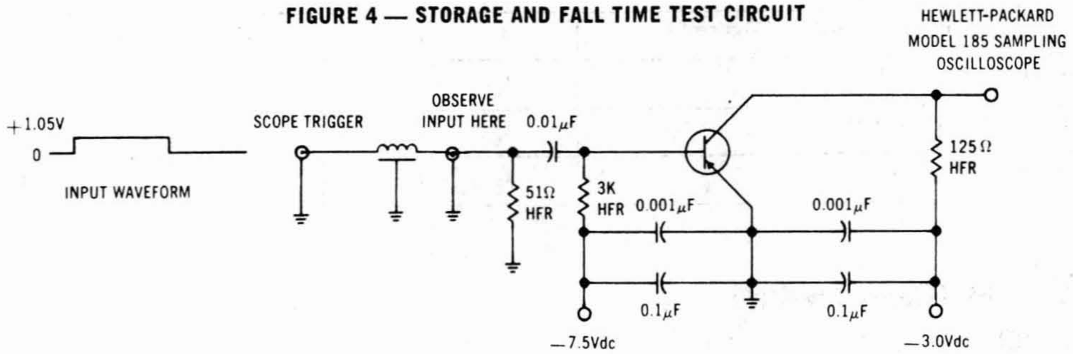

HEWLETT PACKARD
MODEL 185 SAMPLING
OSCILLOSCOPE
SKL MODEL 503
PULSE GENERATOR
3K HFR
0
125Ω
HFR
51Ω
HFR
0.1μF
−7.5V
INPUT WAVEFORM
0.001μF
−3.0Vdc

FIGURE 4 — STORAGE AND FALL TIME TEST CIRCUIT


HEWLETT-PACKARD
MODEL 185 SAMPLING
OSCILLOSCOPE
+1.05V
0
SCOPE TRIGGER
OBSERVE
INPUT HERE
0.01μF
125Ω
HFR
INPUT WAVEFORM
51Ω
HFR
3K
HFR
0.001μF
0.001μF
0.1μF
0.1μF
−7.5Vdc
−3.0Vdc

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

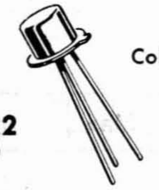
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)	BV_{CEO}	-	10	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	15	25	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100μAdc, I_E = 0)	BV_{CBO}	15	25	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	2.5	-	-	Vdc
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)	I_{CBO}	-	0.4	3	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 10 mAdc, V_{CE} = 0.3 Vdc)	h_{FE}	25	40	-	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc)	($V_{CE(sat)}$	 - -	 0.12 0.18	 0.2 0.25	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	0.34	0.39	0.44	Vdc

2N828 (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Typ	Max	Unit
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 1 Vdc, f = 100 MHz)	f_T	300	400	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)	C_{ob}	-	3.5	-	pF
Small Signal Current Gain (I_C = 10 mAdc, V_{CE} = 1 Vdc, f = 100 MHz)	h_{fe}	3	4	-	-
Delay Plus Rise Time (Figure 1)	$t_d + t_r$	-	50	70	ns
Storage Time (Figure 1)	t_s	-	33	50	ns
Fall Time (Figure 1)	t_f	-	35	50	ns
Charge Storage Time Constant (Figure 2)	τ_s	-	14	25	ns
Rise Time (Figure 3)	t_r	-	7	-	ns
Storage Time (Figure 4)	t_s	-	5	-	ns
Fall Time (Figure 4)	t_f	-	3	-	ns

2N828A (GERMANIUM)
2N829



Collector connected to case

CASE 22
(TO-18)

PNP germanium epitaxial mesa transistors for high-speed switching applications

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector to Base Voltage	V_{CB}	15	Vdc
Collector to Emitter Voltage	V_{CES}	15	Vdc
Emitter to Base Voltage	V_{EB}	2.5	Vdc
Collector Current (Continuous)	I_C	200	mAdc
Total Device Dissipation at 25°C case Temperature (Derate 4.0mw/°C above 25°C)	P_D	300	mW
Total Device Dissipation at 25°C Ambient Temperature (Derate 2.0mw/°C)	P_D	150	mW
Junction Temperature	T_J	+100	°C
Storage Temperature	T_{stg}	-65 to +100	°C

2N828A, 2N829 (continued)

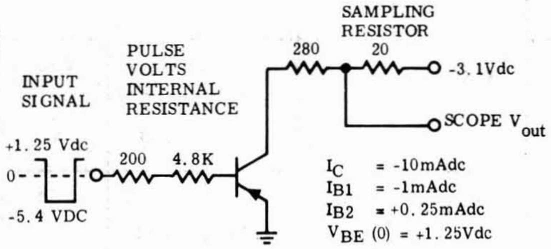
ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Collector to Base Breakdown Voltage I_E = 0, I_C = 100μAdc		BV_{CBO}	15	25	--	Vdc
Collector to Emitter Breakdown Voltage V_{EB} = 0, I_C = 100μAdc		BV_{CES}	15	25	--	Vdc
Emitter to Base Breakdown Voltage I_C = 0, I_E = 100μ Adc		BV_{EBO}	2.5	--	--	Vdc
Collector Cutoff Current I_E = 0, V_{CB} = 6Vdc		I_{CBO}	--	.4	3	μAdc
Forward Current Transfer Ratio I_C = 10mAdc, V_{CE} = 0.3Vdc	2N828A 2N829	h_{FE}	25 50	40 80	--	--
Forward Current Transfer Ratio I_C = 150mAdc, V_{CE} = 1Vdc	2N828A 2N829	h_{fe}	25 50	40 80	--	--
Collector Saturation Voltage I_C = 10mAdc, I_B = 1.0 mAdc I_C = 10mAdc, I_B = 0.5mAdc	2N828A 2N829	$V_{CE(sat)}$	--	0.11 0.11	0.20 0.20	Vdc
Collector Saturation Voltage I_C = 50mAdc, I_B = 5.0mAdc		$V_{CE(sat)}$	--	--	0.25	Vdc
Collector Saturation Voltage I_C = 150mAdc, I_B = 15mAdc I_C = 150mAdc, I_B = 7.5mAdc	2N828A 2N829	$V_{CE(sat)}$	--	0.35 0.38	0.50 0.50	Vdc
Base to Emitter Voltage I_C = 10mAdc, I_B = 1mAdc I_C = 10mAdc, I_B = 0.5mAdc	2N828A 2N829	V_{BE}	0.34 .30	0.40 0.38	0.44 0.44	Vdc
Base to Emitter Voltage I_C = 150mAdc, I_B = 15mAdc I_C = 150mAdc, I_B = 7.5mAdc	2N828A 2N829	V_{BE}	--	0.70 0.65	0.85 0.85	Vdc
Collector Capacitance I_E = 0, V_{CB} = 6Vdc, f = 100 kHz		C_{ob}	--	2.2	4	pF

2N828A, 2N829 (continued)
ELECTRICAL CHARACTERISTICS (continued)

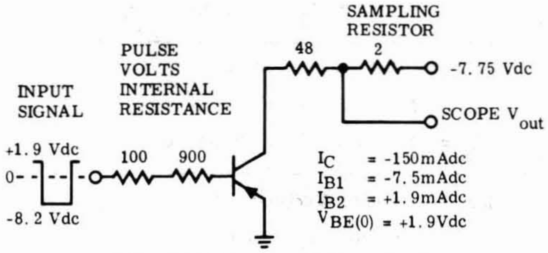
Characteristic	Symbol	Min	Typ	Max	Unit
Input Capacitance V_{BE} = 1Vdc, I_E = 0, f = 100 kHz	C_{ib}	--	2.2	3.5	pF
Small Signal Forward Current Transfer Ratio I_C = 10mAdc, V_{CE} = -1Vdc, f = 100 MHz	h_{fe}	3.0	4.0	--	--
Current Gain Bandwidth Product V_{CE} = 1Vdc, I_C = -10mAdc, f = 100 MHz	f_T	300	400	--	MHz
Delay Plus Rise Time (Fig. 1) I_C = 10mAdc	td+tr	--	35	50	ns
Storage Time (Fig. 1) I_C = 10mAdc	ts	--	30	50	ns
Fall Time (Fig. 1) I_C = 10mAdc	tf	--	30	50	ns
Total Control Charge (Fig. 3) I_C = 10mAdc	Q_T	--	50	80	pC
Delay Plus Rise Time (Fig. 2) I_C = 150mAdc	$t_d + t_r$	--	25	50	ns
Turn Off Time (Fig. 2) I_C = 150mAdc	t_{off}	--	60	100	ns
Total Control Charge (Fig. 4) I_C = 150mAdc	Q_T	--	120	175	pC

FIGURE 1 — 10mA SWITCHING TIME TEST CIRCUIT


SAMPLING RESISTOR
PULSE VOLTS INTERNAL RESISTANCE
280
20
-3.1Vdc
INPUT SIGNAL
SCOPE V$_{out}$
+1.25 Vdc
0-
-5.4 VDC
200
4.8K
I_C = -10mAdc
I_{B1} = -1mAdc
I_{B2} = +0.25mAdc
V_{BE} (0) = +1.25Vdc

SCOPE INPUT IMPEDANCE = 1Megohm
SCOPE INPUT CAPACITANCE = 20 pF
GENERATOR OUTPUT IMPEDANCE = 50 ohms
INPUT PULSE $t_r = t_f$ = 2ns

FIGURE 2 — 150mA SWITCHING TIME TEST CIRCUIT


SAMPLING RESISTOR
PULSE VOLTS INTERNAL RESISTANCE
48
2
-7.75 Vdc
INPUT SIGNAL
SCOPE V$_{out}$
+1.9 Vdc
0-
-8.2 Vdc
100
900
I_C = -150mAdc
I_{B1} = -7.5mAdc
I_{B2} = +1.9mAdc
$V_{BE(0)}$ = +1.9Vdc

SCOPE INPUT IMPEDANCE = 1Megohm
SCOPE INPUT CAPACITANCE = 20 pF
GENERATOR OUTPUT IMPEDANCE = 50 ohms
INPUT PULSE $t_r = t_f$ = 2ns

FIGURE 3 — 10mA TOTAL CONTROL CHARGE TEST CIRCUIT

*ADJUST V_{BB} FOR -5.4 VOLT PULSE AT POINT A

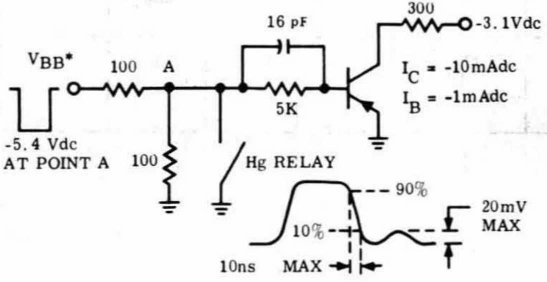
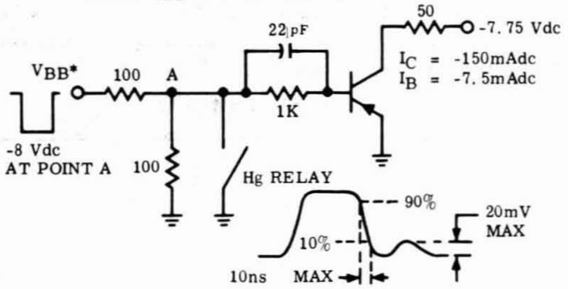

300
-3.1Vdc
16 pF
VBB*
100
A
5K
I_C = -10mAdc
I_B = -1mAdc
-5.4 Vdc AT POINT A
100
Hg RELAY
90%
10%
20mV MAX
10ns MAX

FIGURE 4 — 150mA TOTAL CONTROL CHARGE TEST CIRCUIT

*ADJUST V_{BB} FOR -8 VOLT PULSE AT POINT A


50
-7.75 Vdc
22 pF
I_C = -150mAdc
I_B = -7.5mAdc
VBB*
100
A
1K
-8 Vdc AT POINT A
100
Hg RELAY
90%
10%
20mV MAX
10ns MAX

2N834 (SILICON)
2N835

CASE 22
(TO-18)

Collector connected to case

NPN silicon epitaxial transistors for high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N834	2N835	Unit
Collector-Emitter Voltage	V_{CES}	30	20	Vdc
Collector-Base Voltage	V_{CB}	40	25	Vdc
Emitter-Base Voltage	V_{EB}	5	3	Vdc
Collector Current-Continuous Peak	I_C	200		mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	0.3 2		Watt mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	1.0 6.67		Watt mW/^oC
Total Device Dissipation @ $T_C = 100^oC$ Derate above 100^oC	P_D	0.5 6.67		Watt mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175		^oC

FIGURE 1 — TURN-ON AND TURN-OFF TIME MEASUREMENT CIRCUIT

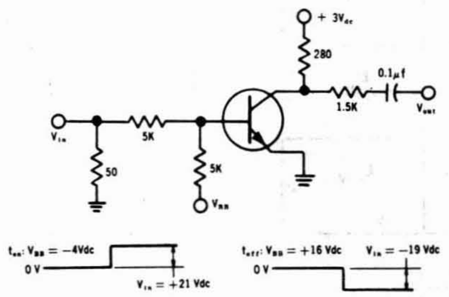
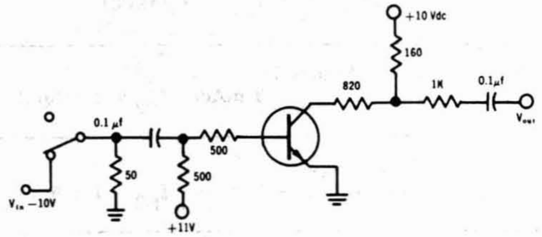

+ 3V$_{dc}$
280
0.1μf
1.5K
V$_{out}$
V$_{in}$
5K
50
5K
V$_{BB}$
t$_{on}$: V$_{BB}$ = −4Vdc
0 V
V$_{in}$ = +21 Vdc
t$_{off}$: V$_{BB}$ = +16 Vdc
V$_{in}$ = −19 Vdc
0 V

FIGURE 2 — CHARGE STORAGE TIME CONSTANT MEASUREMENT CIRCUIT


+10 Vdc
160
820
1K
0.1μf
V$_{out}$
0.1 μf
500
50
500
V$_{in}$ −10V
+11V

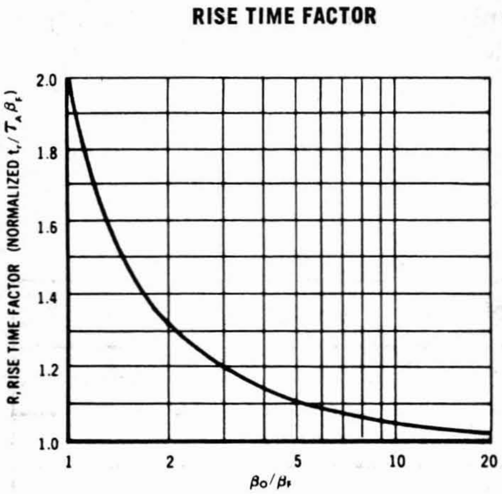
NOTE: ALL SWITCHING TIMES MEASURED WITH LUMATRON MODEL 420 SWITCHING TIME TEST SET OR EQUIVALENT.

2N834, 2N835 (continued)

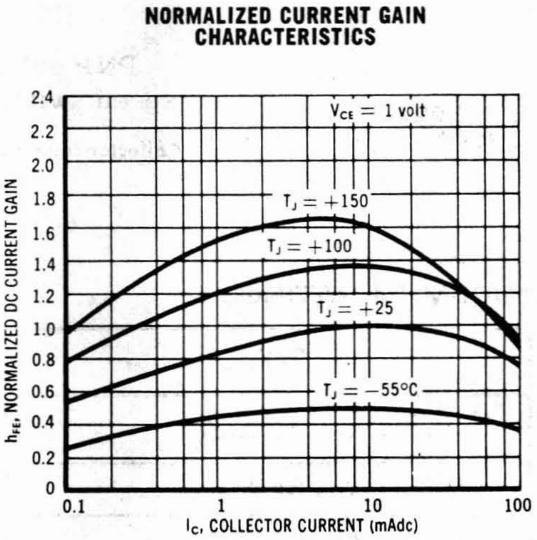
ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0) 2N834	BV_{CBO}	40	-	Vdc
2N835		25	-	
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0) 2N834	BV_{EBO}	5	-	Vdc
2N835		3	-	
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0) 2N834	I_{CES}	-	10	μAdc
(V_{CE} = 20 Vdc, V_{BE} = 0) 2N835		-	10	
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	-	0.5	μAdc
(V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)		-	30	
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1 Vdc) 2N834	h_{FE}*	25	-	-
2N835		20	-	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) 2N834	($V_{CE(sat)}$	-	0.25	Vdc
2N835		-	0.30	
(I_C = 50 mAdc, I_B = 5 mAdc)* 2N834		-	0.4	
2N835		-	-	
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$*	-	0.9	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz) 2N834	f_T	350	-	MHz
(I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 100 MHz) 2N835		300	-	
High-Frequency Current Gain (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz) 2N834	$\|h_{fe}\|$	3.5	-	-
(I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 100 MHz) 2N835		3.0	-	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	4.0	pF
Charge-Storage Time Constant (Figure 2) (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc) 2N834	t_s	-	25	ns
2N835		-	35	
Turn-On Time (Figure 1) (I_C = 10 mAdc, I_{B1} = 3 mAdc, I_{B2} = 1 mAdc) 2N834	t_{on}	-	33	ns
2N835		-	20	
Turn-Off Time (Figure 1) (I_C = 10 mAdc, I_{B1} = 3 mAdc, I_{B2} = 1 mAdc) 2N834	t_{off}	-	75	ns
2N835		-	35	

*Pulse Test: Pulse Width ≤ 12 ms, Duty Cycle ≤ 2%



RISE TIME FACTOR



NORMALIZED CURRENT GAIN CHARACTERISTICS

2N838 (GERMANIUM)

CASE 22
(TO-18)

PNP germanium epitaxial mesa transistor for high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	30	Vdc
Collector-Emitter Voltage	V_{CES}	30	Vdc
Collector-Emitter Voltage	V_{CEX}	15	Vdc
Emitter-Base Boltage	V_{EB}	2.5	Vdc
Collector Current (Continuous)	I_C	100	mAdc
Junction Temperature	T_J	+100	°C
Storage Temperature	T_{stg}	-65 to+ 100	°C
Device Dissipation @ 25°C Ambient Temperature (Derate 2mW/°C above 25°C)	P_D	150	mW

FIGURE 1 — SWITCHING TIME TEST CIRCUIT

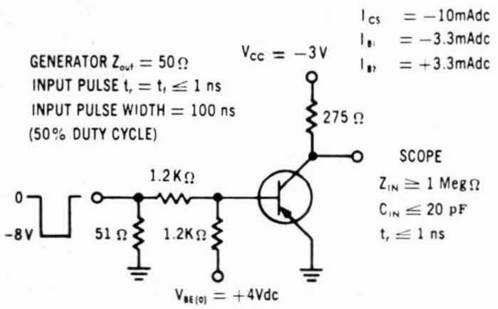
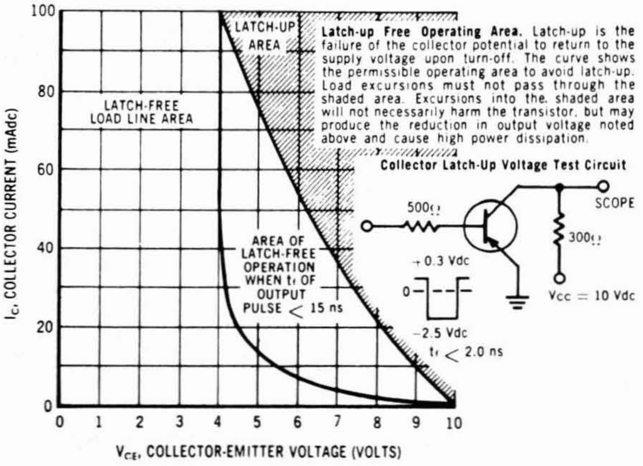

$I_{CS} = -10$mAdc
$I_{B1} = -3.3$mAdc
$I_{B2} = +3.3$mAdc
GENERATOR $Z_{out} = 50\,\Omega$
INPUT PULSE $t_r = t_f \leq 1$ ns
INPUT PULSE WIDTH = 100 ns
(50% DUTY CYCLE)
$V_{CC} = -3$V
275 Ω
SCOPE
$Z_{IN} \geq 1$ Meg Ω
$C_{IN} \leq 20$ pF
$t_r \leq 1$ ns
1.2KΩ
0
-8V
51 Ω
1.2KΩ
$V_{BE(0)} = +4$Vdc

FIGURE 2 — AREA OF PERMISSIBLE LOAD LOCI



Latch-up Free Operating Area. Latch-up is the failure of the collector potential to return to the supply voltage upon turn-off. The curve shows the permissible operating area to avoid latch-up. Load excursions must not pass through the shaded area. Excursions into the shaded area will not necessarily harm the transistor, but may produce the reduction in output voltage noted above and cause high power dissipation.

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C =100 μAdc, I_E =0)	BV_{CBO}	30	35	---	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{EB} = 0)	BV_{CES}	30	35	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	2.5	4.5	---	Vdc
Collector Latch-up Voltage (see Figure 2)	LV_{CEX}	15	---	---	Vdc
Collector-Emitter Cutoff Current (V_{CE} =15 Vdc, V_{EB} =0)	I_{CES}	---	1	10	μAdc
Collector-Base Cutoff Current (V_{CB} = 15 V, I_E = 0)	I_{CBO}	---	1	10	μAdc
DC Forward Current Transfer Ratio (I_C = 10mAdc, V_{CE} = 0.3 Vdc)	h_{FE}	30	70	---	---
Collector-Emitter Saturation Voltage (I_C =10 mAdc, I_B = 3.3 mAdc)	$V_{CE(sat)}$	---	0.1	0.18	Vdc
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 3.3 mAdc)	V_{BE}	---	0.39	0.5	Vdc
Small-Signal Forward Current Transfer Ratio (I_C = 10 mA, V_{CE} = 1V, f = 100 MHz)	h_{fe}	3	4.5	---	---
Collector Output Capacitance (V_{CB} = 10 V, I_E = 0, f = 1 MHz)	C_{ob}	---	2	4	pF
Delay Time (Figure 1)	t_d	---	10	15	ns
Rise Time (Figure 1)	t_r	---	7	15	ns
Storage Time (Figure 1)	t_s	---	10	20	ns
Fall Time (Figure 1)	t_f	---	10	20	ns

2N840 (SILICON)
2N841

CASE 22
(TO-18)

NPN silicon annular transistors designed for small-signal amplifier and general purpose switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	45	Vdc
Collector-Emitter Voltage	V_{CES}	45	Vdc
Collector-Base Voltage	V_{CB}	45	Vdc
Emitter-Base Voltage	V_{EB}	2.0	Vdc
Collector Current	I_C	1.0	Adc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	500 2.86	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	45	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	45	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	2.0	-	Vdc
Collector Cutoff Current (V_{CE} = 45 Vdc, V_{BE} = 0, R_{BE} = 5.0 k ohms)	I_{CER}	-	20	μAdc
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0) (V_{CB} = 45 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	1.0 50	μAdc
Emitter Cutoff Current (V_{BE} = 2.0 Vdc, I_C = 0)	I_{EBO}	-	50	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE} = 5.0 Vdc) 2N840 2N841	h_{FE}	30 60	100 400	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 2.2 mAdc)	$V_{CE(sat)}$	-	2.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 20 MHz) 2N840 2N841	f_T	1.5 2.0	- -	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	15	pF
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N840 2N841 (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz, T_A = -55°C) 2N840 2N841	h_{fe}	40 80 15 25	90 330 - -	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{oe}	-	1.2	μmhos
Input Resistance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	-	80	Ohms
Output Conductance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	1.2	μmhos
Real Part of Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	$Re(h_{ie})$	-	500	Ohms

2N869 (SILICON)
2N995

CASE 22
(TO-18)

PNP silicon annular transistors for high-frequency general-purpose amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Types	Value	Unit
Base Voltage	V_{CB}	2N869 2N995	25 20	Volts Volts
Collector-Emitter Voltage	V_{CEO}	2N869 2N995	18 15	Volts Volts
Emitter-Base Voltage	V_{EB}	2N869 2N995	5 4	Volts Volts
Total Device Dissipation at 25°C Case Temperature at 100°C Case Temperature (Derate 6.86 mW/°C above 25°C)	P_D	Both Types	1.2 0.68	Watts Watt
Total Device Dissipation at 25°C Ambient Temperature (Derate 2.06 mW/°C above 25°C)	P_D	Both Types	0.36	Watt
Storage Temperature	T_{stg}	Both Types	-65 to +200	°C
Junction Temperature	T_J	Both Types	+200	°C

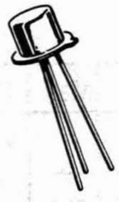
2N869, 2N995 (continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}				Volts
(I_C = 10 μAdc, I_E = 0) 2N869		25	---	---	
2N995		20	---	---	
Collector-Emitter Sustaining Voltage *	$V_{CEO(sust)}$ *				Volts
(I_C = 10 mAdc, I_B = 0) 2N869		18	---	---	
2N995		15	---	---	
Emitter-Base Breakdown Voltage	BV_{EBO}				
(I_E = 10 μAdc, I_C = 0) 2N869		5	---	---	Volts
2N995		4	---	---	
Collector Cutoff Current	I_{CBO}				μ Adc
(V_{CB} = 15 Vdc, I_E = 0) 2N869		---	---	010	
2N995		---	---	005	
(V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C) Both Types		---	---	25	
Emitter Current	I_{EBO}				μ Adc
(V_{EB} = 4.0 Vdc, I_C = 0) 2N995		---	---	10	
Collector Saturation Voltage	$V_{CE\,(sat)}$				Volt
(I_C = 10 mAdc, I_B = 1.0 mAdc) 2N869		---	0.17	1.0	
(I_C = 20 mAdc, I_B = 2.0 mAdc) 2N995		---	---	0.2	
Base Saturation Voltage	$V_{BE\,(sat)}$				Volt
(I_C = 10 mAdc, I_B = 1.0 mAdc) 2N869		---	0.78	1.0	
(I_C = 20 mAdc, I_B = 2.0 mAdc) 2N995		---	---	0.95	
DC Forward-Current Transfer Ratio *	h_{FE} *				---
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc) 2N869		20	---	120	
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc) 2N995		25	---	---	
(I_C = 20 mAdc, V_{CE} = 1.0 Vdc) 2N995		35	---	140	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc) 2N995		25	---	---	
Open-Circuit Output Capacitance	C_{ob}				pF
(V_{CB} = 10 V, I_E = 0) 2N869		---	3	9	
2N995		---	3	10	
Open-Circuit Input Capacitance	C_{ib}				pF
(V_{BE} = 0.5 V, I_C = 0) Both Types		---	7	11	
Small-Signal Forward-Current Transfer Ratio	h_{fe}				---
(I_C = 10 mA, V_{CE} = 15 V, f = 100 MHz) 2N869		1.0	3.0	---	
(I_C = 10 mA, V_{CE} = 10 V, f = 100 MHz) 2N995		1.0	3.0	---	

*Pulse Note: Pulse Width = 300 μs, Duty Cycle = 1%

2N869A (SILICON)



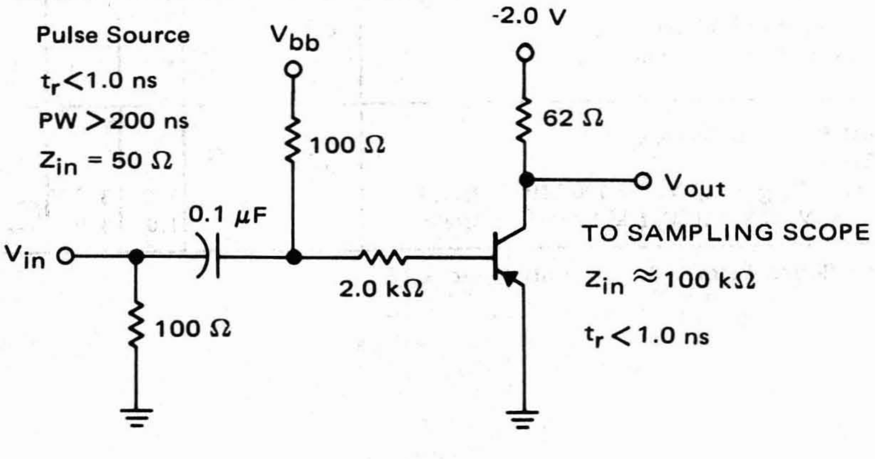
CASE 22
(TO-18)

PNP silicon annular low-power transistor designed for medium-speed, saturated switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	18	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	360 2.1	mW mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.2 6.86	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

FIGURE 1 – SWITCHING TIME TEST CIRCUIT


Pulse Source
$t_r < 1.0$ ns
PW > 200 ns
$Z_{in} = 50\ \Omega$
V_{bb}
100 Ω
-2.0 V
62 Ω
V_{out}
TO SAMPLING SCOPE
$Z_{in} \approx 100$ kΩ
$t_r < 1.0$ ns
0.1 μF
V_{in}
2.0 kΩ
100 Ω

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	18	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 μAdc, V_{BE} = 0)	BV_{CES}	25	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	25	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0)	I_{CES}	-	10	nAdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	-	25	μAdc
Base Current (V_{CE} = 15 Vdc, V_{BE} = 0)	I_B	-	10	nAdc
ON CHARACTERISTICS				
DC Current Gain*	h_{FE}*			-
(I_C = 10 mAdc, V_{CE} = 0.3 Vdc)		30	-	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc)		40	120	
(I_C = 30 mAdc, V_{CE} = 0.5 Vdc)		40	120	
(I_C = 30 mAdc, V_{CE} = 0.5 Vdc, T_A = -55°C)		17	-	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)		25	-	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		-	0.15	
(I_C = 30 mAdc, I_B = 3.0 mAdc)		-	0.2	
(I_C = 100 mAdc, I_B = 10 mAdc)		-	0.5	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		0.78	0.98	
(I_C = 30 mAdc, I_B = 3.0 mAdc)		0.85	1.2	
(I_C = 100 mAdc, I_B = 10 mAdc)		-	1.7	
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain-Bandwidth Product (I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 100 MHz)	f_T	400	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	6.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 150 kHz)	C_{ib}	-	6.0	pF
SWITCHING CHARACTERISTICS				
Turn-On Time (I_C = 30 mAdc, I_{B1} = 1.5 mAdc)	t_{on}	-	50	ns
Turn-Off Time (I_C = 30 mAdc, I_{B1} = I_{B2} = 1.5 mAdc)	t_{off}	-	80	ns

* Pulse Test: Pulse Length = 300 μs, Duty Cycle = 1.0%.

2N910 (SILICON)
2N911

NPN silicon annular transistors designed for small-signal amplifier and general purpose switching applications.

CASE 22
(TO-18)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Emitter Voltage	V_{CER}	80	Vdc
Collector-Base Voltage	V_{CB}	100	Vdc
Emitter-Base Voltage	V_{EB}	7.0	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.5 2.86	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ $T_C = 100°C$ Derate above 25°C	P_D	1.8 0.975 10.3	Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

2N910, 2N911 (Continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 30 mAdc, I_B = 0)		$BV_{CEO(sus)}$*	60	-	Vdc
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, $R_{BE} \leqq$ 10 ohms)		$BV_{CER(sus)}$*	80	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	100	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current (V_{CB} = 75 Vdc, I_E = 0)		I_{CBO}	-	25	nAdc
(V_{CB} = 75 Vdc, I_E = 0, T_A = 150°C)			-	15	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	25	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N910	h_{FE}	35	-	-
	2N911		20	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N910*		75	-	
	2N911*		35	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N910*		30	-	
	2N911*		15	-	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{CE(sat)}$	-	0.4	Vdc
(I_C = 50 mAdc, I_B = 5.0 mAdc)			-	1.2	
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{BE(sat)}$	0.6	0.8	Vdc
(I_C = 50 mAdc, I_B = 5.0 mAdc)			-	0.9	
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N910	f_T	60	-	MHz
	2N911		50	-	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	15	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	-	85	pF
Input Impedance (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N910	h_{ie}	-	1800	Ohms
	2N911		-	1000	
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N910	h_{fe}	76	200	-
	2N911		36	90	
(I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N911		40	100	
Output Admittance (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N910	h_{oe}	-	100	μmhos
	2N911		-	50	
Input Resistance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ib}	20	30	Ohms
(I_C = 5.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)			4.0	8.0	
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N910	h_{rb}	-	3.0	X 10^{-4}
	2N911		-	1.25	
(I_C = 5.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N911		-	1.75	
Output Conductance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ob}	-	0.5	μmho
(I_C = 5.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)			-	1.0	
Noise Figure (I_C = 0.3 mAdc, V_{CB} = 10 Vdc, R_G = 510 ohms, f = 1.0 kHz, B. W. = 200 Hz)	2N910	NF	-	12	dB
	2N911		-	15	

* Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle = 2.0%.

2N914 (SILICON)

CASE 22
(TO-18)

Collector connected to case

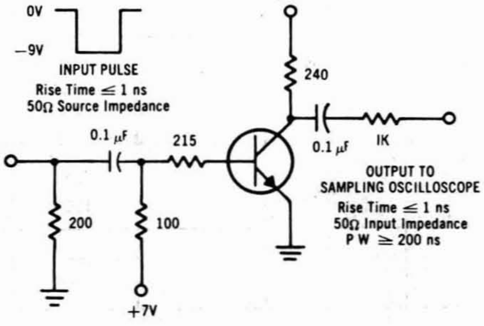
NPN silicon annular transistor for high-speed switching applications.

MAXIMUM RATINGS

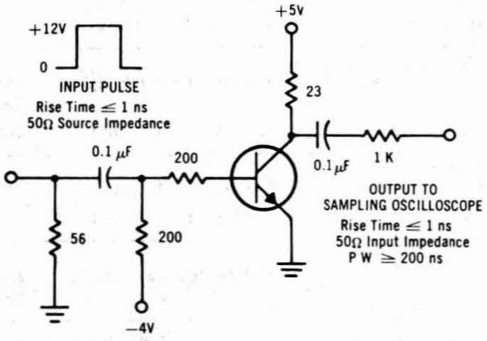
Rating	Symbol	Value	Unit
*Collector-Emitter Voltage	V_{CEO}	15	Vdc
*Collector-Emitter Voltage ($R_{BE} \leq$ 10 ohms)	V_{CER}	20	Vdc
*Collector-Base Voltage	V_{CB}	40	Vdc
*Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current (Note 1)	I_C	150	mAdc
*Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	360 2.06	mW mW/°C
*Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.9	Watts mW/°C
*Total Device Dissipation @ T_C = 100°C	P_D	0.68	Watt
*Operating Junction Temperature Range	T_J	200	°C
*Storage Temperature Range	T_{stg}	-65 to +200	°C

*Indicates JEDEC Registered Data.
Note 1: Limited by Power Dissipation

CHARGE STORAGE TIME CONSTANT TEST CIRCUIT


0V
−9V
INPUT PULSE
Rise Time ≤ 1 ns
50Ω Source Impedance
+5V
240
0.1 μF
215
0.1 μF
IK
OUTPUT TO
SAMPLING OSCILLOSCOPE
Rise Time ≤ 1 ns
50Ω Input Impedance
P W ≥ 200 ns
200
100
+7V

t_{on} and t_{off} TEST CIRCUIT


+12V
0
INPUT PULSE
Rise Time ≤ 1 ns
50Ω Source Impedance
+5V
23
0.1 μF
200
0.1 μF
1 K
OUTPUT TO
SAMPLING OSCILLOSCOPE
Rise Time ≤ 1 ns
50Ω Input Impedance
P W ≥ 200 ns
56
200
−4V

2N914 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted.)

OFF CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
*Collector-Emitter Sustaining Voltage **(Note 1)** (I_C = 30 mAdc, I_B = 0)	$BV_{CEO(sus)}$	15	-	Vdc
*Collector-Emitter Sustaining Voltage **(Note 1)** (I_C = 30 mAdc, R_{BE} ≤ 10 ohms)	$BV_{CER(sus)}$	20	-	Vdc
*Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
*Emitter-Base Breakdown Voltage (I_E = 10μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
*Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 0.25 Vdc, T_A = 125°C)	I_{CEX}	-	10	μAdc
*Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	-	0.025	μAdc
(V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)		-	15	
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	0.1	μAdc

ON CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
DC Current Gain **(Note 1)** *(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	30	120	-
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)		12	-	
*(I_C = 500 mAdc, V_{CE} = 5.0 Vdc)		10	-	
Collector-Emitter Saturation Voltage *(I_C = 200 mAdc, I_B = 20 mAdc)	$V_{CE(sat)}$	-	0.70	Vdc
(I_C = 10 mAdc, I_B = 1.0 thru 20 mAdc, T_A = -55 to +125°C)		-	0.25	
*Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	0.70	0.80	Vdc

DYNAMIC CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
†Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	6.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	-	9.0	pF
*Charge Storage Time Constant **(Note 2)** (I_C = I_{B1} = I_{B2} = 20 mAdc)	τ_s	-	20	ns
Turn-On Time **(Note 2)** (I_C = 200 mAdc, I_{B1} = 40 mAdc, I_{B2} = 20 mAdc)	t_{on}	-	40	ns
Turn-Off Time **(Note 2)** (I_C = 200 mAdc, I_{B1} = 40 mAdc, I_{B2} = 20 mAdc)	t_{off}	-	40	ns

Note 1: Pulse Test: Pulse Width = 300 μs, Duty Cycle ⩽1.0%.

Note 2: Measured on Sampling Scope: Pulse Width ⩾ 200 ns.

*Indicates JEDEC Registered Data.

†JEDEC Registration Defined as h_{fe}.

2N915 (SILICON)

CASE 22
(TO-18)

NPN silicon annular transistor for high-frequency amplifier, oscillator and switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	70	Vdc
Collector-Emitter Voltage	V_{CEO}	50	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	 1.2 6.9	 W mW/°C
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	 .36 2.06	 W mW/°C
Junction Temperature, Operating	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to + 200	°C

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current $I_E = 0 \quad V_{CB} = 60V$	I_{CBO}		10	nA
Collector Cutoff Current @ 150°C $I_E = 0 \quad V_{CB} = 60V$	I_{CBO}		30	μ A
Collector Breakdown Voltage $I_C = 100\,\mu A \quad I_E = 0$	BV_{CBO}	70		Volts
Collector to Emitter Sustaining Voltage $I_C = 10mA \quad I_B = 0$	$*V_{CEO}$	50		Volts
Emitter Breakdown Voltage $I_C = 0 \quad I_E = 100\,\mu A$	BV_{EBO}	5.0		Volts
Base Saturation Voltage $I_C = 10mA \quad I_B = 1.0mA$	$V_{BE(sat)}$		0.9	Volts
Collector Saturation Voltage $I_C = 10mA \quad I_B = 1.0mA$	$V_{CE(sat)}$		1.0	Volts
DC Pulse Current Gain $I_C = 10mA \quad V_{CE} = 5.0V$	h_{FE}	50	200	
Output Capacitance $I_E = 0 \quad V_{CB} = 10V$	C_{ob}		3.5	pF
Emitter Transition Capacitance $I_C = 0 \quad V_{EB} = 0.5V$	C_{TE}		10	pF
High Frequency Current Gain f = 100 MHz $I_C = 10mA \quad V_{CE} = 15V$	h_{fe}	2.5		
Small Signal Current Gain f = 1 kHz $I_C = 1.0mA \quad V_{CE} = 5.0V$ $I_C = 5.0mA \quad V_{CE} = 5.0V$	h_{fe}	40 50	200 250	
Input Resistance f = 1 kHz $I_C = 1.0mA \quad V_{CE} = 5.0V$ $I_C = 5.0mA \quad V_{CE} = 5.0V$	h_{ie}		6000 2000	ohms ohms
Output Conductance f = 1 kHz $I_C = 1.0mA \quad V_{CE} = 5.0V$ $I_C = 5.0mA \quad V_{CE} = 5.0V$	h_{oe}		75 125	μmho μmho

*Pulse Test: PW ≦ 300 μs, Duty Cycle ≦ 1.0%

2N916 (SILICON)

Collector connected to case

CASE 22
(TO-18)

NPN silicon annular transistor for high-frequency amplifier, oscillator and switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	45	Vdc
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	 1.2 6.9	 W mW/°C
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	 .36 2.06	 W mW/°C
Junction Temperature, Operating	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +300	°C

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current $I_E = 0$ $V_{CB} = 30V$	I_{CBO}		10	nAdc
Collector Cutoff Current @150° C $I_E = 0$ $V_{CB} = 30V$	I_{CBO}		10	μAdc
Collector Breakdown Voltage $I_C = 10\mu A$ $I_E = 0$	BV_{CBO}	45		Volts
Collector to Emitter Sustaining Voltage $I_C = 30mA$ $I_B = 0$	$*V_{CEO}$	25		Volts
Emitter Breakdown Voltage $I_C = 0$ $I_E = 10\ \mu A$	BV_{EBO}	5.0		Volts
Base Saturation Voltage $I_C = 10mA$ $I_B = 1.0mA$	$V_{BE(sat)}$		0.9	Volts
Collector Saturation Voltage $I_C = 10mA$ $I_B = 1.0mA$	$V_{CE(sat)}$		0.5	Volts
DC Pulse Current Gain $I_C = 10mA$ $V_{CE} = 1.0V$	$*h_{FE}$	50	200	—
Output Capacitance $I_E = 0$ $V_{CB} = 5.0V$	C_{ob}		6.0	pF
Emitter Transition Capacitance $I_C = 0$ $V_{EB} = 0.5V$	C_{TE}		10	pF
High Frequency Current Gain f = 100 MHz $I_C = 10mA$ $V_{CE} = 15V$	h_{fe}	3.0		—
Small Signal Current Gain f = 1 kHz $I_C = 1.0mA$ $V_{CE} = 5.0V$ $I_C = 5.0mA$ $V_{CE} = 5.0V$	h_{fe}	 40 50	 200 250	
Input Resistance f = 1 kHz $I_C = 1.0mA$ $V_{CE} = 5.0V$ $I_C = 5.0mA$ $V_{CE} = 5.0V$	h_{ie}		 6000 2000	 ohms ohms
Output Conductance f = 1 kHz $I_C = 1.0mA$ $V_{CE} = 5.0V$ $I_C = 5.0mA$ $V_{CE} = 5.0V$	h_{oe}		 75 125	 μmho μmho

***Pulse Test: Pulse Width = 300 μs, Duty Cycle** = 1.0%

2N918 (SILICON)

ALSO AVAILABLE AS JAN AND HI-REL UNITS

CASE 20
(TO-72)

NPN silicon annular transistors with high reliability designed for use in VHF and UHF amplifier, mixer and oscillator applications.

Active elements isolated from case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	30	Vdc
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ $T_C = 25°C$ Derating Factor Above 25° C	P_D	300 1.71	mW mW/° C
Total Device Dissipation @ $T_A = 25°C$ Derating Factor Above 25° C	P_D	200 1.14	mW mW/° C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	° C

TABLE I : GROUP A INSPECTION (T_A = 25°C ± 3°C unless otherwise noted)

Examination or Test		Mil-Std-750 Method	Symbol	Limits		Unit	*LTPD
				Min	Max		
SUBGROUP 1							
Visual and Mechanical Examination		2071	-	-	-	-	10
SUBGROUP 2							
Collector-Base Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)	All Types	3036 Condition D	I_{CBO}	-	10	nAdc	5
Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	All Types	3001 Condition D	BV_{CBO}	30	-	Vdc	
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	All Types	3026 Condition D	BV_{EBO}	3.0	-	Vdc	
Collector-Emitter Breakdown Voltage (I_C = 3.0 mAdc, I_B = 0)	All Types	3011 Condition D	BV_{CEO}	15	-	Vdc	
DC Current Gain		3076	h_{FE}			-	
(V_{CE} = 10 Vdc, I_C = 10 mAdc)	JAN2N918			20	-		
(V_{CE} = 1.0 Vdc, I_C = 3.0 mAdc)	JAN2N918‡			20‡	200		
(V_{CE} = 10 Vdc, I_C = 500 μAdc)	JAN2N918			10	-		
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	All Types	3066 Condition A	V_{BE}	-	1.0	Vdc	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	All Types	3071	$V_{CE(sat)}$	-	0.4	Vdc	

*Applies to Meg-A-Life II and Mil Units Only

‡Minimum value only applies to Standard Unit

TABLE I : GROUP A INSPECTION (T_A = 25°C ± 3°C unless otherwise noted) (continued)

Examination or Test		Mil-Std-750 Method	Symbol	Limits		Unit	*LTPD
				Min	Max		
SUBGROUP 3							10
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f ≥ 0.1 MHz & ≤ 1.0 MHz)	All Types	3236	C_{ob}	-	1.7	pF	
(V_{CB} = 0, I_E = 0, f ≥ 0.1 MHz & ≤ 1.0 MHz)	All Types			-	3.0		
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f ≥ 0.1 MHz & ≤ 1.0 MHz)	All Types	3240 (Note 1)	C_{ib}	-	2.0	pF	
SUBGROUP 4							
Small-Signal Current Gain (V_{CE} = 10 Vdc, I_C = 4.0 mAdc, f = 100 MHz)	All Types	3306	$\|h_{fe}\|$	6.0	-	-	
Small-Signal Amplifier Gain (V_{CC} = 12 Vdc, I_C = 6.0 mAdc, f = 200 MHz)	All Types	(Figure 2)	G_{pe}	15	-	dB	
Collector-Base Time Constant (V_{CB} = 10 Vdc, I_E = -4.0 mAdc, f = 79.8 MHz)	JAN2N918		$r_b'C_c$	-	25	ps	
Noise Figure (V_{CE} = 6.0 Vdc, I_C = 1.0 mAdc, R_G = 400 ohms, f = 60 MHz)	All Types	(Note 2)	NF	-	6.0	dB	
Oscillator Power Output (V_{CB} = 15 Vdc, I_C = 8.0 mAdc, f = 500 MHz)	All Types	(Note 3)	P_{out}	30	-	mW	
Collector-Efficiency Test (V_{CB} = 15 Vdc, I_C = 8.0 mAdc, f = 500 MHz)	All Types	(Note 3)	η	25	-	%	
SUBGROUP 5 (Note 4)		(Note 4)					
High Temperature Operation							
Collector-Base Cutoff Current (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	All Types	3036 Condition D	I_{CBO}	-	1.0	µAdc	
Low Temperature Operation							
DC Current Gain (V_{CE} = 1.0 Vdc, I_C = 3.0 mAdc, T_A = -55°C)	JAN2N918	3076 (Note 4)	h_{FE}	10	-	-	

*Applies to Meg-A-Life II and Mil Units Only

NOTES:

1. This test shall be in accordance with Method 3240 of MIL-STD-750 except that the output capacitor is omitted.
2. Noise Figure shall be measured using a HP 342A NF Meter in accordance with HP 342A pertinent test procedure or by use of a suitable equivalent test-equipment circuit and procedure.
3. Sample units shall be allowed to return to and be stabilized at room ambient temperature prior to being subjected to the Low-Temperature Operation test.
4. Test Measurement shall be made after thermal equilibrium has been reached at the temperature specified.
5. All applicable end-point test measurements shall be made within four hours after the particular sample units have been subjected to the required physical-mechanical or environmental test(s). This requirement is not applicable to measurements specified to be made during (subjection of sample units) a physical-mechanical or environmental test, and shall not be applicable where otherwise specified for life test(s).
6. There shall be no evidence of flaking, pitting, or other visible signs of corrosion on sample units, upon examination without magnifications, after subjection to test.
7. Per MIL-STD-202, Method 112, Test Condition C, Procedure 111a and Test Condition A for Gross Leaks.

TABLE II : GROUP B INSPECTION

(Fourth lead is "floating" unless otherwise specified.)

Examination or Test	Mil-Std-750 Method	Symbol	Limits		Unit	LTPD
			Min	Max		
SUBGROUP 1						
Physical Dimensions	2066	-	-	-	-	20
SUBGROUP 2						
Solderability	2026	-	-	-	-	10
Temperature Cycling	1051 Condition C	-	-	-	-	
Thermal Shock (Glass Strain)	1056 Condition A	-	-	-	-	
Seal (Leak Rate)	(Note 7)					
Moisture Resistance (No Initial Conditioning)	1021	-	-	-	-	
End-Point Tests: (Note 5)						
Collector-Base Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	-	10	nAdc	
DC Current Gain (I_C = 3.0 mAdc, V_{CE} = 1.0 Vdc)	3076	h_{FE}	20	200	-	
SUBGROUP 3						
Shock (1500 G, 0.5 ms, 5 blows each, Orientations X_1, Y_1, Y_2, Z_1; Total = 20 blows)	2016 Non-operating	-	-	-	-	10
Vibration, Variable Frequency	2056	-	-	-	-	
Vibration Fatigue (20 G)	2046 Non-operating	-	-	-	-	
Constant Acceleration (Centrifuge) (20,000 G, Orientations X_1, Y_1, Y_2, Z_1)	2006	-	-	-	-	
End-Point Tests:						
Same as Subgroup 2 (Note 5)						
SUBGROUP 4						
Lead Fatigue	2036 Condition E	-	-	-	-	15
End-Point Tests:						
Seal (Notes 5 and 7)			-	5×10^{-7}	atm cm^3/s	
SUBGROUP 5						
Salt Atmosphere (Corrosion) (Note 6)	1041	-	-	-	-	20
End-Point Tests:						
Same as Subgroup 2						
SUBGROUP 6						
High Temperature Life (Non-Operating) (T_{stg} = +200°C, min)	1031 Non-operating	-	-	-	-	λ = 15
End-Point Tests: (Note 5)						
Collector-Base Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	-	20	nAdc	
DC Current Gain (I_C = 3.0 mAdc, V_{CE} = 1.0 Vdc)	3076	h_{FE}		± 25% of Group A Limits	-	
SUBGROUP 7						
Steady State Operation Life (P_T = 200 mW, I_C = 20 mAdc, T_A = 25°C ± 3°C)	1026	-	-	-	-	λ = 15
End-Point Tests: (Note 5)						
Same as Subgroup 6						

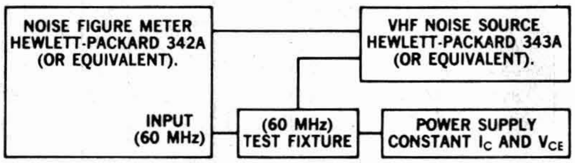
2N918, JAN 2N918 (continued)

TABLE III: CONDITIONING and SCREENING

Procedure	Symbol	Mil-Std-750 Method	Conditions	Limits
BURN-IN at rated Power for 96 hours	–	–	V_{CE} = 10 Vdc, T_A = 25°C	–
ELECTRICAL SCREENS After Burn-In DC Current Gain Changes in h_{FE} before and after Burn-In, measured at stated conditions.	Δh_{FE}	3076	I_C = 3.0 mAdc, V_{CE} = 1.0 Vdc, Pulsed*	±20% Within Group A Limits
Collector-Base Cutoff Current	I_{CBO}	3036 Condition D	V_{CB} = 15 Vdc	Group A Limits
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	3071	I_C = 10 mA, I_B = 1.0 mA; Pulsed*	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	3066 Condition A	I_C = 10 mA, I_B = 1.0 mA; Pulsed*	

* Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%

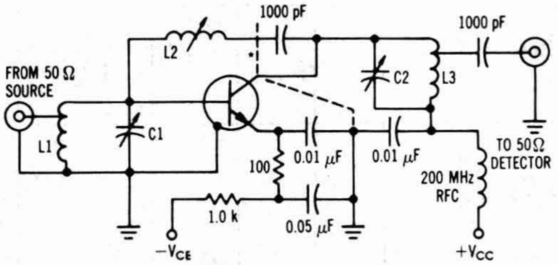
FIGURE 1 — NOISE FIGURE TEST BLOCK DIAGRAM


NOISE FIGURE METER
HEWLETT-PACKARD 342A
(OR EQUIVALENT).
INPUT
(60 MHz)
VHF NOISE SOURCE
HEWLETT-PACKARD 343A
(OR EQUIVALENT).
(60 MHz)
TEST FIXTURE
POWER SUPPLY
CONSTANT I_C AND V_{CE}

The test fixture shall consist of a 60 MHz tuned amplifier and suitable biasing circuits. It should be constructed utilizing good very-high-frequency design techniques.

The effective source susceptance should be tuned for each device being tested to obtain minimum noise figure. Note that because the HP 343A has a 50-ohm output resistance, a suitable impedance transformer must be used to obtain an effective source conductance of 2.5 mmho at the transistor with minimum losses.

FIGURE 2 — NEUTRALIZED 200 MHz POWER AMPLIFIER GAIN TEST CIRCUIT


1000 pF
1000 pF
L2
*
FROM 50 Ω SOURCE
C2
L3
L1
C1
100
0.01 μF
0.01 μF
TO 50 Ω DETECTOR
200 MHz RFC
1.0 k
0.05 μF
$-V_{CE}$
$+V_{CC}$

NEUTRALIZATION PROCEDURE:

A — Connect 200 MHz signal generator (with 50 ohm output impedance) to input terminals of amplifier, and connect 50 ohm RF voltmeter to output terminals of amplifier.

B — Apply V_{EE} and V_{CC} to obtain specified test conditions.

C — Adjust output of signal generator to approximately 10 millivolts and tune C1 and C2 for maximum output.

D — Interchange connections to signal generator and RF voltmeter and with sufficient signal applied at output terminals, tune L2 for minimum indication on RF-voltmeter.

E — Repeat this sequence until optimum settings are obtained for all variables.

CIRCUIT COMPONENT INFORMATION:

C1: 3-12 pF

C2: 1.5-7.5 pF

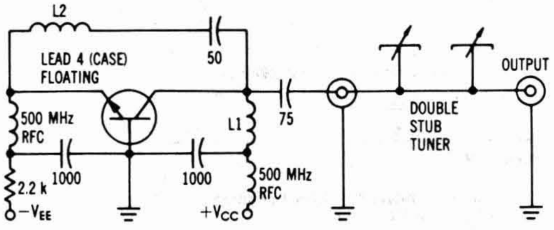
L1: 3 1/2 turns #16 AWG 5/16" ID, 7/16" length, turns ratio — 2 to 1

L2: 0.4-0.65 μH Miller #4303 (or equal)

L3: 8 turns #16 AWG 1/8" ID, 7/8" length, turns ratio — 8 to 1

***External interlead shield to isolate collector lead from emitter and base leads.**

FIGURE 3 — 500 MHz OSCILLATOR TEST CIRCUIT


L2
50
LEAD 4 (CASE) FLOATING
OUTPUT
500 MHz RFC
L1
75
DOUBLE STUB TUNER
2.2 k
1000
1000
500 MHz RFC
$-V_{EE}$
$+V_{CC}$

OSCILLATOR ADJUSTMENT PROCEDURE:

Measurements of P_{out} shall be made in this circuit or a suitable equivalent. The circuit adjustment procedure is as follows:

A — Set V_{CC} and V_{EE} to obtain specified test conditions.

B — Adjust stub tuner to obtain maximum output at specified frequency of oscillation.

C — Check I_C and reset if necessary.

D — Read P_{out}.

Note: Collector efficiency (η), may be determined as follows:

$$\eta \text{ in } \% = \frac{P_{out}}{120} \times 100$$

Where P_{out} is in milliwatts.

CIRCUIT COMPONENT INFORMATION:

L1: 2 turns #16 AWG, 3/8" OD, 1 1/4" length

L2: 9 turns #22 AWG, 3/16" OD, 1/2" length

Capacitance values are in pF.

Double Stub Tuner consists of the following commercially available components.

2 GR Type 874 TEE
1 GR Type 874-D20 Adjustable Stub
1 GR Type 874-LA Adjustable Line
1 GR Type 874-WN3 Short-Circuit Termination
(or equivalents)

2N929, A (SILICON)
2N930, A

CASE 22
(TO-18)

NPN silicon annular transistors for low-level, low-noise amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N929 2N930	2N929A 2N930A	Unit
Collector-Emitter Voltage	V_{CEO}	45	60	Vdc
Collector-Base Voltage	V_{CB}	45	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	6.0	Vdc
Collector Current	I_C	30		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.5 3.33		W mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.8 12		Watt mW/°C
Operating Junction Temperature Range	T_J	-65to + 175		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

2N929, A, 2N930, A (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	45	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0) 2N929A, 2N930A	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0) 2N929, 2N930 2N929A, 2N930A	BV_{EBO}	5.0 6.0	- -	Vdc
Collector Cutoff Current (V_{CE} = 5.0 Vdc, I_B = 0)	I_{CEO}	-	2.0	nAdc
Collector Cutoff Current (V_{CE} = 45 Vdc, V_{BE} = 0) 2N929, 2N930 2N929A, 2N930A	I_{CES}	- -	10 2.0	nAdc
(V_{CE} = 45 Vdc, V_{BE} = 0, T_A = 170°C) 2N929, 2N930 2N929A, 2N930A		- -	10 2.0	μAdc
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0) 2N929, 2N930 2N929A, 2N930A	I_{CBO}	- -	10 2.0	nAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0) 2N929, 2N930 2N929A, 2N930A	I_{EBO}	- -	10 2.0	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 1.0 μAdc, V_{CE} = 5.0 Vdc) 2N929A 2N930A	h_{FE}	25 60	- -	-
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc) 2N929, 2N929A 2N930, 2N930A		40 100	120 300	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C) 2N929 2N929A 2N930 2N930A		10 15 20 30	- - - -	
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc) 2N929, 2N929A 2N930, 2N930A		60 150	- -	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc) 2N929, 2N929A 2N930, 2N930A		- -	350 600	
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 0.5 mAdc) 2N929, 2N930 2N929A, 2N930A	$V_{CE(sat)}$*	- -	1.0 0.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 0.5 mAdc) 2N929, 2N930 2N929A, 2N930A	$V_{BE(sat)}$*	0.6	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 30 MHz) 2N929, 2N930 2N929A, 2N930A	f_T	30 45	- -	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz) 2N929, 2N930 2N929A, 2N930A	C_{ob}	- -	8.0 6.0	pF
Input Impedance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	25	32	ohms
Voltage Feedback Ratio (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	600	X 10^{-6}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N929, 2N929A 2N930, 2N930A	h_{fe}	60 150	350 600	-
Output Admittance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	1.0	μmho
Noise Figure (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 10 Hz to 15.7 kHz) 2N929, 2N929A 2N930, 2N930A	NF	- -	4.0 3.0	dB

* Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

2N956

For Specifications, See 2N718A Data.

2N960 (GERMANIUM)
2N961
2N962
2N964
2N965
2N966

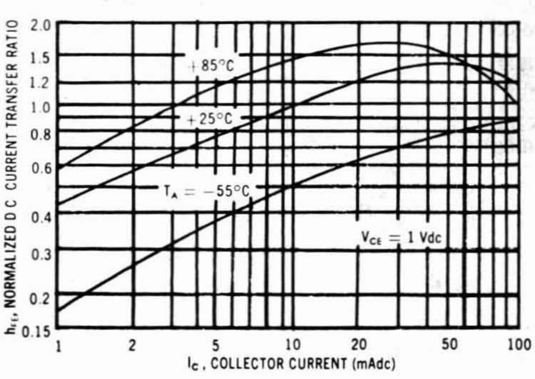
CASE 22
(TO-18)

PNP germanium epitaxial mesa transistors for high-speed switching applications.

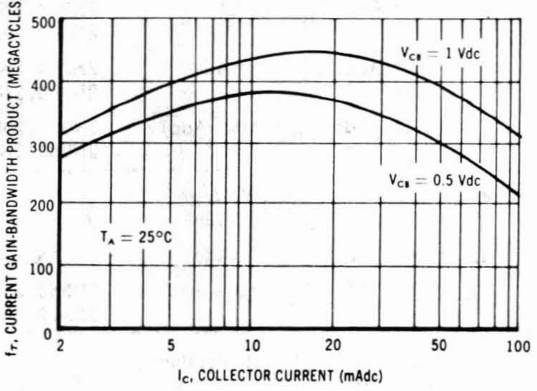
Collector connected to case

MAXIMUM RATINGS

Characteristic	Symbol	2N960 2N964	2N961 2N965	2N962 2N966	Unit
Collector-Emitter Voltage	V_{CE}	15	12	12	Vdc
Collector-Base Voltage	V_{CB}	15	12	12	Vdc
Emitter-Base Voltage	V_{EB}	2.5	2.0	1.25	Vdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	150 2			mW $mW/^oC$
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	300 4			mW $mW/^oC$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100			^oC

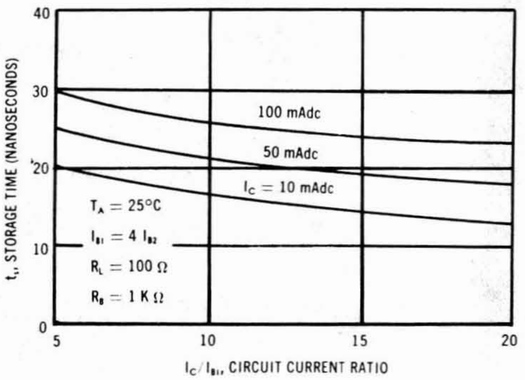


NORMALIZED D C CURRENT TRANSFER RATIO versus COLLECTOR CURRENT

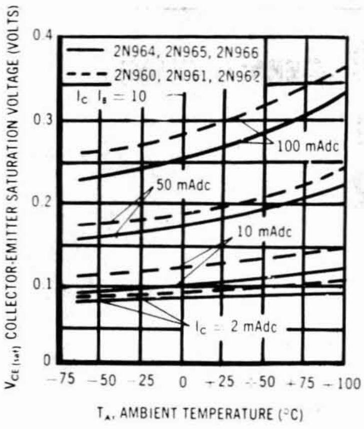


CURRENT GAIN-BANDWIDTH PRODUCT (f_T) versus COLLECTOR CURRENT

STORAGE TIME versus CIRCUIT RATIO



COLLECTOR-EMITTER SATURATION VOLTAGE versus AMBIENT TEMPERATURE



ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage ($I_C = 100\ \mu Adc$, $I_E = 0$)	2N960, 2N964	BV_{CBO}	15	25	-	Vdc
	2N961, 2N962, 2N965, 2N966		12	20	-	
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu Adc$, $I_C = 0$)	2N960, 2N964	BV_{EBO}	2.5	-	-	Vdc
	2N961, 2N965		2.0	-	-	
	2N962, 2N966		1.25	-	-	
Collector-Latch-up Voltage $V_{CC} = 11.5$ Vdc		LV_{CEX}	11.5	-	-	Vdc
Collector-Emitter Cutoff Current ($V_{CE} = 15$ Vdc)	2N960, 2N964	I_{CES}	-	-	100	μAdc
($V_{CE} = 12$ Vdc)	2N961, 2N962, 2N965, 2N966		-	-	100	
Collector-Base Cutoff Current ($V_{CB} = 6$ Vdc, $I_E = 0$)		I_{CBO}	-	0.4	3	μAdc
DC Current Gain ($I_C = 10$ mAdc, $V_{CE} = 0.3$ Vdc)	2N960, 2N961, 2N962	h_{FE}	20	40	-	-
	2N964, 2N965, 2N966		40	70	-	
($I_C = 50$ mAdc, $V_{CE} = 1$ Vdc)	2N960, 2N961, 2N962		20	55	-	
	2N964, 2N965, 2N966		40	90	-	
($I_C = 100$ mAdc, $V_{CE} = 1$ Vdc)	2N960, 2N961, 2N962		20	50	-	
	2N964, 2N965, 2N966		40	85	-	
Collector-Emitter Saturation Voltage ($I_C = 10$ mAdc, $I_B = 1$ mAdc)	2N964, 2N965, 2N966	$V_{CE(sat)}$	-	0.11	0.18	Vdc
	2N960, 2N961, 2N962		-	0.13	0.20	
($I_C = 50$ mAdc, $I_B = 5$ mAdc)	2N964, 2N965, 2N966		-	0.18	0.35	
	2N960, 2N961, 2N962		-	0.20	0.40	
($I_C = 100$ mAdc, $I_B = 10$ mAdc)	2N964, 2N965, 2N966		-	0.27	0.60	
	2N960, 2N961, 2N962		-	0.30	0.70	
Base-Emitter Saturation Voltage ($I_C = 10$ mAdc, $I_B = 1$ mAdc)	All Types	$V_{BE(sat)}$	0.30	0.40	0.50	Vdc
($I_C = 50$ mAdc, $I_B = 5$ mAdc)	All Types		0.40	0.55	0.75	
($I_C = 100$ mAdc, $I_B = 10$ mAdc)	2N960, 2N961, 2N964, 2N965		0.40	0.65	1.00	
	2N962, 2N966		0.40	0.75	1.25	
Current-Gain – Bandwidth Product ($I_E = 20$ mAdc, $V_{CB} = 1.0$ Vdc, f = 100 MHz)		f_T	300	460	-	MHz

2N960 SERIES (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Typ	Max	Unit
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	-	2.2	4	pF
Emitter Transition Capacitance (V_{EB} = 1 Vdc)	C_{Te}	-	2.0	3.5	pF
Turn-On Time All Types (I_C = 10 mAdc, I_{B1} = 5 mAdc, $V_{BE(off)}$ = 1.25 Vdc)	t_{on}	-	35	50	ns
(I_C = 100 mAdc, I_{B1} = 5 mAdc, $V_{BE(off)}$ = 1.25 Vdc)		-	30	50	
Turn-Off Time (I_C = 10 mAdc, I_{B1} = 1 mAdc, I_{B2} = 0.25 mAdc)	t_{off}				ns
2N960, 2N961, 2N964, 2N965		-	60	85	
2N962, 2N966		-	80	100	
(I_C = 100 mAdc, I_{B1} = 5 mAdc, I_{B2} = 1.25 mAdc)					
2N960, 2N961, 2N964, 2N965		-	50	85	
2N962, 2N966		-	60	100	
Rise Time Constant	τ_{RE}	-	0.6	-	ns
Hole Storage Factor	K'_s	-	16	-	ns
Fall Time Constant	τ_{FE}	-	0.5	-	ns
Total Control Charge (I_C = 10 mAdc, I_B = 1 mAdc) 2N960, 2N961, 2N964, 2N965	Q_T	-	50	80	pC
2N962, 2N966		-	60	90	
(I_C = 100 mAdc, I_B = 5 mAdc) 2N960, 2N961, 2N964, 2N965		-	80	125	
2N962, 2N966		-	100	150	

2N963 (GERMANIUM)
2N967

CASE 22
(TO-18)

PNP germanium epitaxial mesa transistors for high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS

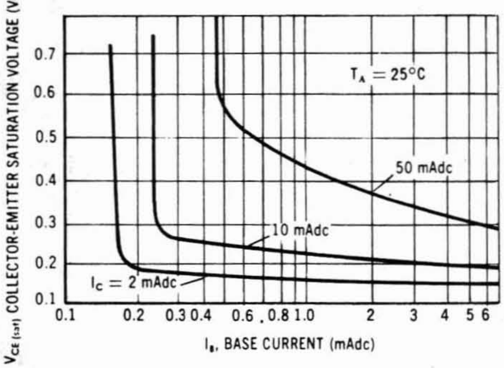
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CES}	12	Vdc
Collector-Base Voltage	V_{CB}	12	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	150 2	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	300 4	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	100	°C

2N963, 2N967 (continued)

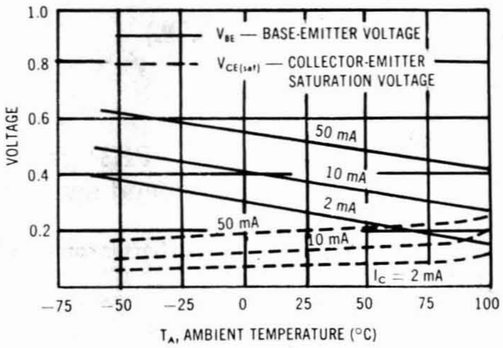
ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	12	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	2	-	Vdc
Collector-Latch-up Voltage (V_{CC} = 10 Vdc)	LV_{CEX}	10	-	Vdc
Collector Cutoff Current (V_{CE} = 12 Vdc, V_{BE} = 0)	I_{CES}	-	100	μAdc
Collector Cutoff Current (V_{CE} = 10 Vdc, V_{BE} = 0.3 Vdc, T_A = 55°C)	I_{CEX}	-	20	μAdc
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)	I_{CBO}	-	5	μAdc
Emitter Cutoff Current (V_{BE} = 5 Vdc, I_C = 0)	I_{EBO}	-	1	mAdc
Base Cutoff Current (V_{CE} = 10 Vdc, V_{BE} = 0.3 Vdc, T_A = 55°C)	I_{BL}	-	20	μAdc
DC Current Gain (I_C = 10 mAdc, V_{CE} = 0.3 Vdc) 2N963 2N967	h_{FE}	20 40	- -	-
Collector Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc	$V_{CE(sat)}$	-	0.2	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	0.3	0.5	Vdc
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 1 Vdc, f = 100 MHz)	f_T	300	-	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	-	5	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	4	pF
Turn-On Time (I_C = 10 mAdc, I_{B1} = 1 mAdc, $V_{BE(off)}$ = 1.25 Vdc)	t_{on}	-	60	ns
Turn-Off Time (I_C = 10 mAdc, I_{B1} = 1 mAdc, I_{B2} = 1.25 mAdc)	t_{off}	-	120	ns
Total Control Charge (I_C = 10 mAdc, I_B = 1 mAdc)	Q_T	-	120	pC

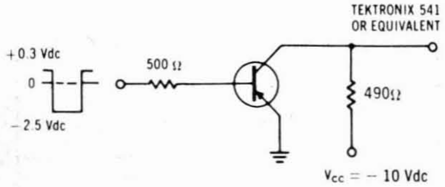
COLLECTOR-EMITTER SATURATION VOLTAGE versus BASE CURRENT



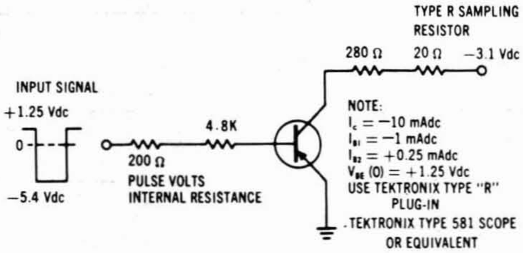
VOLTAGE versus TEMPERATURE CHARACTERISTICS



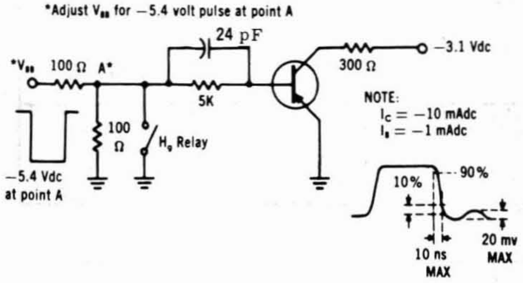
COLLECTOR LATCH-UP VOLTAGE TEST CIRCUIT


+0.3 Vdc
0
−2.5 Vdc
500 Ω
TEKTRONIX 541 OR EQUIVALENT
490Ω
$V_{CC} = -10$ Vdc

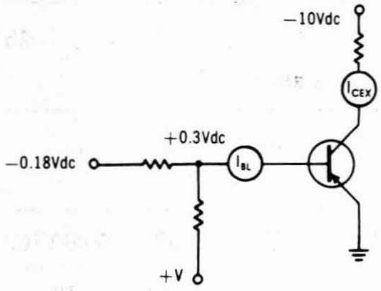
10-mA (I_C) SWITCHING TIME TEST CIRCUIT


TYPE R SAMPLING RESISTOR
280 Ω
20 Ω
−3.1 Vdc
INPUT SIGNAL
+1.25 Vdc
0
−5.4 Vdc
4.8K
200 Ω
PULSE VOLTS INTERNAL RESISTANCE
NOTE:
$I_C = -10$ mAdc
$I_{B1} = -1$ mAdc
$I_{B2} = +0.25$ mAdc
$V_{BE}(0) = +1.25$ Vdc
USE TEKTRONIX TYPE "R" PLUG-IN
TEKTRONIX TYPE 581 SCOPE OR EQUIVALENT

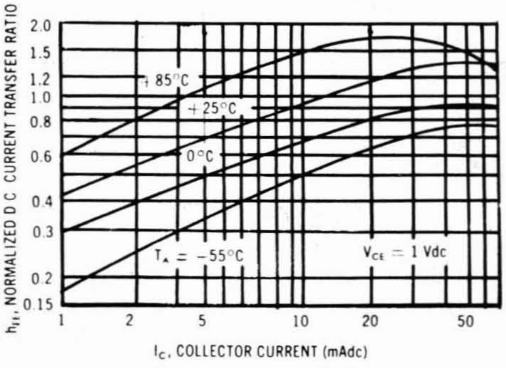
BASE AND COLLECTOR CUTOFF CURRENT TEST CIRCUIT


*Adjust V_{BB} for −5.4 volt pulse at point A
24 pF
$*V_{BB}$
100 Ω
A*
5K
300 Ω
−3.1 Vdc
100 Ω
H_g Relay
−5.4 Vdc at point A
NOTE:
$I_C = -10$ mAdc
$I_B = -1$ mAdc
10%
90%
10 ns MAX
20 mv MAX

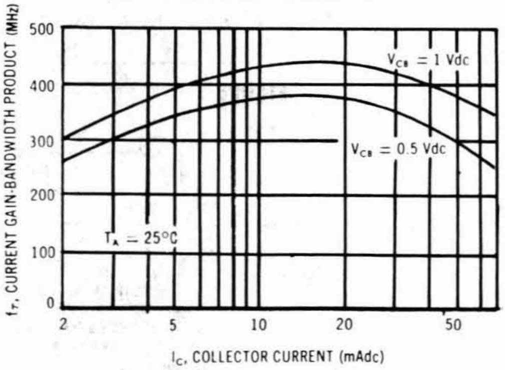
10-mA (I_C) TOTAL CONTROL CHARGE TEST CIRCUIT


−10Vdc
I_{CEX}
+0.3Vdc
−0.18Vdc
I_{BL}
+V

NORMALIZED DC CURRENT TRANSFER RATIO versus COLLECTOR CURRENT



CURRENT GAIN-BANDWIDTH PRODUCT (f_T) versus COLLECTOR CURRENT



2N964 (GERMANIUM)

For Specifications, See 2N960 Data.

2N964A (GERMANIUM)

CASE 22
(TO-18)

PNP germanium epitaxial mesa transistor for high-speed switching applications.

Collector connected to case

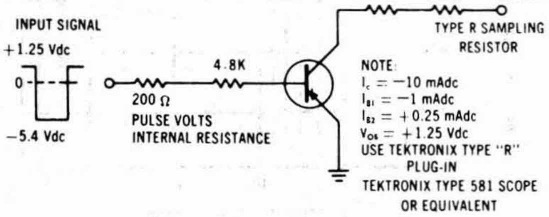
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	7	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	2.5	Vdc
Collector Current	I_C	100	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	150 2	mW mW/°C
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	300 4	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	°C

THERMAL CHARACTERISTICS

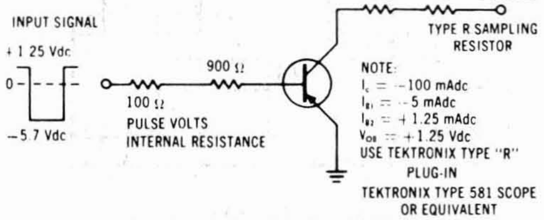
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.25	°C/mW
Thermal Resistance, Case to Ambient	θ_{CA}	0.5	°C/mW

FIGURE 1


INPUT SIGNAL
+1.25 Vdc
0
−5.4 Vdc
200 Ω
PULSE VOLTS
INTERNAL RESISTANCE
4.8K
280 Ω
20 Ω
−3.1 Vdc
TYPE R SAMPLING RESISTOR
NOTE:
$I_c = -10$ mAdc
$I_{B1} = -1$ mAdc
$I_{B2} = +0.25$ mAdc
$V_{OB} = +1.25$ Vdc
USE TEKTRONIX TYPE "R" PLUG-IN
TEKTRONIX TYPE 581 SCOPE OR EQUIVALENT

10-mA (I_C) SWITCHING TIME TEST CIRCUIT

FIGURE 2


INPUT SIGNAL
+1.25 Vdc
0
−5.7 Vdc
100 Ω
PULSE VOLTS
INTERNAL RESISTANCE
900 Ω
48 Ω
2 Ω
5.2 Vdc
TYPE R SAMPLING RESISTOR
NOTE:
$I_c = -100$ mAdc
$I_{B1} = -5$ mAdc
$I_{B2} = +1.25$ mAdc
$V_{OB} = +1.25$ Vdc
USE TEKTRONIX TYPE "R" PLUG-IN
TEKTRONIX TYPE 581 SCOPE OR EQUIVALENT

100-mA (I_C) SWITCHING TIME TEST CIRCUIT

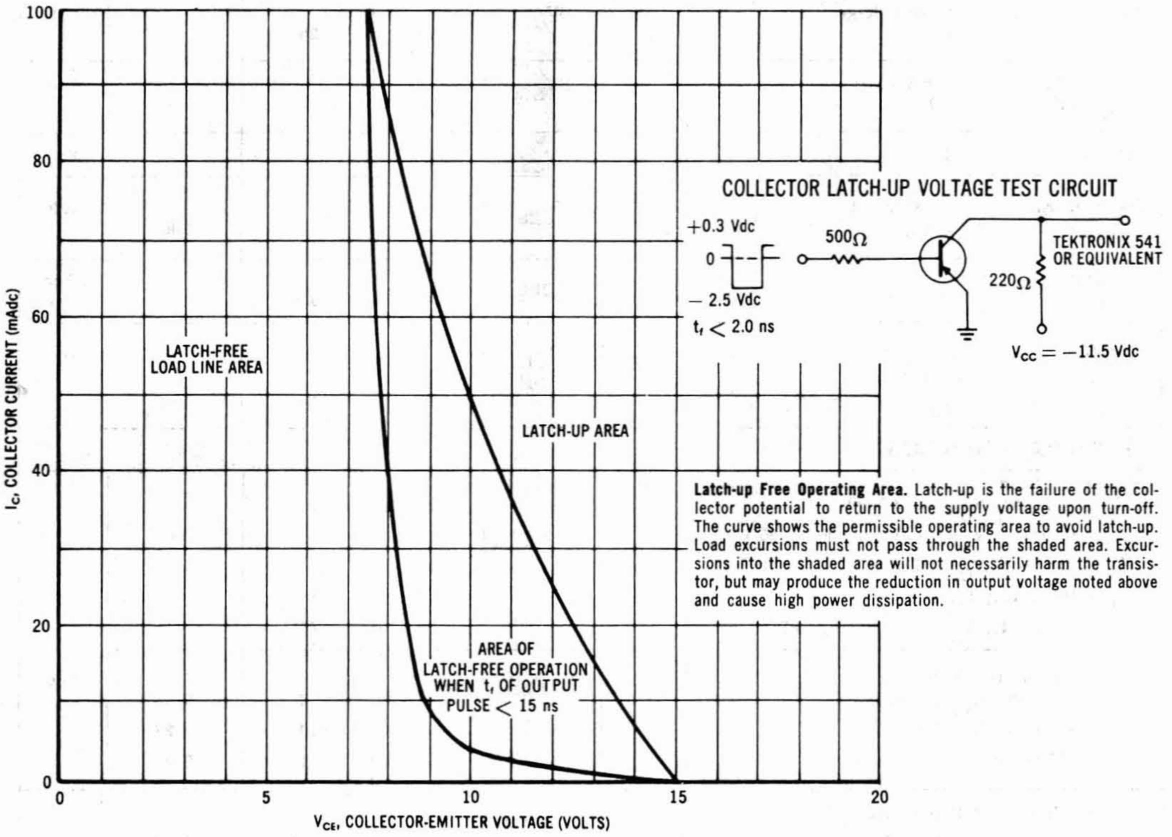
2N964A (continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Fig.	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	7	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	15	25	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	2.5	- -	-	Vdc
Collector Latch-up Voltage	3	LV_{CEX}	11.5	-	-	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0)		I_{CES}	-	-	100	μAdc
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)		I_{CBO}	-	0.4	3	μAdc
Base Leakage Current	4	I_{BL}				μAdc
(V_{CE} = 6 Vdc, $V_{BE(off)}$ = 0.5 Vdc)			-	-	4	
(V_{CE} = 6 Vdc, $V_{BE(off)}$ = 0.5 Vdc, T_J = 85°C)			-	50	140	
ON CHARACTERISTICS						
DC Current Gain	8	h_{FE}				
(I_C = 10 mAdc, V_{CE} = 0.3 Vdc)			40	80	-	
(I_C = 10 mAdc, V_{CE} = 0.3 Vdc, T_J = -55°C)			20	45	-	
(I_C = 50 mAdc, V_{CE} = 1 Vdc)			48	105	-	
(I_C = 100 mAdc, V_{CE} = 1 Vdc)			40	95	-	
(I_C = 100 mAdc, V_{CE} = 1 Vdc, T_J = 85°C)			35	85	-	
Collector Saturation Voltage	5	$V_{CE(sat)}$				Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			-	0.1	0.18	
(I_C = 50 mAdc, I_B = 5 mAdc)			-	0.16	0.28	
(I_C = 100 mAdc, I_B = 10 mAdc)			-	0.22	0.4	
Base-Emitter Saturation Voltage	6	$V_{BE(sat)}$				Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			0.3	0.38	0.44	
(I_C = 50 mAdc, I_B = 5 mAdc)			0.4	0.48	0.58	
(I_C = 100 mAdc, I_B = 10 mAdc)			0.4	0.6	0.72	
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_E = 20 mAdc, V_{CB} = 1 Vdc, f = 100 MHz)		f_T	300	460	-	MHz
High-Frequency Current Gain (I_C = 20 mAdc, V_{CE} = 1 Vdc, f = 100 MHz)		h_{fe}	3.0	4.6	-	-
Output Capacitance	11	C_{ob}				pF
(V_{CB} = 1 Vdc, I_E = 0, f = 1 MHz)			-	2.7	5	
(V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)			-	2.2	4	
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 100 kHz)	11	C_{ib}	-	2	3.5	pF
Delay Time Plus Rise Time		$t_d + t_r$				ns
(I_C = 10 mAdc)	1		-	35	50	
(I_C = 100 mAdc)	2		-	30	50	
Storage Time Plus Fall Time		$t_s + t_f$				ns
(I_C = 10 mAdc)	1		-	60	85	
(I_C = 100 mAdc)	2		-	50	85	
Active Region Time Constant (I_C = 10 mAdc)	9	τ_A	-	0.6	1.5	ns
Total Control Charge (I_C = 10 mAdc, I_B = 1 mAdc)	10	Q_T	-	50	75	pC

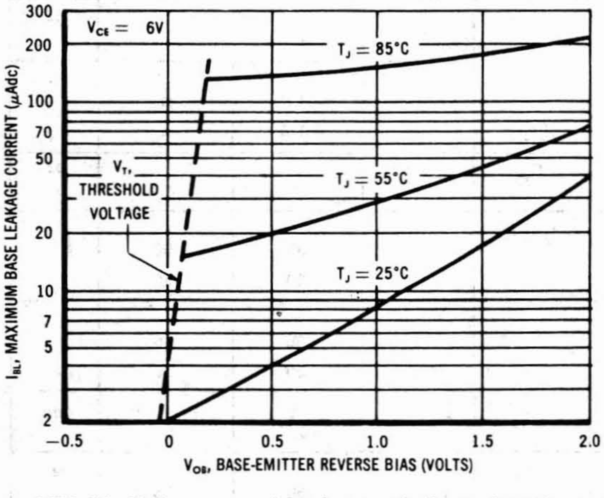
2N964A LIMIT CURVES

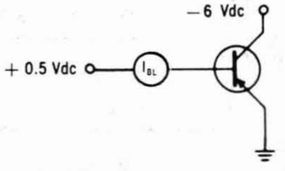
FIGURE 3—AREA OF PERMISSIBLE LOAD LOCI



Latch-up Free Operating Area. Latch-up is the failure of the collector potential to return to the supply voltage upon turn-off. The curve shows the permissible operating area to avoid latch-up. Load excursions must not pass through the shaded area. Excursions into the shaded area will not necessarily harm the transistor, but may produce the reduction in output voltage noted above and cause high power dissipation.

FIGURE 4—COMMON EMITTER DC LEAKAGE CHARACTERISTICS





BASE LEAKAGE CURRENT TEST CIRCUIT

Base Leakage Current. I_{BL} is defined as base leakage current with both junctions reverse biased. I_c is always less than I_{BL} for $V_{OB} > V_T$. (V_{OB} is off condition base bias, V_T is base voltage at threshold of conduction.)

NOTE: Limit Curves are based on periodic engineering evaluation. Production Tests are made at points indicated in the Electrical Characteristics Table.

2N964A LIMIT CURVES

FIGURE 5 — COLLECTOR-EMITTER SATURATION VOLTAGE versus BASE CURRENT

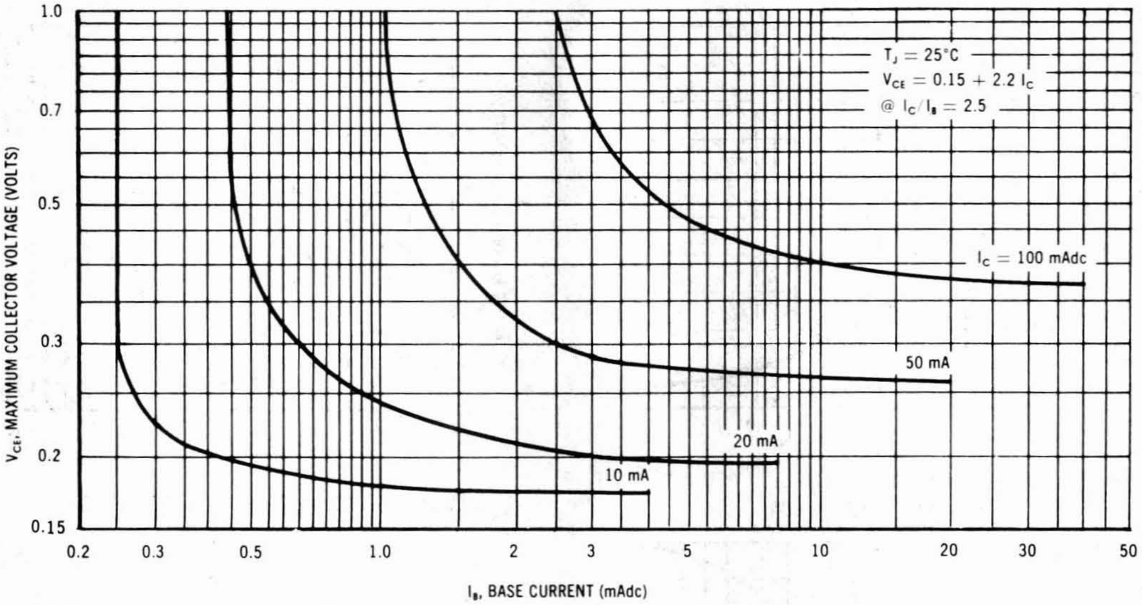


FIGURE 6 — BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT

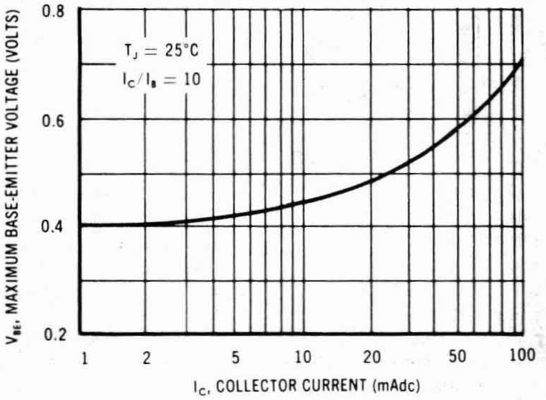


FIGURE 7 — TEMPERATURE CO-EFFICIENTS

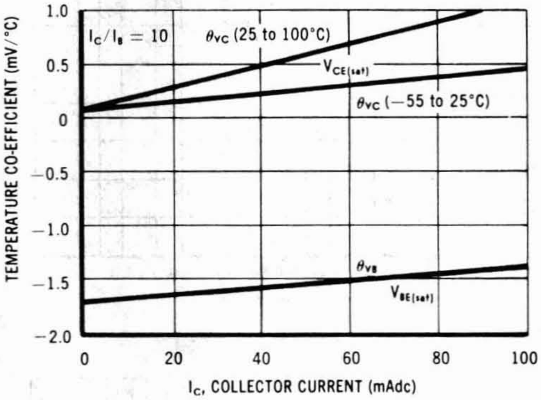
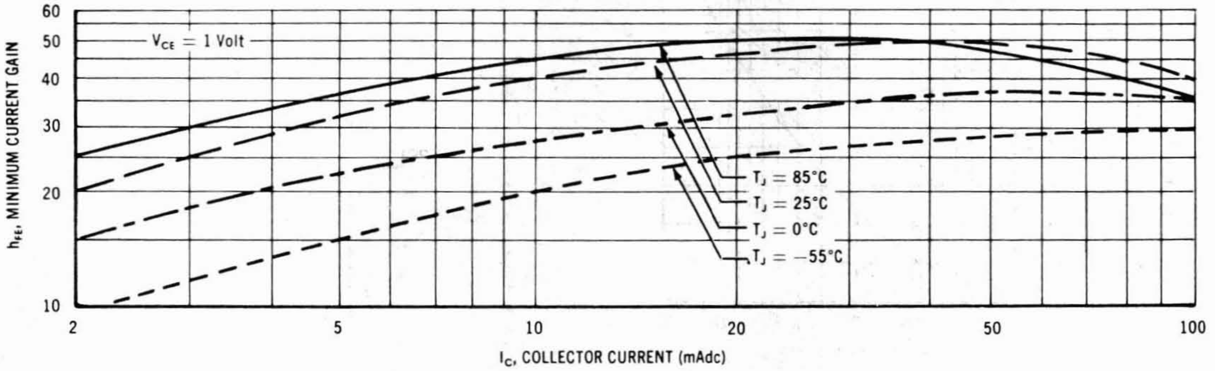


FIGURE 8 — CURRENT GAIN CHARACTERISTICS

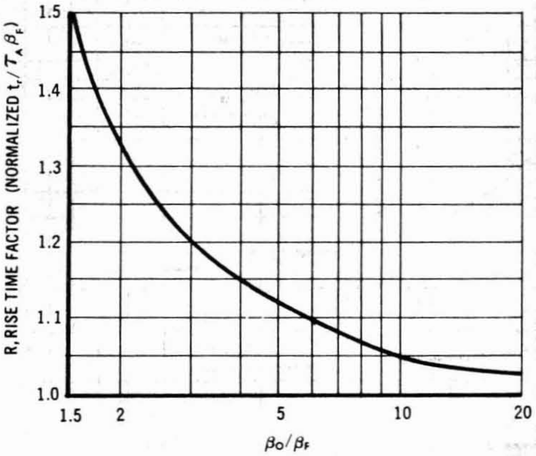


NOTE: Limit Curves are based on periodic engineering evaluation. Production Tests are made at points indicated in the Electrical Characteristics Table.

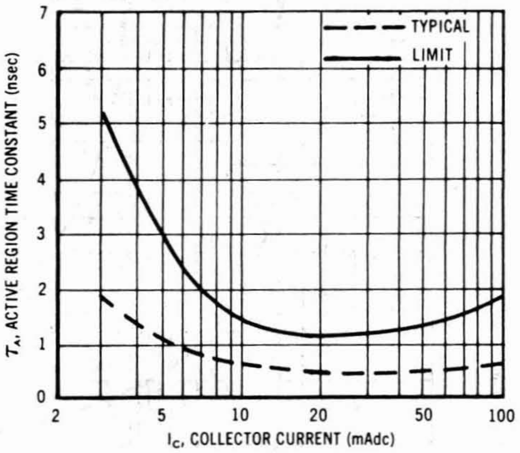
2N964A LIMIT CURVES

FIGURE 9—SWITCHING TIME CURVES FOR RESISTOR COUPLED CIRCUITS

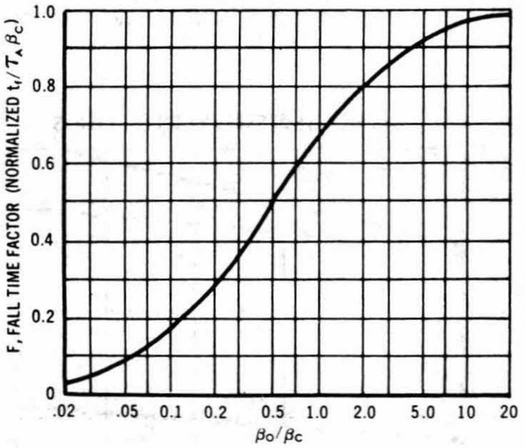
9a—RISE TIME FACTOR



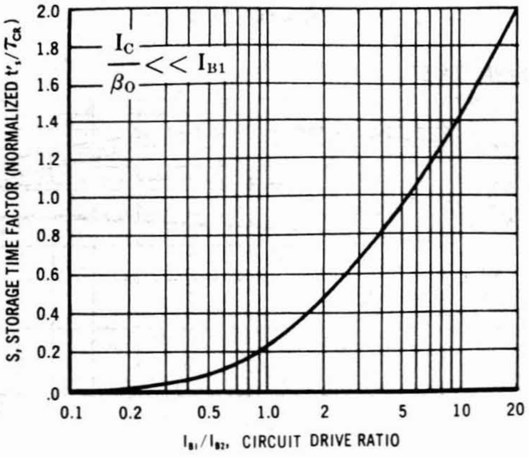
9b—ACTIVE REGION TIME CONSTANT



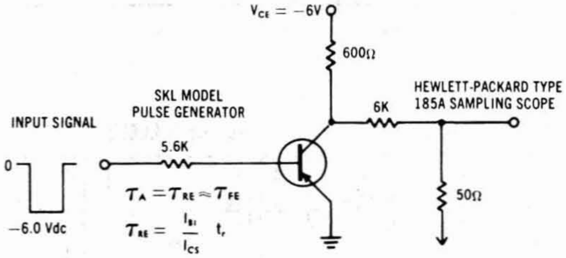
9c— FALL TIME FACTOR



9d—STORAGE TIME



ACTIVE REGION TIME CONSTANT TEST CIRCUIT


$V_{CE} = -6V$
600Ω
SKL MODEL PULSE GENERATOR
6K
HEWLETT-PACKARD TYPE 185A SAMPLING SCOPE
INPUT SIGNAL
5.6K
0
$\tau_A = \tau_{RE} \approx \tau_{FE}$
50Ω
−6.0 Vdc
$\tau_{RE} = \frac{I_{B1}}{I_{CS}} t_r$

SWITCHING TIME EQUATIONS

RISE-TIME $= t_r = \tau_A\beta_F R$

FALL-TIME $= t_f = \tau_A\beta_C F$

STORAGE TIME $= t'_s = \tau_{CR} S$

$t_r =$ 10 to 90% rise-time

$t_f =$ 10 to 90% fall-time

$t_s = t'_s + \frac{1}{8} t_f$

$\tau_{CR} =$ the effective collector recovery time and is virtually uninfluenced by current levels. 20 ns typical and 60 ns maximum for this transistor.

$\tau_A =$ active region time constant

$\tau_A = \tau_{RE} \approx \tau_{FE}$ (Figure 9b)

$\beta_O = h_{FE}$ at edge of saturation ($\beta_O \approx h_{FE}$ on Figure 8)

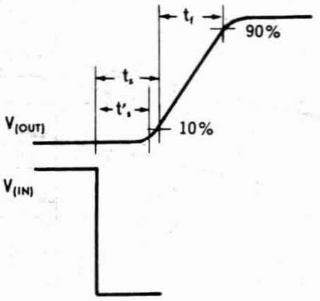
$\beta_F = I_C$ in saturation$/I_{B1}$ (base "on" current)

$\beta_C = I_C$ in saturation$/I_{B2}$ (base "off" current)

R see Figure 9a

F see Figure 9c

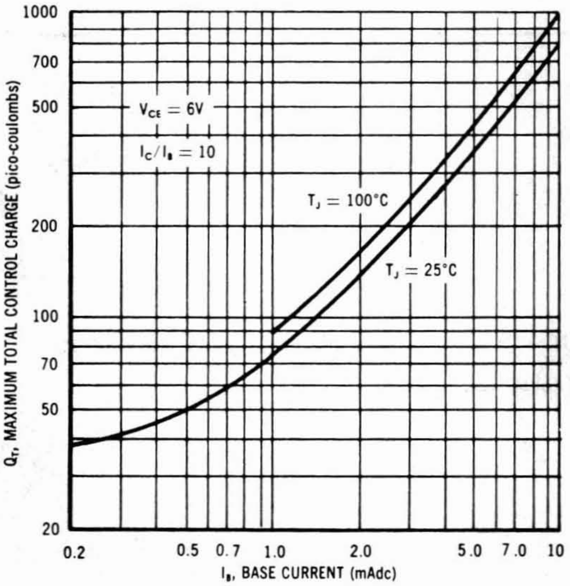
S see Figure 9d


t_f
90%
t_s
t'_s
$V_{(OUT)}$
10%
$V_{(IN)}$

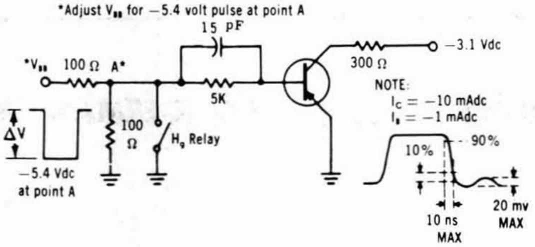
NOTE: Limit Curves are based on periodic engineering evaluation. Production Tests are made at points indicated in the Electrical Characteristics Table.

2N964A LIMIT CURVES

FIGURE 10—TOTAL CONTROL CHARGE



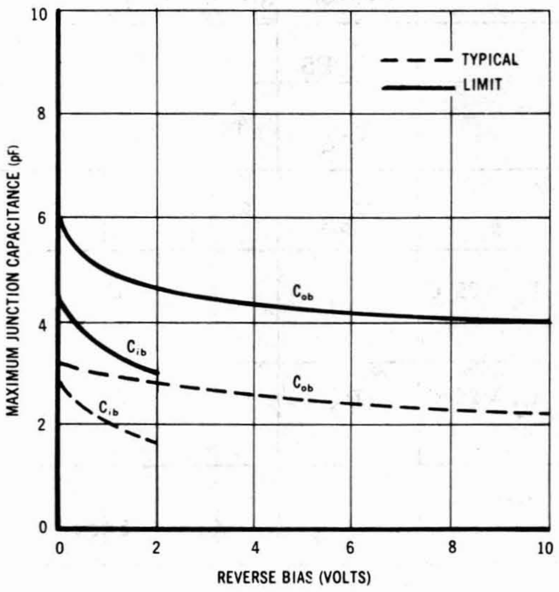
10a


*Adjust V_{BB} for −5.4 volt pulse at point A
15 pF
*V_{BB}
100 Ω
A*
5K
300 Ω
−3.1 Vdc
ΔV
100 Ω
H_g Relay
−5.4 Vdc at point A
NOTE:
I_C = −10 mAdc
I_B = −1 mAdc
10%
90%
10 ns MAX
20 mv MAX

10b

Total Control Charge. When a transistor is held in a conductive state by a current, I_{B1}, a charge Q_S is developed in the active region. A charge Q_T of opposite polarity, equal in magnitude, can be stored on an external capacitor C to neutralize the internal charge and considerably reduce the turn-off time of the transistor. Figure 10b shows the test circuit and turn-off waveform. Given Q_T from Figure 10a, the external C for worst case turn-off in any circuit is: $C = Q_T/\Delta V$, where ΔV is defined in Figure 10b.

FIGURE 11— JUNCTION CAPACITANCE VARIATIONS



NOTE: Limit Curves are based on periodic engineering evaluation. Production Tests are made at points indicated in the Electrical Characteristics Table.

2N965 (GERMANIUM)
2N966

For Specifications, See 2N960 Data.

2N967 (GERMANIUM)

For Specifications, See 2N963 Data.

2N968 thru 2N975 (GERMANIUM)

CASE 22
(TO-18)

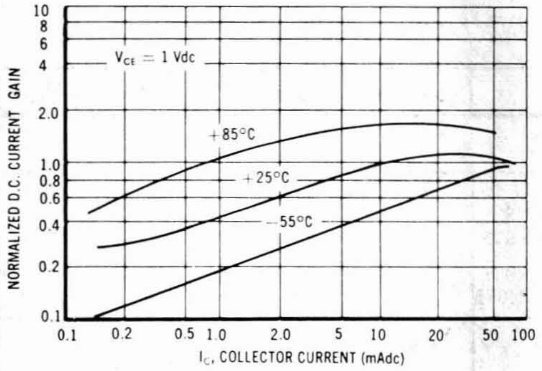
Collector connected to case

PNP germanium mesa transistors for high-speed switching applications.

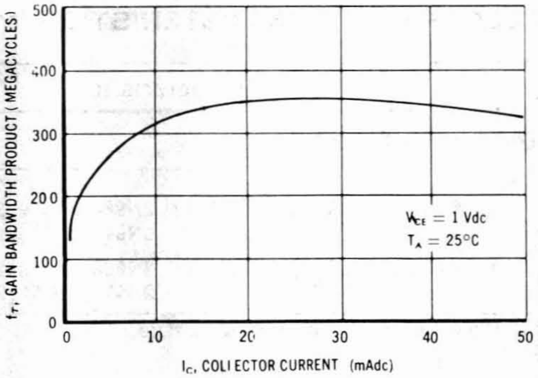
MAXIMUM RATINGS

Rating	Symbol	2N968 2N972	2N969 2N973	2N970 2N974	2N971 2N975	Unit
Collector-Emitter Voltage	V_{CES}	15	12	12	7	Vdc
Collector-Base Voltage	V_{CB}	15	12	12	7	Vdc
Emitter-Base Voltage	V_{EB}	2.5	2.0	1.25	1.25	Vdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	150 2				mW mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	300 4				mW mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100				^oC

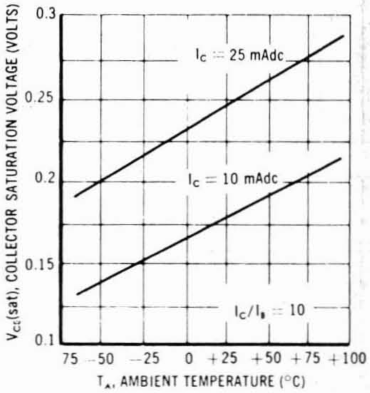
NORMALIZED D.C. CURRENT GAIN
versus COLLECTOR CURRENT



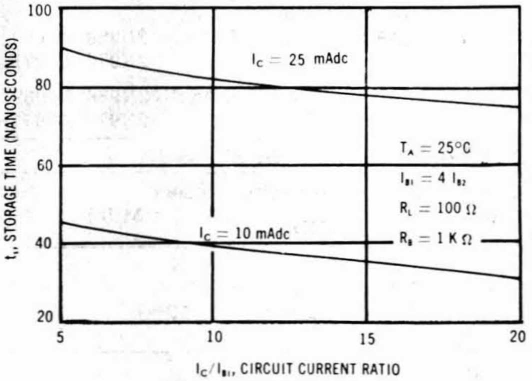
CURRENT GAIN-BANDWIDTH PRODUCT (f_T)
versus COLLECTOR CURRENT



COLLECTOR SATURATION VOLTAGE versus AMBIENT TEMPERATURE



STORAGE TIME versus CIRCUIT CURRENT RATIO



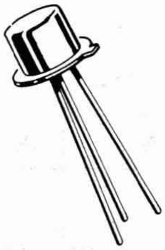
ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N968, 2N972	BV_{CBO}	15	25	-	Vdc
	2N969, 2N970, 2N973, 2N974		12	20	-	
	2N971, 2N975		7	15	-	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	2N968, 2N972	BV_{EBO}	2.5	-	-	Vdc
	2N969, 2N973		2.0	-	-	
	2N970, 2N974		1.25	-	-	
	2N971, 2N975		1.25	-	-	
Collector Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0)	2N968, 2N972	I_{CES}	-	-	100	μAdc
(V_{CE} = 12 Vdc, V_{BE} = 0)	2N969, 2N970, 2N973, 2N974		-	-	100	
(V_{CE} = 7 Vdc, V_{BE} = 0)	2N971, 2N975		-	-	100	
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)	2N968, 2N969, 2N970,	I_{CBO}	-	-	3	μAdc
	2N972, 2N973, 2N974		-	-	3	
	2N971, 2N975		-	-	10	

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS					
DC Current Gain	h_{FE}				
(I_C = 10 mAdc, V_{CE} = 0.5 Vdc) 2N968, 2N969, 2N970, 2N971		17	35	-	
2N972, 2N973, 2N974, 2N975		40	75	-	
(I_C = 25 mAdc, V_{CE} = 0.7 Vdc) 2N968, 2N969, 2N970, 2N971		20	40	-	
2N972, 2N973, 2N974, 2N975		40	85	-	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$				Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		-	0.19	0.25	
(I_C = 25 mAdc, I_B = 1.5 mAdc)		-	0.25	0.5	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$				Vdc
(I_C = 10 mAdc, I_B = 1 mAdc) 2N968, 2N969, 2N972, 2N973		0.30	0.39	0.55	
2N970, 2N971, 2N974, 2N975		0.30	0.43	0.65	
(I_C = 25 mAdc, I_B = 1.5 mAdc) 2N968, 2N969, 2N972, 2N973		-	0.45	0.80	
2N970, 2N971, 2N974, 2N975		-	0.60	1.0	
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_E = 10 mAdc, V_{CB} = 1 Vdc, f = MHz)	f_T	250	320	-	MHz
Collector Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	-	4.0	9.0	pF
Emitter Transition Capacitance (V_{EB} = 1 Vdc, I_C = 0)	C_{Te}	-	3.5	-	pF
Turn-On Time ($V_{BE(off)}$ = 1.25 Vdc, I_C = 10 mAdc, I_{B1} = 1 mA)	t_{on}				ns
2N968, 2N969, 2N972, 2N973		-	50	75	
2N970, 2N971, 2N974, 2N975		-	65	100	
Turn-Off Time (I_C = 10 mAdc, I_{B1} = 1 mAdc, I_{B2} = 0.25 mAdc)	t_{off}				ns
2N968, 2N969		-	70	150	
2N972, 2N973		-	75	175	
2N970, 2N971, 2N974, 2N975		-	100	275	
Total Control Charge	Q_T				pC
(I_C = 10 mAdc, I_B = 1 mAdc) 2N968, 2N969, 2N972, 2N973		-	75	100	
2N970, 2N971, 2N974, 2N975		-	80	150	
(I_C = 25 mAdc, I_B = 1.5 mAdc) 2N968, 2N969, 2N972, 2N973		-	90	175	
2N970, 2N971, 2N974, 2N975		-	175	300	

2N985 (GERMANIUM)



CASE 22
(TO-18)

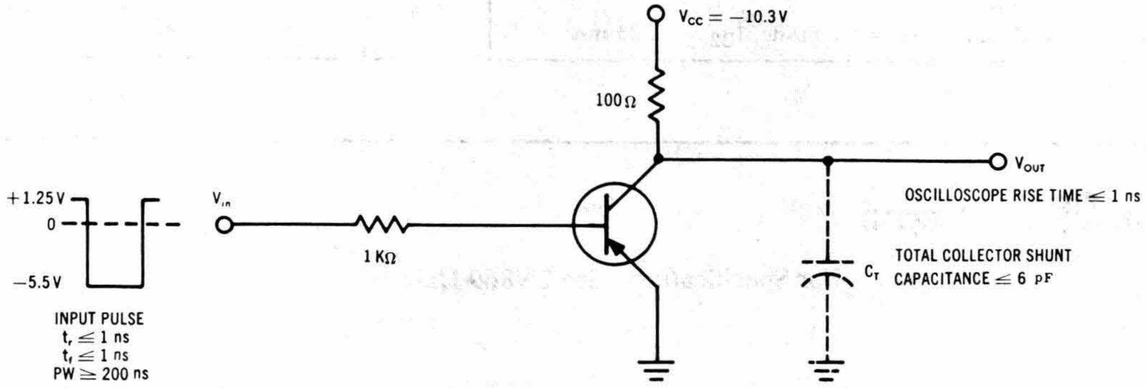
Collector connected to case

PNP germanium epitaxial mesa transistor for high-speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	15	Vdc
Collector-Emitter Voltage	V_{CEO}	7	Vdc
Emitter-Base Voltage	V_{EB}	3	Vdc
Collector Current	I_C	200	mAdc
Junction Temperature	T_J	100	°C
Storage Temperature	T_{stg}	-65 to +100	°C
Device Dissipation @ $T_C = 25^oC$ Derate above 25°C	P_D	300 4	mW mW/°C
Device Dissipation @ $T_A = 25^oC$ Derate above 25°C	P_D	150 2	mW mW/°C

SWITCHING TIME TEST CIRCUIT


$V_{CC} = -10.3$ V
100 Ω
V_{OUT}
OSCILLOSCOPE RISE TIME ≤ 1 ns
+1.25 V
0
−5.5 V
V_{in}
1 KΩ
C_T
TOTAL COLLECTOR SHUNT CAPACITANCE ≤ 6 pF
INPUT PULSE
$t_r \leq 1$ ns
$t_f \leq 1$ ns
PW ≥ 200 ns

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	15	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 5 mAdc, I_B = 0)	BV_{CEO}	7	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, R_{BE} = 0)	BV_{CES}	15	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3	—	Vdc
Collector Cutoff Current (V_{CB} = 5 Vdc, I_E = 0)	I_{CBO}	—	3	μAdc
Emitter Cutoff Current (V_{EB} = 3 Vdc, I_C = 0)	I_{EBO}	—	100	μAdc
DC Current Gain (I_C = 10 mAdc, V_{CE} = 0.25 Vdc) (I_C = 100 mAdc, V_{CE} = 0.5 Vdc)	h_{FE}	 40 60	 — —	—
Collector Saturation Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc) (I_C = 100 mAdc, I_B = 5 mAdc)	$V_{CE(sat)}$	 — —	 0.15 0.30	Vdc
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc) (I_C = 100 mAdc, I_B = 5 mAdc)	V_{BE}	 0.28 0.40	 0.40 0.60	Vdc
Small Signal Current Gain (V_{CE} = 2 Vdc, I_C = 30 mAdc, f = 100 MHz)	$\|h_{fe}\|$	3.0	—	—
Collector Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	6	pF
Turn-on Time (I_C = 10 mAdc, I_{B1} = 5 mAdc, $V_{BE(0)}$ = 1.25 Vdc)	t_{on}	—	35	ns
Turn-off Time (I_C = 10 mAdc, I_{B1} = 5 mAdc, I_{B2} = 1.25 mA)	t_{off}	—	80	ns

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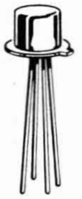
2N995 (SILICON)

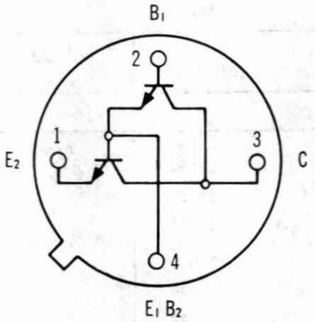
For Specifications, See 2N869 Data.

2N998 (SILICON)
2N999



CASE 20(8)
(TO-72)

Darlington amplifiers containing two NPN silicon annular transistors are designed for applications requiring very high-gain, low-noise, and high-input impedance.



MAXIMUM RATINGS

Rating	Symbol	2N998	2N999	Unit
Collector-Emitter Voltage	V_{CEO}	60	60	Vdc
Collector-Base Voltage	V_{CB}	100	60	Vdc
Emitter-Base Voltage	V_{EB}	15		Vdc
Collector Current	I_C	500		mAdc
Total Device Dissipation @ $T_A = 25^{\circ}C$ Derate above 25°C	P_D	0.5 2.86		Watt mW/°C
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above 25°C	P_D	1.8 10.3		Watts mW/°C
Operating Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Sustaining Voltage* (I_C = 30 mAdc, I_B = 0)		$BV_{CEO(sus)}$*	60	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N998	BV_{CBO}	100	—	Vdc
	2N999		60		
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	15	—	Vdc
Collector Cutoff Current (V_{CB} = 90 Vdc, I_E = 0)	2N998	I_{CBO}	—	0.01	μAdc
(V_{CB} = 90 Vdc, I_E = 0, T_A = 150°C)	2N998		—	15	
(V_{CB} = 60 Vdc, I_E = 0)	2N999		—	0.01	
(V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)	2N999		—	10	
Emitter Cutoff Current (V_{BE} = 10 Vdc, I_C = 0)		I_{EBO}	—	0.01	μAdc

ON CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
DC Current Gain* (I_C = 1 mAdc, V_{CE} = 5 Vdc)	2N998	h_{FE}*	800	—	—
(I_C = 10 mAdc, V_{CE} = 5 Vdc)	2N998		1,600	8,000	
(I_C = 100 mAdc, V_{CE} = 5 Vdc)	2N998		2,000	—	
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N999		1,000	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N999		4,000	—	
(I_C = 100 mAdc, V_{CE} = 10 Vdc)	2N999		7,000	70,000	
(I_C = 100 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N999		1,000	—	
(I_C = 10 mAdc, V_{CE} = 5 Vdc, measured across each transistor within the device)	2N998		25	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, measured across each transistor within the device)	2N999		25	—	

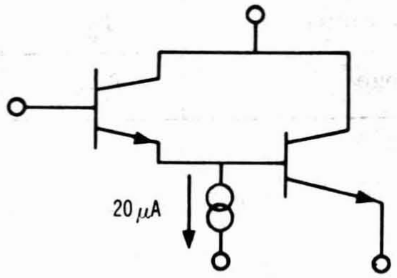
DYNAMIC CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	2N998	C_{ob}	—	30	pF
	2N999		—	20	
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	2N998	C_{ib}	—	50	pF
	2N999		—	10	
Small-Signal Current Gain (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	2N998	h_{fe}	1,000	—	—
Noise Figure** (I_C = 0.1 mAdc, V_{CE} = 10 Vdc, R_S = 5 kohms, f = 1 kHz, Bandwidth = 200 Hz)	2N998	NF**	—	6	dB

*Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1%

**Measured with constant current supply of 20 μAdc connected to the emitter of the input transistor. (See Figure 1)

FIGURE 1 — NOISE FIGURE TEST CIRCUIT



2N1008, A, B (GERMANIUM)

CASE 31(1)
(TO-5)
All leads isolated

PNP germanium transistor for audio driver and medium speed switching applications.

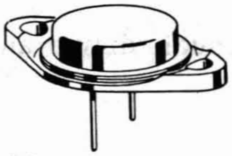
MAXIMUM RATINGS

Rating	Symbol	2N1008	2N1008A	2N1008B	Unit
Collector-Base Voltage	V_{CB}	20	40	60	Volts
Collector-Emitter Voltage	V_{CEO}	20	40	60	Volts
Emitter-Base Voltage	V_{EB}	15			Volts
Collector Current	I_C	300			mAdc
Base Current	I_B	30			mAdc
Collector Dissipation $T_A = 25^oC$ derate $T_C = 25^oC$ derate	P_D	 200 2.78 300 4.0			 mW mW/^{o}C mW mW/^{o}C
Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +100			^{o}C

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristics	Symbol	Min	Typ	Max	UNIT
Collector Leakage Current (V_{CB} = 10 Vdc) 2N1008 (V_{CB} = 10 Vdc, T_A = 85°C) 2N1008 (V_{CB} = 25 Vdc) 2N1008A (V_{CB} = 25 Vdc, T_A = 85°C) 2N1008A (V_{CB} = 45 Vdc) 2N1008B (V_{CB} = 45 Vdc, T_A = 85°C) 2N1008B	I_{CBO}	 --- --- --- --- --- ---	 5.0 --- 5.0 --- 7.0 ---	 10 500 10 500 15 750	µAdc
Emitter Leakage Current (V_{EB} = 10 Vdc) 2N1008 2N1008A 2N1008B	I_{EBO}	 --- --- ---	 5.0 --- ---	 10 10 10	µAdc
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, R_{BE} = 10 K) 2N1008 2N1008A 2N1008B	BV_{CER}	 15 35 55	 --- --- ---	 --- --- ---	Vdc
Collector-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{CE\ (sat)}$	---	---	0.25	Vdc
Small Signal Current Gain (I_C = -10 mAdc, V_{CE} = 5.0 Vdc, f = 1 kHz)	h_{fe}	40	---	150	---
Input Resistance (V_{CB} = 6 V, I_E = 1 mA)	h_{ie}	200	---	1000	ohms

2N1011 (GERMANIUM)



CASE 11
(TO-3)

PNP germanium power transistor for general purpose power amplifier and switching applications in military and industrial equipment. Operating temperature range and power dissipation exceed military specifications.

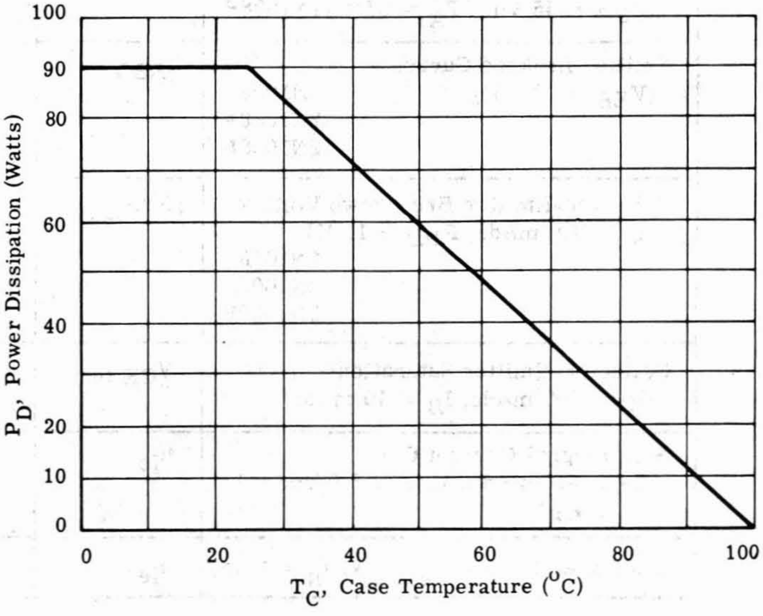
MAXIMUM RATINGS

Rating	Symbol	2N1011	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Emitter Voltage	V_{CES}	80	Vdc
Collector-Base Voltage	V_{CB}	80	Vdc
Emitter-Base Voltage	V_{EB}	40	Vdc
Collector Current	I_C	5.0	Adc
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above $25^{\circ}C$	P_D	90 1.2	Watts $W/^{\circ}C$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	$^{\circ}C$

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	$^{\circ}C/W$

POWER-TEMPERATURE DERATING CURVE

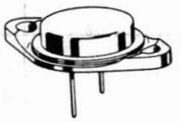


2N1011 (continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Minimum	Maximum	Unit
DC Current Transfer Ratio V_{CE} = 2 V I_C = 1.0 Adc	h_{FE}	—	150	—
DC Current Transfer Ratio V_{CE} = 2 V I_C = 3.0 Adc	h_{FE}	30	75	—
Small-Signal Current Transfer Ratio Cutoff Frequency V_{CE} = 2 Vdc I_C = 3 Amp	$f_{\alpha e}$	5.0	—	kHz
Emitter-Base Cutoff Current V_{EB} = 40 Vdc I_C = 0	I_{EBO}	—	3.0	mAdc
Collector-Base Cutoff Current V_{CB} = 2 Vdc I_E = 0	I_{CBO}	—	200	μAdc
Collector-Base Cutoff Current V_{CB} = 80 Vdc I_E = 0	I_{CBO}	—	15.0	mAdc
Base Current V_{CE} = 2 Vdc I_C = 1 Adc	I_B	6.7	—	mAdc
Base Current V_{CE} = 2 Vdc I_C = 3 Adc	I_B	40	100	mAdc
Emitter-Base Voltage V_{CE} = 2 Vdc I_C = 3 Adc	V_{EB}	—	2.0	Vdc
Floating Potential V_{CB} = 50 Vdc (Voltmeter input resistance = 10 Megohm min)	V_{fl}	—	1.0	Vdc
Collector-Emitter Saturation Voltage I_C = 3 Adc I_B = 200 mAdc	$V_{CE(SAT)}$	—	1.5	Vdc
Collector-Emitter Voltage I_C = 300 mAdc I_B = 0	BV_{CEO}	40	—	Vdc
Collector-Emitter Voltage I_C = 300 mAdc V_{EB} = 0	BV_{CES}	80	—	Vdc
High-Temperature Operation T_C = +90°C min Collector Cutoff Current V_{CB} = 30 Vdc I_E = 0	I_{CBO}	—	20	mAdc

2N1021 (GERMANIUM)
2N1022



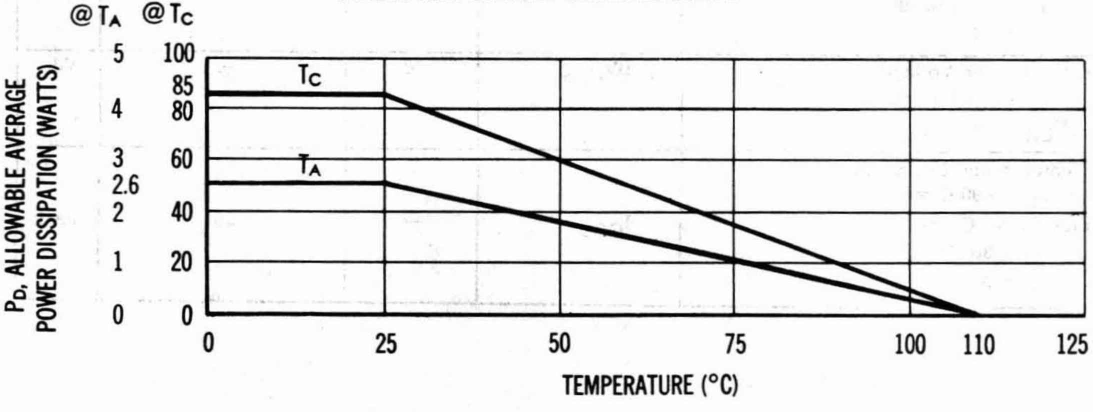
CASE 11
(TO-3)

PNP germanium power transistors for industrial and general purpose power amplifier and switching applications.

MAXIMUM RATINGS (Tc = 25°C unless otherwise noted)

Rating	Symbol	2N1021	2N1022	Unit
Collector-Base Voltage	V_{CB}	100	120	Volts
Collector-Emitter Voltage	V_{CEX}	100	120	Volts
Collector-Emitter Voltage	V_{CEO}	50		Volts
Emitter-Base Voltage	V_{EB}	30		Volts
Collector Current	I_C	5.0		Amp
Operating Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +110		°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	85 1.0		Watts W/°C

POWER-TEMPERATURE DERATING CURVE



2N1021, 2N1022 (continued)

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 50 Vdc)	2N1021		—	0.5	
(V_{CB} = 60 Vdc)	2N1022		—	0.5	
(V_{CB} = 100 Vdc)	2N1021		—	2.0	
(V_{CB} = 120 Vdc)	2N1022		—	2.0	
(V_{CB} = 50 Vdc, T_C = +55°C)	2N1021		—	8.0	
(V_{CB} = 60 Vdc, T_C = +55°C)	2N1022		—	8.0	
Collector-Emitter Breakdown Voltage* (I_C = 200 mAdc)		BV_{CEO}*	50	—	Vdc
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = 10 Vdc)			—	0.5	
(V_{EB} = 30 Vdc)			—	2.0	
Base-Emitter Voltage (V_{CE} = -1.5 Vdc, I_C = 1.0 Adc)		V_{BE}	—	3.0	Vdc
Collector-Emitter Saturation Voltage (I_C = 5 Adc, I_B = 500 mAdc)		$V_{CE(sat)}$	—	0.5	Vdc
DC Current Gain		h_{FE}			—
(I_C = 1 Adc, V_{CE} = 1.5 Vdc)			40	—	
(I_C = 3 Adc, V_{CE} = 1.5 Vdc)			35	—	
(I_C = 5 Adc, V_{CE} = 1.5 Vdc)			30	90	
(I_C = 7 Adc, V_{CE} = 1.5 Vdc)			22	—	
Input Impedance (I_C = 1.0 Adc, V_{CE} = 1.5 Vdc)		h_{ie}	—	28	ohms
Current Gain-Bandwidth Product (I_C = 1.0 Adc, V_{CE} = 2 Vdc)		f_T	200	—	kHz

*Sweep Test: 1/2 sine wave, 60 Hz .

2N1038 (GERMANIUM)
thru
2N1041

CASE 180

Collector Connected to Case

PNP germanium medium power transistors designed for relay drivers, pulse amplifiers, audio amplifiers and high-current switching applications.

- High Current Capability – I_C = 3.0 Amperes
- Guaranteed Excellent Collector-Emitter Sustaining Voltage
- 20–Watt Power Dissipation at 25°C Case Temperature
- 100°C Maximum Junction Temperature

MAXIMUM RATINGS

Rating	Symbol	2N1038	2N1039	2N1040	2N1041	Unit
Collector-Emitter Voltage	V_{CEO}	30	40	50	60	Vdc
*Collector-Base Voltage	V_{CB}	40	60	80	100	Vdc
*Emitter-Base Voltage	V_{EB}	← 20 →				Vdc
*Collector Current - Continuous	I_C	← 3.0 →				Adc
*Base Current - Continuous	I_B	← 1.0 →				Adc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	← 450 → ← 6.0 →				mW mW/°C
*Total Device Dissipation @ $T_C = 25°C$ *Derate above 25°C (Note 1)	P_D	← 20 → ← 0.267 →				Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +100 →				°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	3.75	°C/W

*Indicates JEDEC Registered Data

Note 1: Case Temperature shall be measured 0.100 ± 0.010 inches above the seating plane.

2N1038 thru 2N1041 (continued)

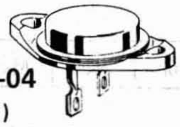
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
*Collector-Emitter Sustaining Voltage		$V_{CEO(sus)}$			Vdc
(I_C = 100 mAdc, I_B = 0)	2N1038		30	-	
	2N1039		40	-	
	2N1040		50	-	
	2N1041		60	-	
*Collector Cutoff Current		I_{CEO}			mAdc
(V_{CE} = 15 Vdc, I_B = 0)	2N1038		-	25	
(V_{CE} = 20 Vdc, I_B = 0)	2N1039		-	20	
(V_{CE} = 25 Vdc, I_B = 0)	2N1040		-	20	
(V_{CE} = 30 Vdc, I_B = 0)	2N1041		-	20	
*Collector-Emitter Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1038		-	0.65	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1039		-	0.65	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1040		-	0.65	
(V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N1041		-	0.65	
(V_{CE} = 20 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C)	2N1038		-	5.0	
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C)	2N1039		-	5.0	
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C)	2N1040		-	5.0	
(V_{CE} = 50 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C)	2N1041		-	5.0	
*Collector Cutoff Current		I_{CBO}			μAdc
*(V_{CB} = 20 Vdc, I_E = 0)	2N1038		-	125	
*(V_{CB} = 30 Vdc, I_E = 0)	2N1039		-	125	
*(V_{CB} = 40 Vdc, I_E = 0)	2N1040		-	125	
*(V_{CB} = 50 Vdc, I_E = 0)	2N1041		-	125	
**(V_{CB} = 40 Vdc, I_E = 0)	2N1038		-	750	
**(V_{CB} = 60 Vdc, I_E = 0)	2N1039		-	750	
**(V_{CB} = 80 Vdc, I_E = 0)	2N1040		-	750	
**(V_{CB} = 100 Vdc, I_E = 0)	2N1041		-	750	
*Emitter Cutoff Current (V_{BE} = 20 Vdc, I_C = 0)		I_{EBO}	-	650	μAdc
ON CHARACTERISTICS					
*DC Current Gain		h_{FE}			-
(I_C = 50 mAdc, V_{CE} = 0.5 Vdc)			33	200	
(I_C = 1.0 Adc, V_{CE} = 0.5 Vdc)			20	60	
*Collector-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 100 mAdc)		$V_{CE(sat)}$	-	0.25	Vdc
*Base-Emitter Input Voltage (I_C = 1.0 Adc, V_{CE} = 0.5 Vdc)		V_{BE}	-	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS					
*Small-Signal Current Gain (I_C = 500 mAdc, V_{CE} = 1.5 Vdc, f = 1.0 kHz)		h_{fe}	18	72	-
*Small-Signal Current Gain (I_C = 500 mAdc, V_{CE} = 1.5 Vdc, f = 112.5 kHz)		$\|h_{fe}\|$	2.0	-	-

*Indicates JEDEC Registered Data.

**Motorola Guarantees this data in addition to the JEDEC Registered Data Shown.

2N1073, A, B (GERMANIUM)



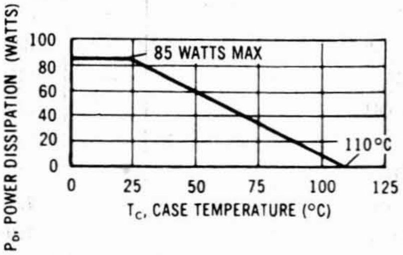
CASE 4-04
(TO-41)

PNP germanium power transistors for high-voltage power switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N1073	2N1073A	2N1073B	Unit
Collector-Emitter Voltage	V_{CER}	40	80	120	Vdc
Collector-Base Voltage	V_{CB}	40	80	120	Vdc
Emitter-Base Voltage	V_{EB}	1.5	1.5	1.5	Vdc
Collector Current (Cont)	I_C	10	10	10	Amp
Base Current (Cont)	I_B		5.0		Amp
Emitter Reverse Current (Surge 60 cps Recurrent)	I_E		1.5		Amp
Storage and Operating Temperature	T_{stg} T_J		-65 to +110		^{o}C
Collector Dissipation (25°C Mtg. Case Temp.)	P_D		85		Watts

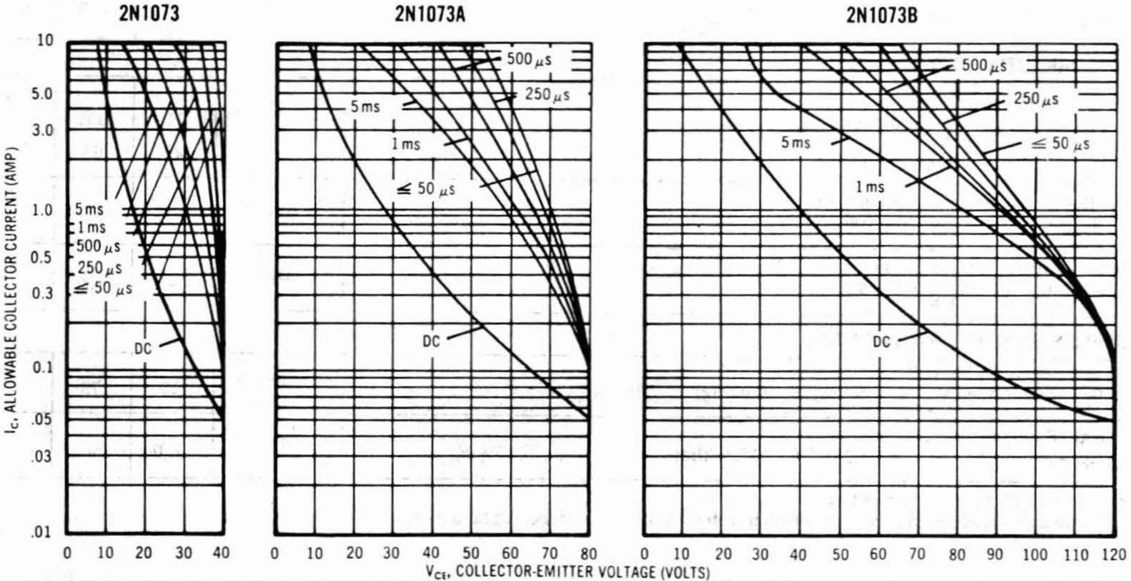
POWER-TEMPERATURE DERATING CURVE



The maximum continuous power is related to maximum junction temperature by the thermal resistance factor. This curve has a value of 85 watts at a case temperature of 25°C and is 0 watts at 110°C with a linear relation between the two temperatures such that:

$$\text{Allowable } P_D = \frac{110° - T_C}{1.0} \text{ Watts}$$

SAFE OPERATING AREAS — PULSE CONDITIONS



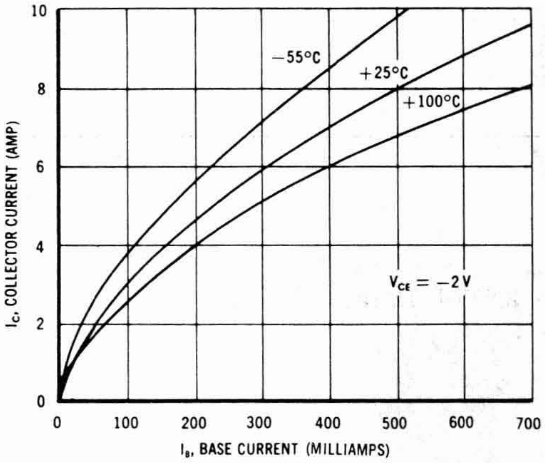
The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

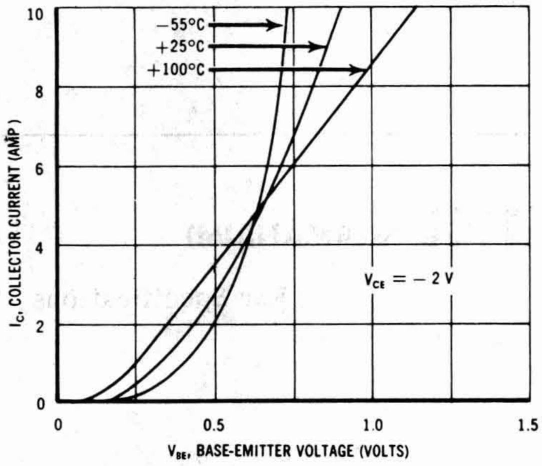
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current		I_{CBO}				mAdc
(V_{CB} = 25 Vdc, I_E = 0)	2N1073		-	-	1.0	
(V_{CB} = 25 Vdc, I_E = 0, T_C = 85°C)	2N1073		-	-	15	
(V_{CB} = 40 Vdc, I_E = 0)	2N1073		-	-	20	
(V_{CB} = 60 Vdc, I_E = 0)	2N1073A		-	-	1.0	
(V_{CB} = 60 Vdc, I_E = 0, T_C = 85°C)	2N1073A		-	-	15	
(V_{CB} = 80 Vdc, I_E = 0)	2N1073A		-	-	20	
(V_{CB} = 100 Vdc, I_E = 0)	2N1073B		-	-	2.0	
(V_{CB} = 100 Vdc, I_E = 0, T_C = 85°C)	2N1073B		-	-	20	
(V_{CB} = 120 Vdc, I_E = 0)	2N1073B		-	-	20	
(V_{CB} = 2.0 Vdc, I_E = 0)			-	-	0.3	
Emitter-Base Leakage Current (V_{EB} = 0.75 Vdc)		I_{EBO}	-	-	50	mAdc
Emitter Floating Potential		V_{EBF}				Vdc
(V_{CE} = 40 Vdc)	2N1073		-	-	1.0	
(V_{CE} = 80 Vdc)	2N1073A		-	-	1.0	
(V_{CE} = 120 Vdc)	2N1073B		-	-	1.0	
Collector-Emitter Breakdown Voltage* (I_C = 50 mAdc, R_{BE} = 100Ω)	2N1073	BV_{CER}*	40	-	-	Vdc
	2N1073A		80	-	-	
	2N1073B		120	-	-	
DC Current Gain (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)		h_{FE}	20	-	60	-
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 12 Vdc, f = 30 kHz)		h_{fe}	-	15	-	-
Base Input Voltage (V_{CE} = 2.0 Vdc, I_C = 5.0 Adc)		V_{BE}	-	-	1.0	Vdc
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)		$V_{CE(sat)}$	-	0.5	1.0	Vdc
Rise Time		t_r	-	5.5	-	µs
Storage Time		t_s	-	1.2	-	µs
Fall Time		t_f	-	2.0	-	µs

*To avoid excessive heating of collector junction, perform this test with a sweep method.

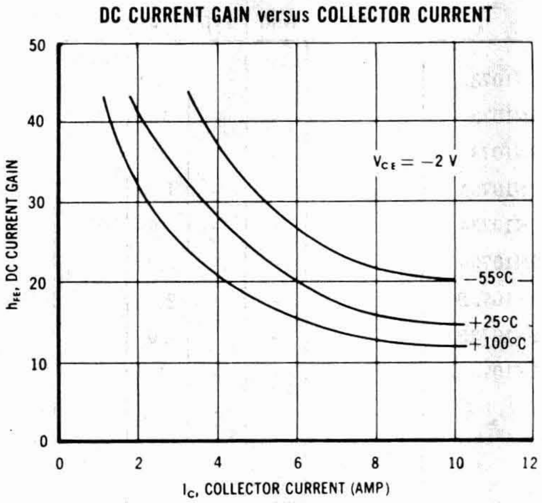
COLLECTOR CURRENT versus BASE CURRENT

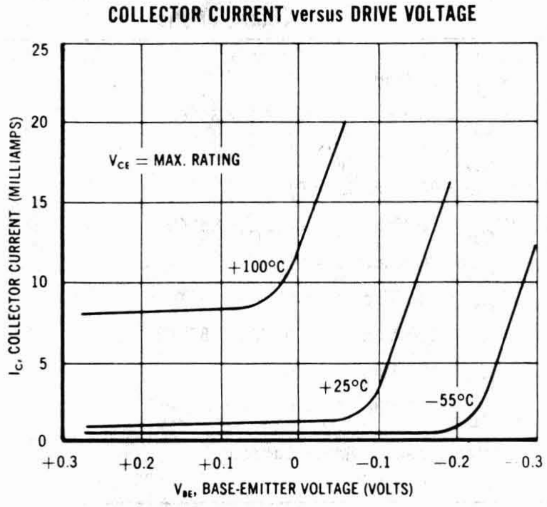


COLLECTOR CURRENT versus DRIVE VOLTAGE

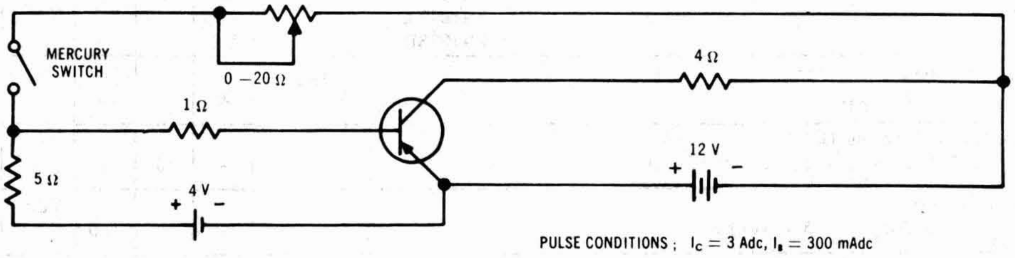


2N1073, A, B (continued)


DC CURRENT GAIN versus COLLECTOR CURRENT


COLLECTOR CURRENT versus DRIVE VOLTAGE

SWITCHING TEST CIRCUIT



MERCURY SWITCH
0 − 20 Ω
1 Ω
5 Ω
4 V
+
−
4 Ω
12 V
+
−
PULSE CONDITIONS ; I_C = 3 Adc, I_B = 300 mAdc

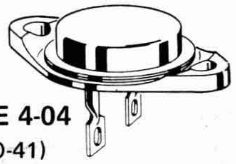
2N1099 (GERMANIUM)

For Specifications, See 2N277 Data.

2N1100 (GERMANIUM)

For Specifications, See 2N174 Data.

2N1120 (GERMANIUM)



CASE 4-04
(TO-41)

PNP germanium power transistor for military and industrial power applications.

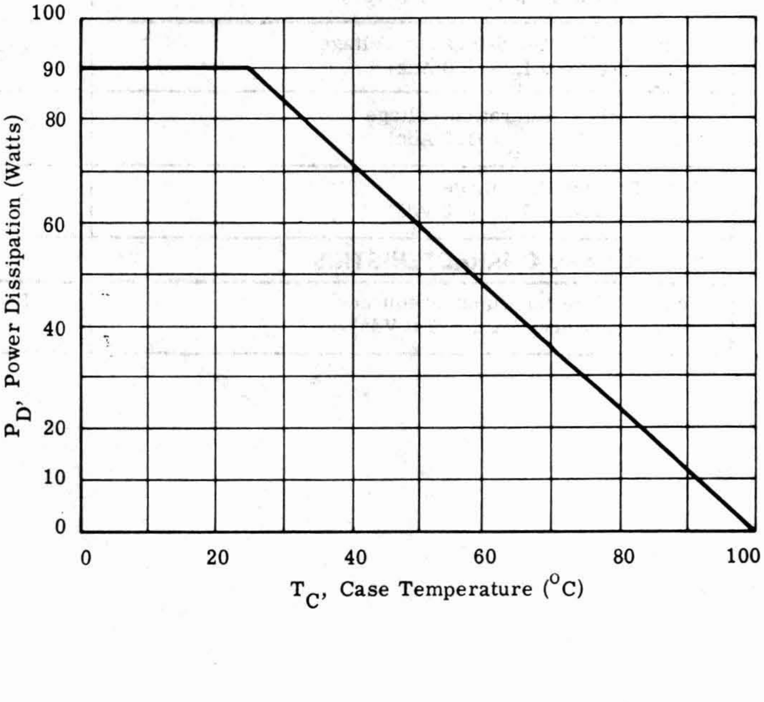
MAXIMUM RATINGS

Rating	Symbol	2N1120	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Emitter Voltage	V_{CES}	70	Vdc
Collector-Base Voltage	V_{CB}	80	Vdc
Emitter-Base Voltage	V_{EB}	40	Vdc
Emitter Current	I_E	15	Adc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	90 1.2	Watts $W/^oC$
Operating Junction Temperature Range	T_J	-65 to +100	^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	$^oC/W$

POWER-TEMPERATURE DERATING CURVE



ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 300 mAdc, I_B = 0)	BV_{CEO}	40	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 300 mAdc, V_{BE} = 0)	BV_{CES}	70	-	Vdc
Floating Potential (V_{CB} = 80 Vdc, I_E = 0) (Voltmeter Input Resistance = 10 meg. min.)	V_{EBF}	-	1.0	Vdc
Collector Cutoff Current (V_{CB} = 2 Vdc, I_E = 0)	I_{CBO}	-	0.3	mAdc
(V_{CB} = 30 Vdc, I_E = 0)			20	
(V_{CB} = 80 Vdc, I_E = 0)		-	15	
Emitter Cutoff Current (V_{BE} = 40 Vdc, I_C = 0)	I_{EBO}	-	5.0	mAdc
Base Current (V_{CE} = 2 Vdc, I_C = 5 Adc)	I_B	50	-	mAdc
(V_{CE} = 2 Vdc, I_C = 10 Adc)		200	500	
ON CHARACTERISTICS				
DC Current Gain (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	-	100	-
(I_C = 10.0 Adc, V_{CE} = 2.0 Vdc)		20	50	
Collector-Emitter Saturation Voltage (I_C = 10 Adc, I_B = 1.0 Adc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 10 Adc, I_B = 1.0 Adc)	$V_{BE(sat)}$	-	1.5	Vdc
Base-Emitter On Voltage (I_C = 10 Adc, V_{CE} = 2 Vdc)	$V_{BE(on)}$	-	2.0	Vdc
SMALL SIGNAL CHARACTERISTICS				
Common-Emitter Cutoff Frequency (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	$f_{\alpha e}$	3.0	-	kHz

2N1131 (SILICON)
2N1991

CASE 31
(TO-5)

PNP silicon annular transistors for medium-current switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage 2N1131 2N1991	V_{CB}	 50 30	Vdc
Collector-Emitter Voltage 2N1131 2N1991	V_{CEO}	 35 20	Vdc
Emitter-Base Voltage 2N1131, 2N1991	V_{EB}	 5	Vdc
Collector-Emitter Voltage ($R_{be} \leqq 10\,\Omega$) 2N1131	V_{CER}	 50	Vdc
Collector Current 2N1131	I_C	 600	mAdc
Total Device Dissipation @ 25°C Case Temperature Both Types Derating Factor Above 25°C 2N1131 2N1991	P_D	 2 13.3 16.0	 Watts mW/°C mW/°C
Total Device Dissipation @ 25°C Ambient Temperature Both Types Derating Factor Above 25°C 2N1131 2N1991	P_D	 0.6 4.0 4.8	 Watt mW/°C mW/°C
Junction Temperature 2N1131 2N1991	T_J	 +175 +150	°C
Storage Temperature Range 2N1131 2N1991	T_{stg}	 -65 to +300 -65 to +150	°C

2N1131, 2N1991 (continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Types	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0) (I_C = 1.0 mA, I_E = 0)	 2N1131 2N1991	BV_{CBO}	 50 30	 — —	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	 5	 —	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc pulse, I_B = 0)	 2N1131 2N1991	BV_{CEO}	 35 20	 — —	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc pulsed, $R_{be} \leqq 10\,\Omega$)	 2N1131	BV_{CER}	 50	 —	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C) (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 10 Vdc, I_E = 0) (V_{CB} = 10 Vdc, I_E = 0, T_A = 150°C)	 2N1131 2N1131 2N1131 2N1991 2N1991	I_{CBO}	 — — — — —	 1 100 100 5 200	μ Adc
Emitter Cutoff Current (V_{EB} = 2 Vdc, I_C = 0) (V_{EB} = 1 Vdc, I_C = 0)	 2N1131 2N1991	I_{EBO}	 — —	 100 200	μ Adc
DC Forward Current Transfer Ratio (I_C = 5 mAdc, V_{CE} = 10 Vdc) (I_C = 30 mAdc, V_{CE} = 10 Vdc) (I_C = 150 mAdc, V_{CE} = 10 Vdc)	 2N1131 2N1991 2N1131 2N1991	h_{FE}	 15 15 20 15	 — — 45 60	—
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE\,(sat)}$	 —	 1.5	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	 2N1131 2N1991	$V_{BE\,(sat)}$	 — —	 1.3 1.5	Vdc
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	 —	 45	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)	 2N1131	C_{ib}	 —	 80	pF
AC Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	 2N1131 2N1991	$\|h_{fe}\|$	 2.5 2.0		—
Small-Signal Forward Current Transfer Ratio (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz) (I_C = 5 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	 2N1131 2N1991	h_{fe}	 15 20	 50 —	—
Small Signal Input Resistance (I_C = 1 mAdc, V_{CB} = 5 Vdc, f = 1 kHz) (I_C = 5 mAdc, V_{CB} = 10 Vdc, f = 1 kHz)	 2N1131	h_{ib}	 25 —	 35 10	ohms
Small Signal Output Admittance (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz) (I_C = 5 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	 2N1131	h_{ob}	 — —	 1 5	μ mhos
Small Signal Voltage Feedback Ratio (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz) (I_C = 5 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	 2N1131	h_{rb}	 — —	 8 8	x 10^{-4}

Pulse Test: Pulse width $\leqq$ 300 μs Duty Cycle $\leqq$ 2%

2N1132, A (SILICON)

For Specifications, See 2N722 Data

2N1141 thru 2N1143 (GERMANIUM)
2N1195

CASE 31
(TO-5)

PNP germanium mesa transistors for amplifier, driver, oscillator and doubler applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N1141	2N1142	2N1143	2N1195	Unit
Collector-Base Voltage	V_{CB}	35	30	25	30	Vdc
Emitter-Base Voltage	V_{EB}	1.0	0.7	0.5	1.0	Vdc
Collector Current-Continuous	I_C	100	100	100	40	mAdc
Base Current	I_B	50	50	50	-	mAdc
Emitter Current-Continuous	I_E	100	100	100	-	mAdc
Total Device Dissipation @ $T_A = 25^{\circ}C$	P_D	300	300	300	-	mW
Derate above $25^{\circ}C$		4	4	4	-	mW/°C
Total Device Dissipation @ $T_C = 25^{\circ}C$	P_D	750	750	750	-	mW
Derate above $25^{\circ}C$		10	10	10	-	mW/°C
Collector Dissipation @ $T_A = 25^{\circ}C$	P_C	-	-	-	225	mW
Derate above $25^{\circ}C$		-	-	-	3	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100				°C

2N1141-2N1143, 2N1195 (continued)

TRANSISTOR SELECTION CHART

TYPE	Minimum BV_{CBO} @I_C = −100μ Adc, I_E = 0			Typical 100 MHz Noise Figure @ V_{CE} = −10Vdc, I_E = 1mAdc R_S = 75Ω			Minimum h_{fe} @ I_C = −10mAdc, V_{CE} = −10Vdc, f = 100 MHz		
	35 Vdc	30 Vdc	25 Vdc	4.0 db	4.5 db	5.0 db	12 db	10 db	8 db
2N1141	✓			✓			✓		
2N1142		✓			✓			✓	
2N1143			✓			✓			✓
2N1195		✓		✓			✓		

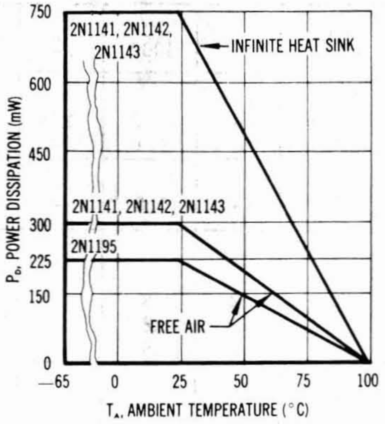
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N1141	BV_{CBO}	35	45	-	Vdc
	2N1142		30	45	-	
	2N1143		25	45	-	
	2N1195		30	45	-	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	2N1141	BV_{EBO}	1.0	1.3	-	Vdc
	2N1142		0.7	1.3	-	
	2N1143		0.5	1.3	-	
	2N1195		1.0	1.3	-	
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)		I_{CBO}	-	0.5	5	μAdc
(V_{CB} = 20 Vdc, I_E = 0)			-	0.5	5	
Emitter Cutoff Current (V_{BE} = 0.5 Vdc, I_C = 0)		I_{EBO}	-	0.2	-	μAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N1141, 2N1142, 2N1143	h_{FE}	10	25	-	-
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N1195		-	25	-	
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 10 mAdc)	2N1141, 2N1142, 2N1143	$V_{CE(sat)}$	-	0.185	2	Vdc
(I_C = 50 mAdc, I_B = 10 mAdc)	2N1195		-	0.185	-	

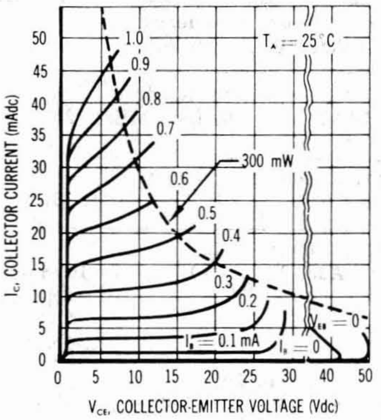
2N1141-2N1143, 2N1195 (continued)

Characteristic	Symbol	Min	Typ	Max	Unit
SMALL-SIGNAL CHARACTERISTICS					
Common-Base Cutoff Frequency (I_C = 10 mAdc, V_{CE} = 10 Vdc) All Types	$f_{\alpha b}$	-	1000	-	MHz
Collector Transition Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz) 2N1141	C_{Tc}	-	1.1	1.5	pF
2N1142, 2N1143, 2N1195		-	1.1	-	
Emitter Transition Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1 MHz) All Types	C_{Te}	-	2.5	-	pF
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N1141, 2N1195	h_{fe}	12	18	-	-
2N1142		10	18	-	
2N1143		8	18	-	
Small-Signal Current Gain (I_C = 10 mAdc, V_{CB} = 10 Vdc, f = 1 kHz) 2N1141, 2N1142, 2N1143	h_{fb}	-	0.98	-	-
2N1195		0.96	0.98	0.995	
Output Admittance (I_C = 10 mAdc, V_{CB} = 10 Vdc, f = 1 kHz) 2N1141, 2N1142, 2N1143	h_{ob}	-	10	-	µmhos
2N1195		-	10	20	
Input Impedance (I_C = 10 mAdc, V_{CB} = 10 Vdc, f = 1 kHz) 2N1141, 2N1142, 2N1143	h_{ib}	-	3.6	-	Ohms
2N1195		-	3.6	10	
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CB} = 10 Vdc, f = 1 kHz) 2N1141, 2N1142, 2N1143	h_{rb}	-	0.0013	-	-
2N1195		-	0.0013	0.003	
Collector-Base Time Constant (I_E = 3 mAdc, V_{CB} = 10 Vdc, f = 30 MHz) All Types	$r'_b C_c$	-	23	-	ps
Extrinsic Base Resistance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 250 MHz) 2N1141	r'_b	-	65	70	Ohms
2N1142		-	80	-	
2N1143		-	110	-	
2N1195		-	65	80	
Collector Series Resistance (I_E = 10 mAdc, V_{CB} = 10 Vdc) All Types	r'_c	-	2	-	Ohms
Noise Figure (I_E = 0.8 mAdc, V_{CE} = 5 Vdc, R_S = 300 ohms, f = 4.5 MHz) 2N1141, 2N1195	NF	-	3.0	-	dB
2N1142		-	3.5	-	
2N1143		-	4.0	-	
(I_E = 1 mAdc, V_{CE} = 10 Vdc, R_S = 75 ohms, f = 100 MHz) 2N1141		-	4.0	-	
2N1142, 2N1195		-	4.5	-	
2N1143		-	5.0	-	
(I_E = 1 mAdc, V_{CE} = 10 Vdc, R_S = 50 ohms, f = 200 MHz) 2N1141		-	5.5	-	
2N1142, 2N1195		-	6.0	-	
2N1143		-	6.5	-	
Oscillator Efficiency (V_{CE} = 20 Vdc, I_C = 10 mAdc, f = 400 MHz) 2N1141	η	-	20	-	%
2N1142		-	18	-	
2N1143		-	12	-	
2N1195		-	18	-	

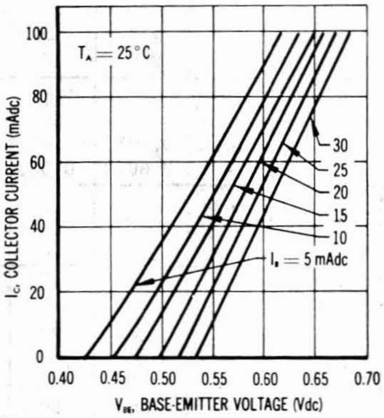
POWER-TEMPERATURE DERATING CURVE



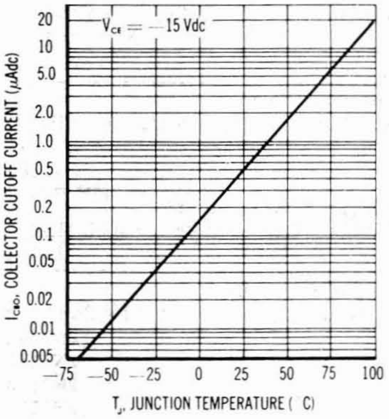
COLLECTOR CHARACTERISTICS, COMMON EMITTER



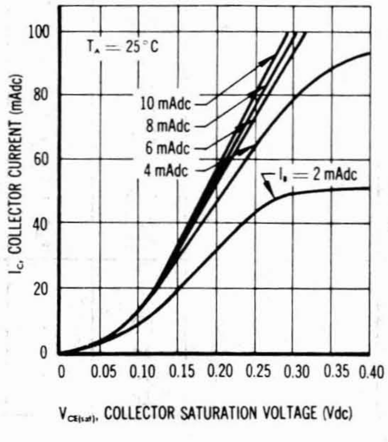
BASE CHARACTERISTICS, COMMON EMITTER



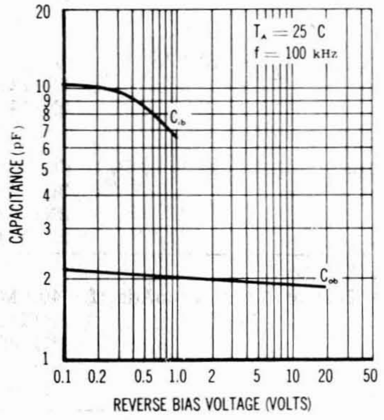
COLLECTOR CUTOFF CURRENT versus JUNCTION TEMPERATURE

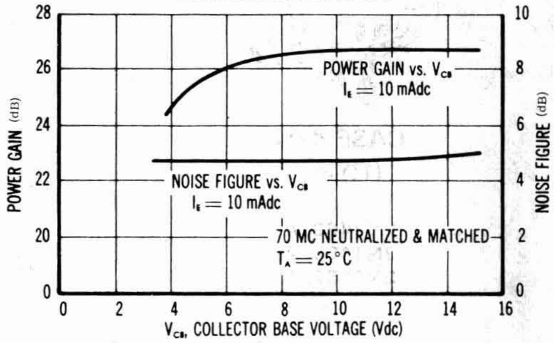


COLLECTOR SATURATION CHARACTERISTICS

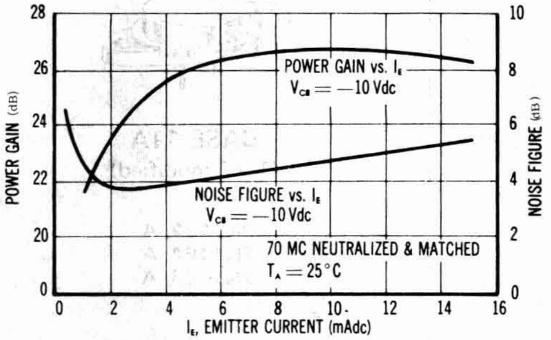


COLLECTOR INPUT AND OUTPUT CAPACITANCE versus VOLTAGE

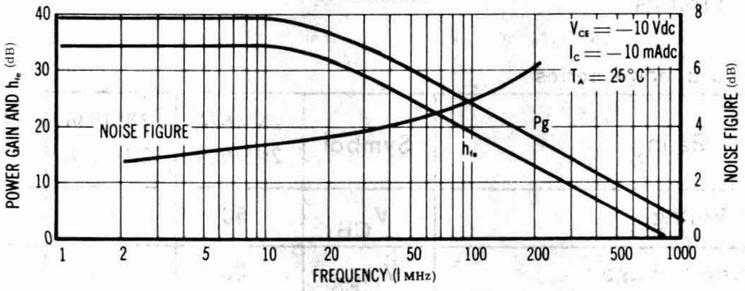




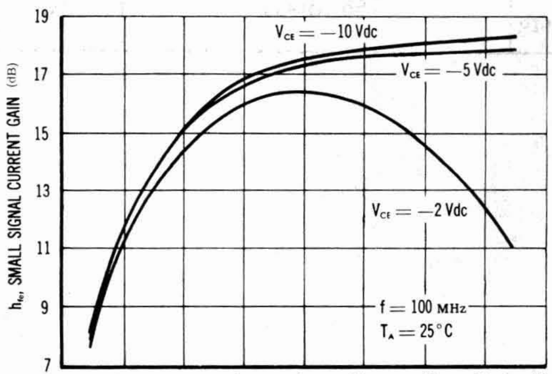
POWER GAIN AND NOISE FIGURE versus COLLECTOR-BASE VOLTAGE



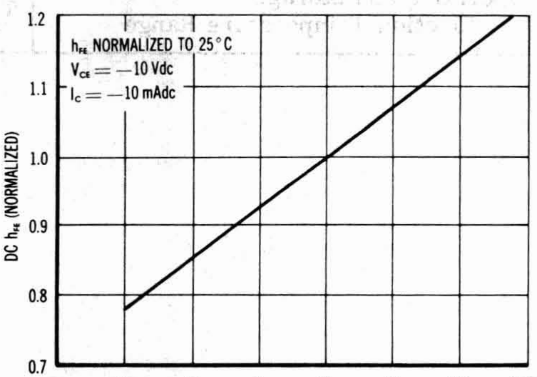
POWER GAIN AND NOISE FIGURE versus EMITTER CURRENT



COMMON EMITTER POWER GAIN, h_{fe}, AND NOISE FIGURE versus FREQUENCY



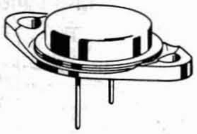
SMALL SIGNAL CURRENT GAIN (h_{fe}) versus COLLECTOR CURRENT



NORMALIZED h_{FE} versus AMBIENT TEMPERATURE

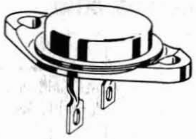
2N1162 thru 2N1167 (GERMANIUM)
2N1162A thru 2N1167A

PNP germanium power transistors for switching and amplifier applications in high reliability equipment.



CASE 11A
(TO-3 modified)

2N1162, A
2N1164, A
2N1166, A



CASE 4-04
(TO-41)

2N1163, A
2N1165, A
2N1167, A

MAXIMUM RATINGS

Apply also to standard, non-A series

Rating	Symbol	2N1162A 2N1163A	2N1164A 2N1165A	2N1166A 2N1167A	Units
Collector-Base Voltage	V_{CB}	50	80	100	Vdc
Collector-Emitter Voltage	V_{CES}	35	60	75	Vdc
Emitter-Base Voltage	V_{EB}	25	40	50	Vdc
Total Device Dissipation @ 25°C Derate above 25°C	P_D	106 1.25			Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110			°C

GROUP A ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current ($V_{CB} = V_{CB}$(max), $I_E = 0$)	I_{CBO1}	—	3.0	15	mA
Collector Cutoff Current (V_{CB} = 2 V, I_E = 0) (V_{CB} = 15 V, I_E = 0, T_C = 90°C) 2N1162A-3A* (V_{CB} = 30 V, I_E = 0, T_C = 90°C) 2N1164A-7A*	I_{CBO}	— — —	125 10 10	225 20 20	μA mA mA
Collector-Emitter Breakdown Voltage** (I_C = 500 mA, V_{EB} = 0) 2N1162A-3A* 2N1164A-5A* 2N1166A-7A*	BV_{CES}**	35 60 75	— — —	— — —	Vdc
Emitter Cutoff Current (V_{EB} = 12 V, I_C = 0)	I_{EBO}	—	0.5	1.2	mA
DC Forward Current Gain (V_{CE} = 1 V, I_C = 25 A) (V_{CE} = 2 V, I_C = 5 A)	h_{FE1} h_{FE}	15 —	25 65	— 125	—
Collector-Emitter Saturation Voltage (I_C = 25 A, I_B = 1.6 A)	$V_{CE(sat)}$	—	0.3	0.8	volts
Base-Emitter Saturation Voltage (I_C = 25 A, I_B = 1.6 A)	$V_{BE(sat)}$	—	0.7	1.7	volts
Common Emitter-Cutoff Frequency (V_{CE} = 2 V, I_C = 2 A)	$f_{\alpha e}$	—	4.0	—	kHz

*Characteristics apply also to corresponding, non-A type numbers

**Sweep Method: 1/2 cycle sine wave, 60 Hz

SWITCHING CHARACTERISTICS (Typical)

Saturated Collector Current	Pulsed Drive Base Current		Response times in μs		
	On	Off	$t_d + t_r$	t_s	t_f
5 amp	330 mA	100 mA	11	5.0	17
10 amp	660 mA	200 mA	15	4.0	20
25 amp	1650 mA	500 mA	19	3.0	18

FIGURE 1 — POWER TEMPERATURE DERATING CURVE

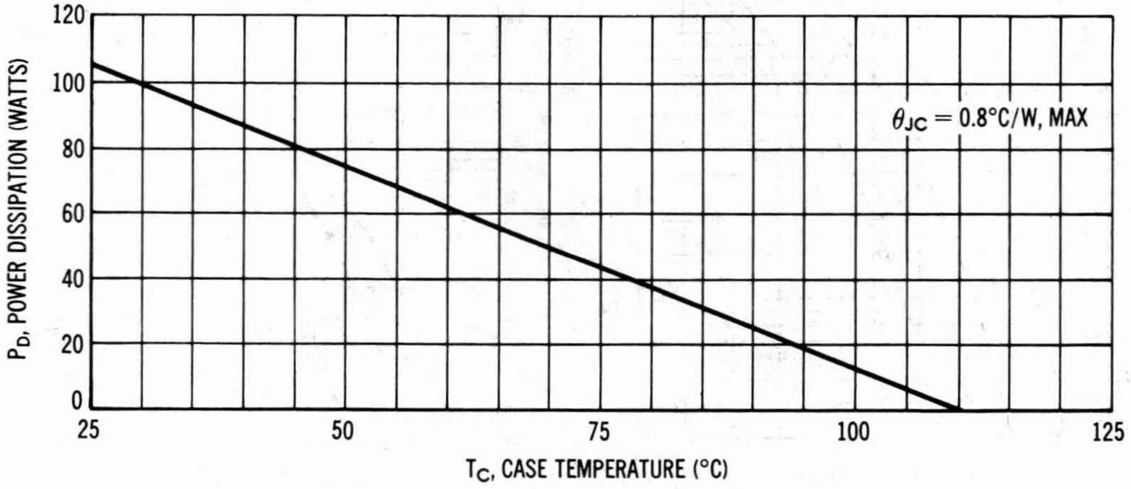
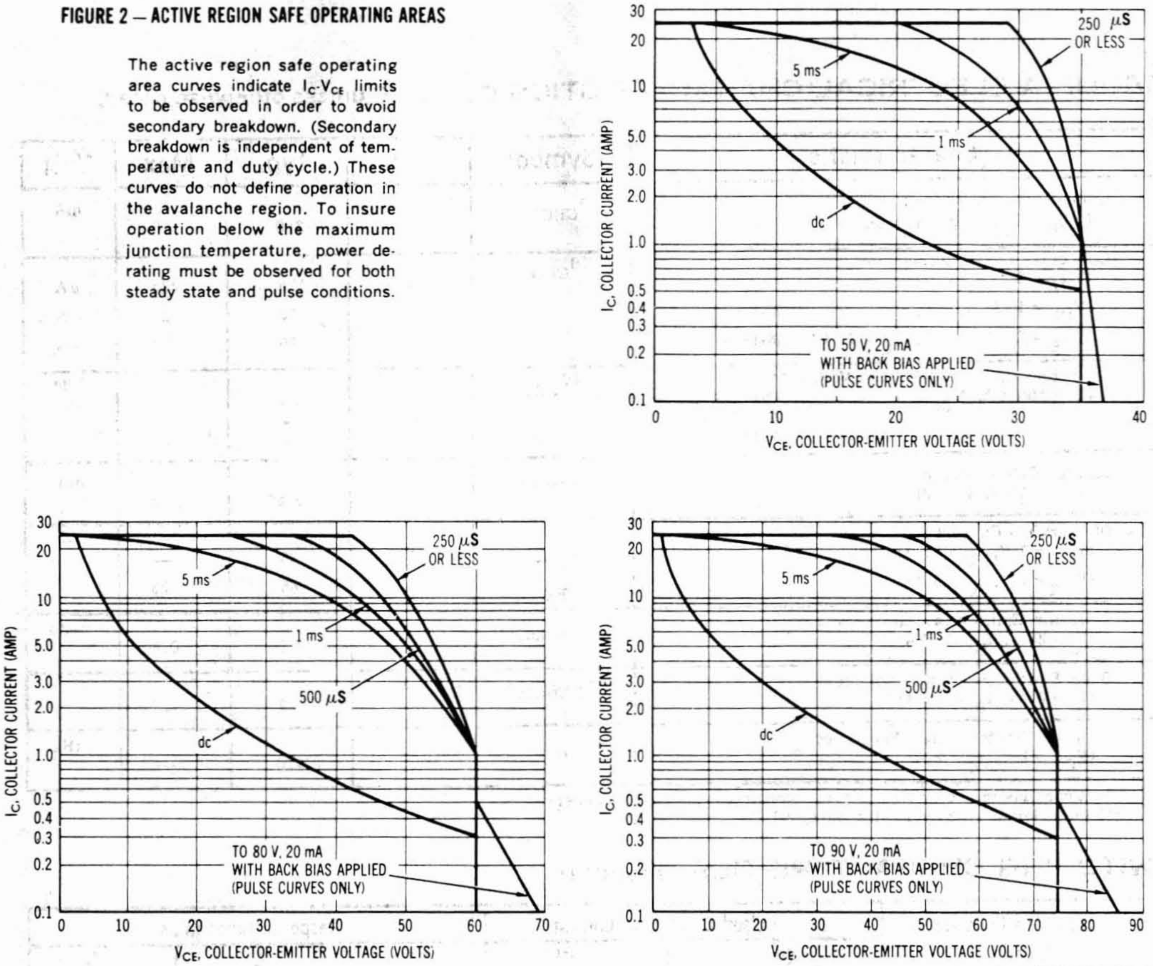


FIGURE 2 — ACTIVE REGION SAFE OPERATING AREAS

The active region safe operating area curves indicate I_C-V_{CE} limits to be observed in order to avoid secondary breakdown. (Secondary breakdown is independent of temperature and duty cycle.) These curves do not define operation in the avalanche region. To insure operation below the maximum junction temperature, power derating must be observed for both steady state and pulse conditions.



LARGE SIGNAL CHARACTERISTICS

FIGURE 3 — TRANSCONDUCTANCE

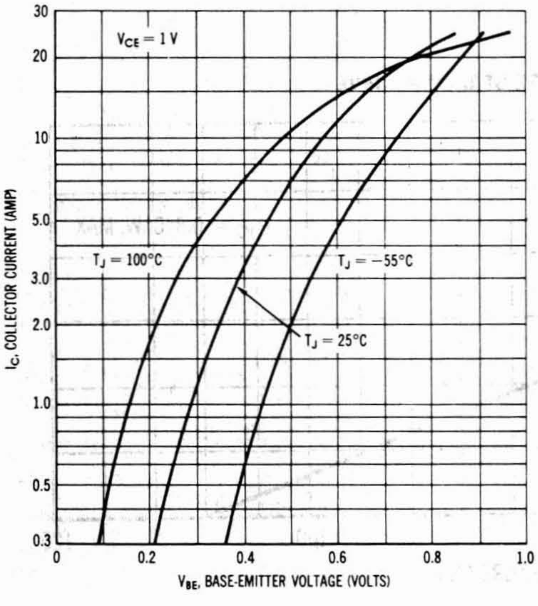


FIGURE 4 — INPUT ADMITTANCE

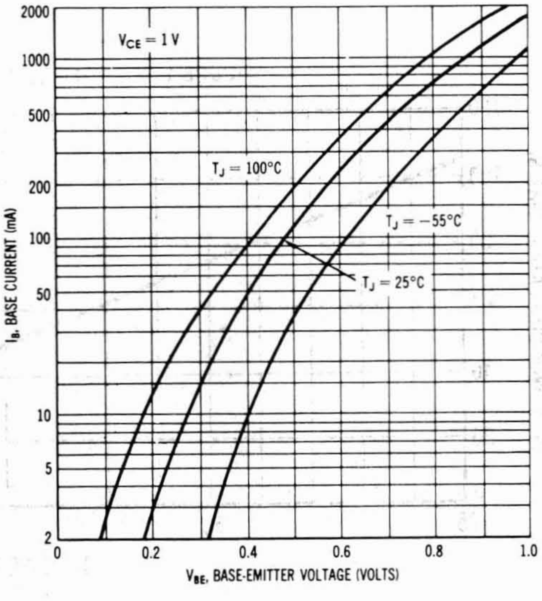


FIGURE 5 — CURRENT GAIN

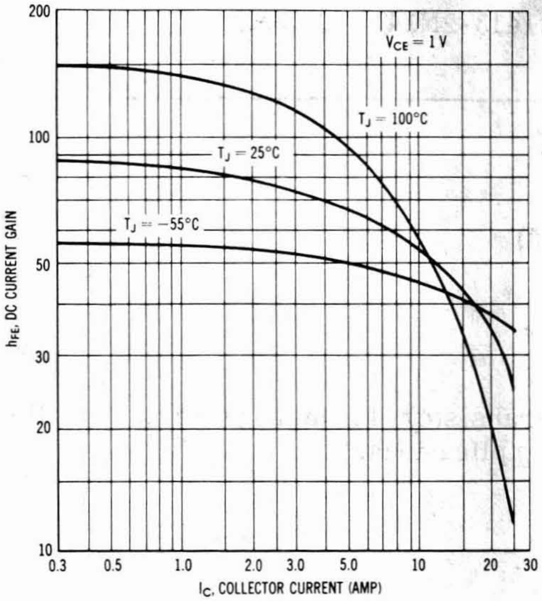
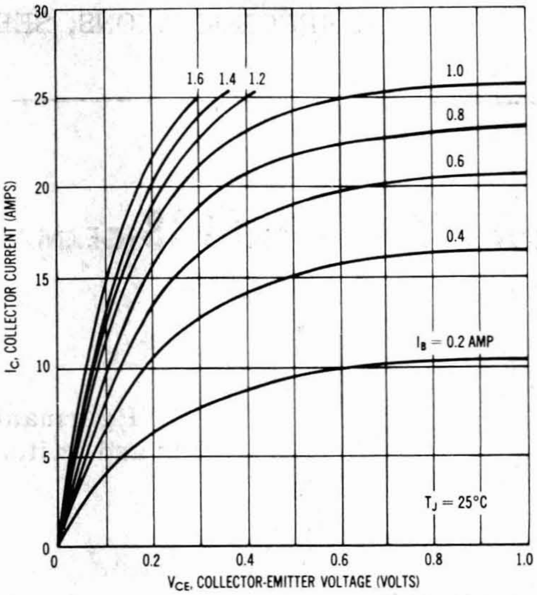


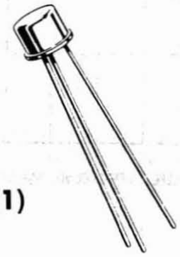
FIGURE 6 — SATURATION REGION



2N1175

FOR SPECIFICATIONS, SEE 2N1413-2N1415 DATA.

2N1185 thru 2N1188 (GERMANIUM)



CASE 31 (1)
(TO-5)

All leads isolated from case

PNP germanium transistors for high-gain audio amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage 2N1185 2N1186-2N1188	V_{CB}	 45 60	Vdc
Collector-Emitter Voltage 2N1185 2N1186-2N1188	V_{CER}	 30 45	Vdc
Emitter-Base Voltage	V_{EB}	30	Vdc
Collector Current* (Continuous)	I_C	500*	mAdc
Storage and Operating Temperature	T_{stg}, T_J	-65 to +100	°C
Collector Dissipation in, Ambient (Derate 2.67 mW/°C above 25°C)	P_D	200	mW
Thermal Resistance Junction to Ambient	θ_{JA}	0.375	°C/mW
Thermal Resistance (Junction to Case)	θ_{JC}	0.250	°C/mW

*Limited by power dissipation

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

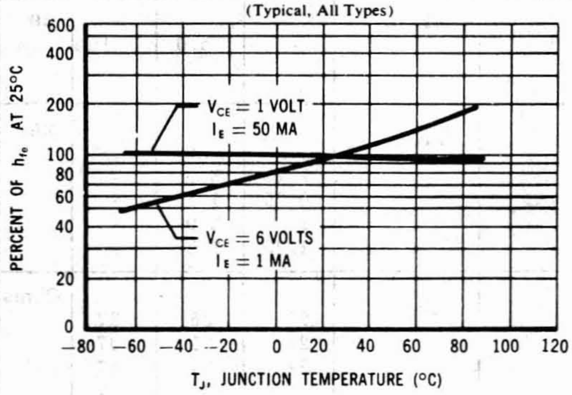
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 30 V, I_E = 0)	2N1185		-	3.0	10	
(V_{CB} = 45 V, I_E = 0)	2N1186 thru 2N1188		-	5.0	10	
(V_{CB} = 60 V, I_E = 0)	2N1186 thru 2N1188		-	-	50	
(V_{CB} = 10 V, I_E = 0, T_A = +71° C)	All Types		-	55	100	
Emitter-Base Cutoff Current (V_{EB} = 30 V, I_C = 0)		I_{EBO}	-	3.0	10	μAdc
Collector-Emitter Leakage Current		I_{CER}				μAdc
(V_{CE} = 30 V, R_{BE} = 10 K)	2N1185		-	-	600	
(V_{CE} = 45 V, R_{BE} = 10 K)	2N1186 thru 2N1188		-	-	600	
Collector-Emitter Punch-Thru Voltage		V_{pt}				Vdc
(V_F = 1.0 V,	2N1185		45	-	-	
VTVM Impedance ≥ 1 M ohm)	2N1186 thru 2N1188		60	-	-	
Output Capacitance (V_{CB} = 6 V, I_E = 0)		C_{ob}	-	10	25	pF
Noise Figure (V_{CE} = 4.5 V, I_E = 0.5 mA, R_g = 1 K, f = 1 kHz, Δf = 1 Hz)		NF	-	5.0	15	dB
Small Signal Current Gain Cutoff Frequency		$f_{\alpha b}$				MHz
(V_{CB} = 6 V, I_E = 1 mA)	2N1185		1.75	3.0	-	
	2N1186		0.75	1.5	-	
	2N1187		1.0	2.0	-	
	2N1188		1.25	2.5	-	
Input Impedance		h_{ib}				Ohms
(V_{CB} = 6 V, I_E = 1 mA, f = 1 kHz)	2N1185		27	35	37	
	2N1186		27	31	37	
	2N1187		27	34	37	
	2N1188		27	35	37	
Output Admittance		h_{ob}				μmho
(V_{CB} = 6 V, I_E = 1 mA, f = 1 kHz)	2N1185		0.2	0.50	0.7	
	2N1186		0.2	0.65	1.0	
	2N1187		0.2	0.60	0.9	
	2N1188		0.2	0.55	0.8	
Small Signal Current Gain		h_{fe}				-
(V_{CE} = 6 V, I_E = 1 mA, f = 1 kHz)	2N1185		190	260	400	
	2N1186		30	49	70	
	2N1187		50	80	120	
	2N1188		100	130	225	
DC Current Transfer Ratio		h_{FE}				-
(V_{CE} = 1.0 V, I_C = 10 mA)	2N1185		130	170	-	
	2N1186		33	44	-	
	2N1187		45	75	-	
	2N1188		80	115	-	

ELECTRICAL CHARACTERISTICS (continued)

Characteristics		Symbol	Min	Typ	Max	Unit
Base-Emitter Input Voltage (V_{CE} = 1.0 V, I_C = 10 mA)	2N1185 2N1186 2N1187 2N1188	V_{BE}	- - - -	0.215 0.245 0.235 0.225	0.240 0.270 0.260 0.250	Vdc
Collector-Emitter Saturation Voltage (I_C = 50 mA, I_B = 1.0 mA) (I_C = 50 mA, I_B = 2.5 mA) (I_C = 50 mA, I_B = 1.67 mA) (I_C = 50 mA, I_B = 1.25 mA)	2N1185 2N1186 2N1187 2N1188	$V_{CE\,(sat)}$	- - - -	0.175 0.175 0.175 0.175	0.250 0.250 0.250 0.250	Vdc
Collector-Emitter Saturation Voltage (I_C = 100 mA, I_B = 2.0 mA) (I_C = 100 mA, I_B = 5.0 mA) (I_C = 100 mA, I_B = 3.33 mA) (I_C = 100 mA, I_B = 2.5 mA)	2N1185 2N1186 2N1187 2N1188	$V_{CE\,(sat)}$	- - - -	0.250 0.250 0.250 0.250	0.500 0.500 0.500 0.500	Vdc

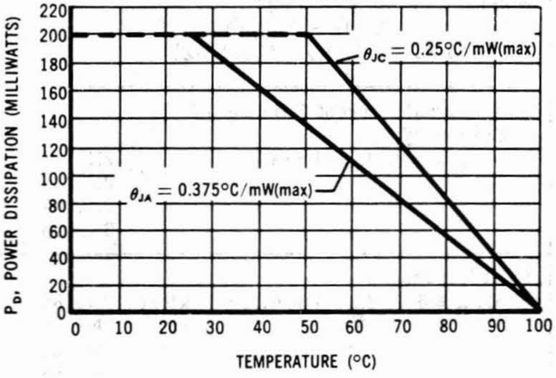
SMALL SIGNAL CURRENT GAIN(h_{fe}) versus TEMPERATURE

(Typical, All Types)

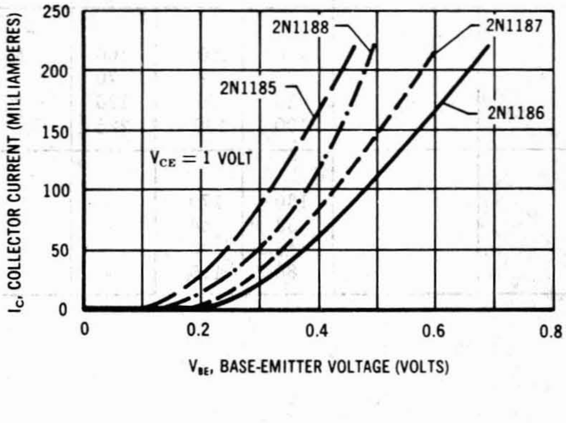


POWER-TEMPERATURE DERATING CURVE

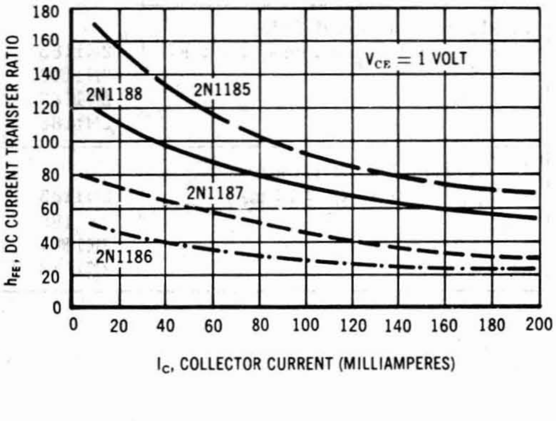
(For All Types)



OUTPUT CURRENT versus BASE DRIVE VOLTAGE



DC CURRENT TRANSFER RATIO versus COLLECTOR CURRENT



2N1189 2N1190 (GERMANIUM)

CASE 31(1)
(TO-5)
All leads isolated

PNP germanium transistors for high-gain audio amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	45	Vdc
Collector-Emitter Voltage	V_{CER}	30	Vdc
Emitter-Base Voltage	V_{EB}	15	Vdc
Collector Current (Continuous)	I_C	500*	mAdc
Junction, Storage Temperature	T_J, T_{stg}	-65 to +100	°C
Collector Dissipation, Ambient (Derate 2.67 mW/°C above 25°C)	P_D	200	mW
Thermal Resistance (Junction to Ambient)	θ_{JA}	0.375	°C/mW
Thermal Resistance (Junction to Case)	θ_{JC}	0.250	°C/mW

*Limited by power dissipation.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

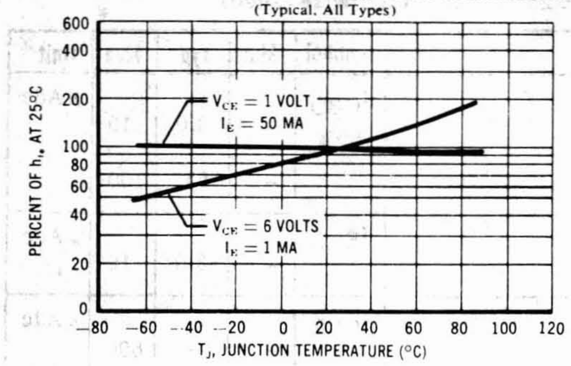
Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current	I_{CBO}				μAdc
($V_{CB} = 30$ Vdc, $I_E = 0$)		—	3.0	10	
($V_{CB} = 45$ Vdc, $I_E = 0$)		—	—	50	
($V_{CB} = 10$ Vdc, $I_E = 0$, $T_A = +71°C$)		—	55	100	
Emitter-Base Cutoff Current	I_{EBO}				μAdc
($V_{EB} = 15$ Vdc, $I_C = 0$)		—	3.0	10	
Collector-Emitter Leakage Current	I_{CER}				μAdc
($V_{CE} = 30$ Vdc, $R_{BE} = 10K$)		—	—	600	
Collector-Emitter Punch-Thru Voltage	V_{pt}				Vdc
($V_{EB} = 1$ Vdc, VTVM Impedance ≥ 1 M ohm		45	—	—	
Output Capacitance	C_{ob}				pF
($V_{CB} = 6$ Vdc, $I_E = 0$, f = 1 MHz)		—	12.0	25	
Noise Figure	NF				dB
($V_{CE} = 4.5$ V_{dc}, $I_E = 0.5$ mAdc $R_g = 1$ K, f = 1 kHz Δf = 1 Hz)		—	5.0	15	
Small-Signal Current-Gain Cutoff Frequency	$f_{\alpha b}$				MHz
($V_{CB} = 6$ Vdc, $I_E = 1$ mAdc)					
2N1189		1.75	3.5	—	
2N1190		2.25	4.5	—	

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Typ	Max	Unit
Input Impedance (V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)		h_{ib}	27	31	37	Ohms
Output Admittance (V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)		h_{ob}	0.1	–	0.9	μmho
Small Signal Current Gain (V_{CE} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)		h_{fe}				–
	2N1189		75	120	175	
	2N1190		125	190	300	
DC Current Transfer Ratio (V_{CE} = 1.0 Vdc, I_E = 10 mAdc)		h_{FE}				–
	2N1189		60	115	–	
	2N1190		100	170	–	
Base-Emitter Drive Voltage (V_{CE} = 1.0 Vdc, I_E = 10 mAdc)		V_{BE}				Vdc
	2N1189		–	0.24	0.26	
	2N1190		–	0.22	0.25	
Collector-Emitter Saturation Voltage		V_{CE} (sat)				Vdc
(I_C = 50 mAdc, I_B = 1.5 mA)	2N1189		–	0.14	0.22	
(I_C = 50 mAdc, I_B = 1.0 mA)	2N1190		–	0.15	0.22	
(I_C = 100 mAdc, I_B = 3.0 mA)	2N1189		–	0.17	0.3	
(I_C = 100 mAdc, I_B = 2.0 mA)	2N1190		–	0.19	0.3	

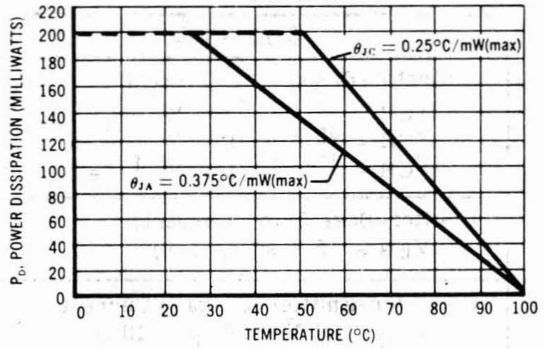
SMALL SIGNAL CURRENT GAIN(h_{fe}) versus TEMPERATURE

(Typical, All Types)

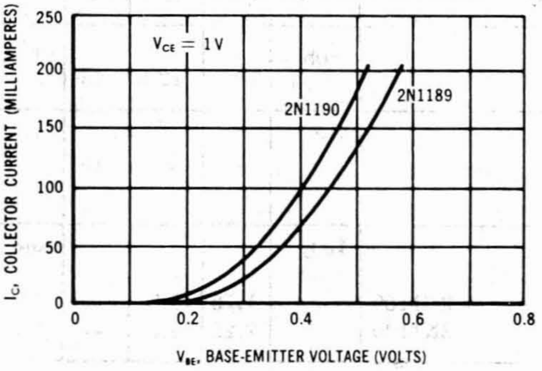


POWER-TEMPERATURE DERATING CURVE

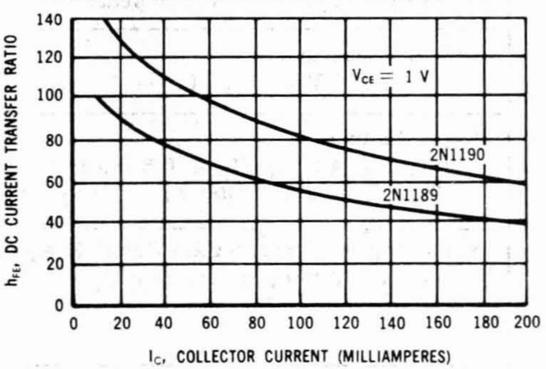
(For All Types)



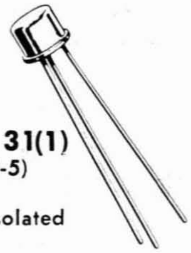
OUTPUT CURRENT versus BASE DRIVE VOLTAGE



DC CURRENT TRANSFER RATIO versus COLLECTOR CURRENT



2N1191 thru 2N1194 (GERMANIUM)



CASE 31(1)
(TO-5)
All leads isolated

PNP germanium transistors for high-gain audio amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CER}	25	Vdc
Emitter-Base Voltage	V_{EB}	25	Vdc
Collector Current (Continuous)	I_C	200	mAdc
Storage and Operating Temperature	T_{stg}, T_J	-65 to +100	°C
Collector Dissipation in, Ambient (Derate 2.67 mW/°C above 25°C)	P_D	200	mW
Thermal Resistance (Junction to Ambient)	θ_{JA}	0.375	°C/mW
Thermal Resistance (Junction to Case)	θ_{JC}	0.250	°C/mW

ELECTRICAL CHARACTERISTICS (TA = 25°C unless otherwise noted)

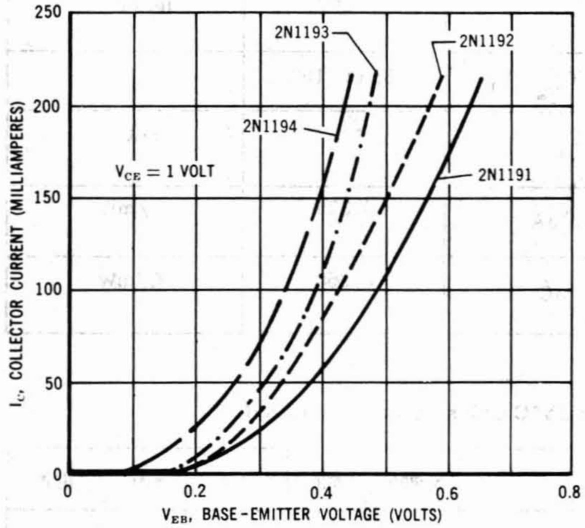
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current		I_{CBO}				
(V_{CB} = 25 V, I_E = 0)			–	–	15	μAdc
(V_{CB} = 1.0 V, I_E = 0)			–	2.0	–	μAdc
Emitter-Base Cutoff Current (V_{EB} = 25 V, I_C = 0)		I_{EBO}	–	–	15	μAdc
Collector-Emitter Leakage Current (V_{CB} = 25 V, R_{BE} = 10 K)		I_{CER}	–	–	600	μAdc
Output Capacitance (V_{CE} = 6 V, I_E = 1.0 mA)		C_{ob}	–	20	–	pF
Noise Figure (V_{CE} = 4.5 V, I_E = 0.5 mA, f = 1 kHz, R_s = 100 ohms)		NF	–	10	–	dB
Small Signal Current Gain Cutoff Frequency (V_{CB} = 6 V, I_E = 1.0 mA)	2N1191	$f_{\alpha b}$	–	1.5	–	MHz
	2N1192		–	2.0	–	
	2N1193		–	2.5	–	
	2N1194		–	3.0	–	

2N1191 thru 2N1194 (continued)

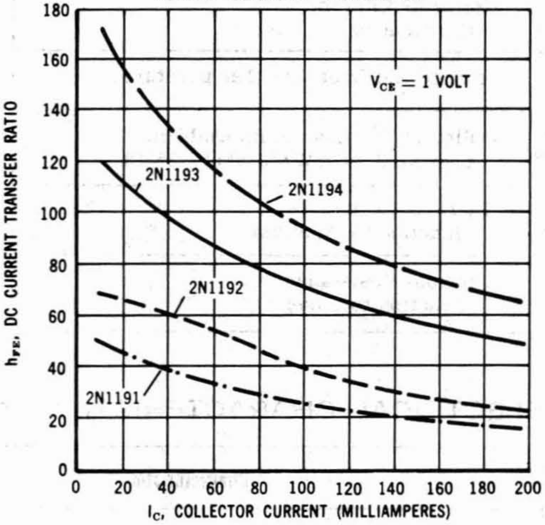
ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Typ	Max	Unit
Small Signal Current Gain (V_{CE} = 6 V, I_E = 1.0 mA, f = 1 kHz)	2N1191 2N1192 2N1193 2N1194	h_{fe}	30 50 100 190	40 75 160 280	70 125 250 500	–
DC Current Gain (V_{CE} = 1 V, I_C = 10 mA)	2N1191 2N1192 2N1193 2N1194	h_{FE}	20 40 70 125	– – – –	80 135 300 600	–
Small Signal Power Gain (V_{CE} = 6 V, I_E = 1.0 mA, f = 1 kHz, matched)	2N1191 2N1192 2N1193 2N1194	G_e	– – – –	42 44 46 48	– – – –	dB
Base-Emitter Input Voltage (V_{CE} = 6 V, I_C = 1.0 mA)		V_{BE}	–	–	0.3	Vdc

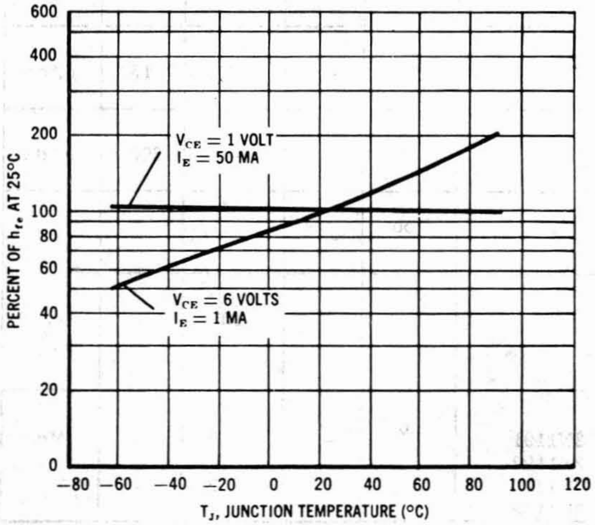
OUTPUT CURRENT versus BASE DRIVE VOLTAGE



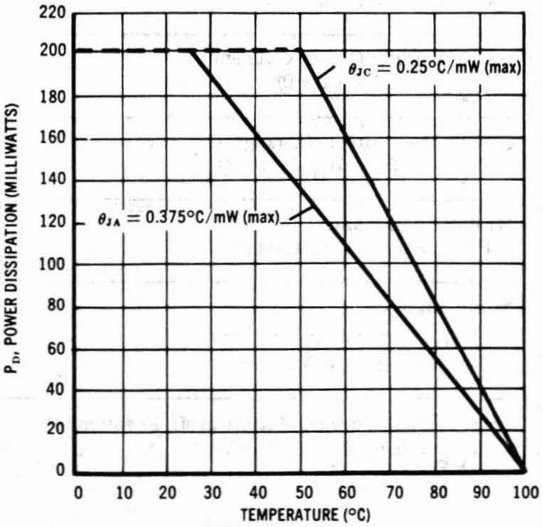
DC CURRENT TRANSFER RATIO versus CURRENT COLLECTOR



SMALL SIGNAL CURRENT GAIN versus TEMPERATURE
(For All Types)



POWER-TEMPERATURE DERATING CURVE
(For All Types)



2N1195

FOR SPECIFICATIONS, SEE 2N1141 DATA.

2N1204, A (GERMANIUM)
2N1494, A
2N1495
2N1496
2N2096
2N2097
2N2099
2N2100

PNP germanium epitaxial mesa transistors for high-speed, high-current switching in line and core driver applications.

CASE 31
(TO-5)

2N1204,A
2N1495
2N2099
2N2100

Collector connected to case

CASE 25

2N1494,A
2N1496
2N2096
2N2097

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}		Vdc
2N1204, 2N1204A, 2N1494, 2N1494A		20	
2N2096, 2N2099		25	
2N1495, 2N1496, 2N2097, 2N2100		40	
Collector-Emitter Voltage	V_{CEO}		Vdc
2N2096, 2N2099		12	
2N1204, 2N1204A, 2N1494A		15	
2N2097, 2N2100		20	
2N1495, 2N1496		25	
Collector-Emitter Voltage	V_{CES}		Vdc
2N1204, 2N1204A, 2N1494, 2N1494A		20	
2N2096, 2N2099		25	
2N1495, 2N1496, 2N2097, 2N2100		40	
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ $T_C = 25°C$	P_D		
All Types		750	mW
Derate above 25°C		10	mW/°C
Total Device Dissipation @ $T_A = 25°C$	P_D		
TO-5 Case			
2N1204, 2N1204A, 2N1495, 2N2099, 2N2100		300	mW
Derate above 25°C		4.0	mW/°C
Case 25			
2N1494, 2N1494A, 2N1496, 2N2096, 2N2097		500	mW
Derate above 25°C		6.67	mW/°C
Operating Junction and Storage Temperature Range	T_J T_{stg}	-65 to +100	°C

2N1204,A SERIES (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristics		Symbol	Minimum	Typical	Maximum	Unit
Collector-Base Breakdown Voltage ($I_C = 100\ \mu Adc$, $I_E = 0$)	2N1204, 2N1204A, 2N1494, 2N1494A	BV_{CBO}	20	40	–	Vdc
	2N2096, 2N2099		25	–	–	
	2N1495, 2N1496, 2N2097, 2N2100		40	–	–	
Collector-Emitter Breakdown Voltage ($I_C = 100\ \mu Adc$, $V_{BE} = 0$)	2N1204, 2N1204A, 2N1494, 2N1494A	BV_{CES}	20	40	–	Vdc
	2N2096, 2N2099		25	–	–	
	2N1495, 2N1496, 2N2097, 2N2100		40	–	–	
Collector-Emitter Breakdown Voltage ($I_C = 2$ mAdc, $I_B = 0$)	2N1204, 2N1204A, 2N1494, 2N1494A	BV_{CEO}	15	25	–	Vdc
($I_C = 10$ mAdc, $I_B = 0$)	2N2096, 2N2099		12	–	–	
	2N2097, 2N2100		20	–	–	
	2N1495, 2N1496		25	–	–	
Emitter-Base Breakdown Voltage ($I_E = 1$ mAdc, $I_C = 0$)	2N1204, 2N1204A, 2N1494 thru 2N1496, 2N1494A	BV_{EBO}	4	–	–	Vdc
($I_E = 10$ mAdc, $I_C = 0$)	2N2096, 2N2097, 2N2099, 2N2100		4	–	–	
Collector Cutoff Current ($V_{CB} = 5$ Vdc, $I_E = 0$)	2N1204, 2N1204A, 2N1494 thru 2N1496, 2N1494A	I_{CBO}	–	0.4	7	μAdc
($V_{CB} = 12$ Vdc, $I_E = 0$)	2N2096, 2N2099		–	–	12	
($V_{CB} = 15$ Vdc, $I_E = 0$)	2N2097, 2N2100		–	–	12	
Emitter Cutoff Current ($V_{BE} = 0.5$ Vdc, $I_C = 0$)	2N1494 thru 2N1496, 2N1494A	I_{EBO}	–	–	5	μAdc
($V_{BE} = 1$ Vdc, $I_C = 0$)	2N2096, 2N2097, 2N2099, 2N2100		–	10	50	
DC Current Gain ($I_C = 200$ mAdc, $V_{CE} = 0.5$ Vdc)	2N1204A, 2N1494A, 2N1495, 2N1496	h_{FE}	25	–	–	–
($I_C = 200$ mAdc, $V_{CE} = 1$ Vdc)	2N2097, 2N2100		30	70	–	
($I_C = 400$ mAdc, $V_{CE} = 1.5$ Vdc)*	2N1204, 2N1494, 2N2096, 2N2099		15	35	–	
	2N2097, 2N2100		20	50	–	
Collector-Emitter Saturation Voltage ($I_C = 50$ mAdc, $I_B = 2.5$ mAdc)	2N2097, 2N2100	$V_{CE(sat)}$	–	–	0.3	Vdc
($I_C = 200$ mAdc, $I_B = 10$ mAdc)	2N1204, 2N1204A, 2N1494, 2N1494A		–	–	0.4	
	2N2097, 2N2100		–	–	0.5	
	2N2096, 2N2099		–	–	0.6	
($I_C = 200$ mAdc, $I_B = 20$ mAdc)	2N1495, 2N1496		–	–	0.3	
($I_C = 400$ mAdc, $I_B = 25$ mAdc)**	2N1204A, 2N1494A, 2N1495, 2N1496		–	–	0.7	
Base-Emitter Saturation Voltage ($I_C = 50$ mAdc, $I_B = 2.5$ mAdc)	2N2097, 2N2100	$V_{BE(sat)}$	–	–	0.5	Vdc
($I_C = 200$ mAdc, $I_B = 10$ mAdc)	2N1204, 2N1204A, 2N1494 thru 2N1496, 2N1494A		0.40	0.60	0.72	
	2N2097, 2N2100		–	–	0.8	
	2N2096, 2N2099		–	–	0.9	
Collector Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 4 MHz)	2N1204, 2N1204A, 2N1494 thru 2N1496, 2N1494A	C_{ob}	–	3.5	6.5	pF
	2N2096, 2N2097, 2N2099, 2N2100		–	3.5	20	
Input Capacitance ($V_{BE} = 1$ Vdc, $I_C = 0$, f = 4 MHz)	All Types	C_{ib}	–	8	50	pF
AC Current Gain ($I_C = 20$ mA, $V_{CE} = 10$ V, f = 100 MHz)	2N1204, 2N1204A, 2N1494, 2N1494A	h_{fe}	1.1	2	–	–
	2N1495, 2N1496		1.5	–	–	
Rise Time (Figure 5)	2N2097, 2N2100	t_r	–	–	20	ns
	2N1204, 2N1204A, 2N1494, 2N1494A, 2N2096, 2N2099		–	–	35	
	2N1495, 2N1496		–	–	55	
Minority Carrier Storage Time Constant (Figure 4)	2N1204, 2N1204A, 2N1494, 2N1494A	τ_s	–	30	75	ns
	2N1495, 2N1496		–	–	90	
Storage Time (Figure 6)	2N2097, 2N2100	t_s	–	–	50	ns
	2N2096, 2N2099		–	–	70	
Fall Time (Figure 6)	2N2097, 2N2100	t_f	–	–	40	ns
	2N2096, 2N2099		–	–	60	

*Pulse Test: Pulse width ≤ 1 ms, Duty cycle ≤ 6%

**Pulse Test: Pulse width ≤ 5 ms, Duty cycle ≤ 2%

2N1204,A SERIES (continued)

FIGURE 1 — TYPICAL RISE AND FALL TIME BEHAVIOR

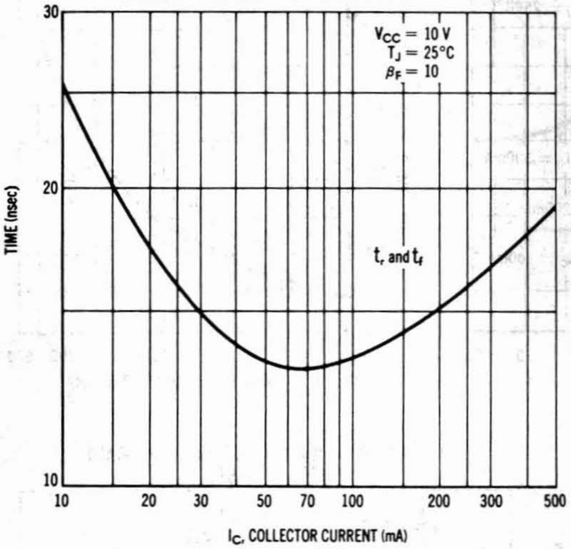


FIGURE 2 — STORAGE TIME VARIATIONS

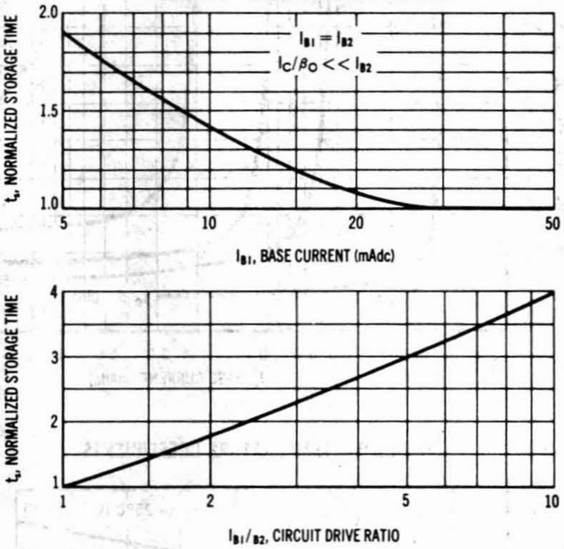


FIGURE 3 — TOTAL CONTROL CHARGE

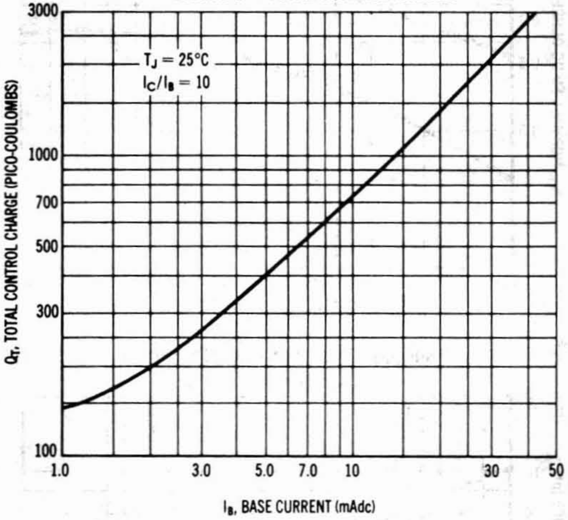
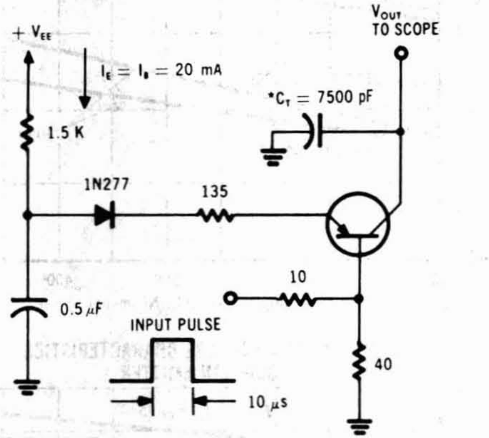


FIGURE 4 — CARRIER STORAGE TIME CONSTANT TEST CIRCUIT

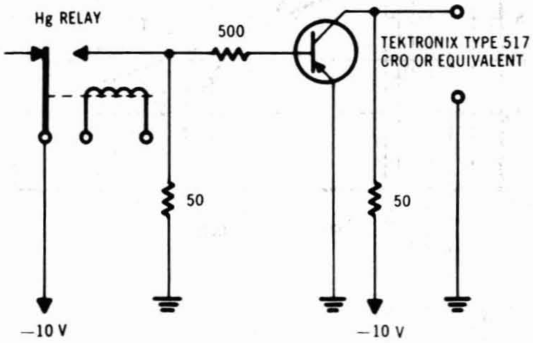


+ V_{EE}
$I_E = I_B$ = 20 mA
1.5 K
1N277
135
*C_T = 7500 pF
V_{OUT} TO SCOPE
10
0.5 μF
INPUT PULSE
40
10 μs

*ADD SCOPE AND PROBE CAPACITANCE TO C_T FOR CORRECT CALCULATION OF τ_S (K'$_S$).

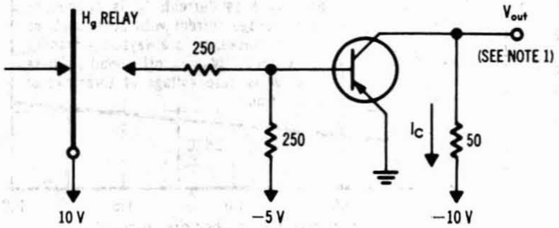
$$\tau_s = \frac{C_T V_{OUT}}{I_E}$$

FIGURE 5 — RISE TIME TEST CIRCUIT



Hg RELAY
500
TEKTRONIX TYPE 517 CRO OR EQUIVALENT
50
50
−10 V
−10 V

FIGURE 6 — STORAGE AND FALL TIME TEST CIRCUIT



H_g RELAY
250
V_{out}
(SEE NOTE 1)
250
I_C
50
10 V
−5 V
−10 V

NOTE 1: SCOPE IMPEDANCE SUFFICIENTLY HIGH SO THAT DOUBLING OR HALVING ITS VALUE DOES NOT CHANGE THE READING.

SCOPE RISE TIME FAST ENOUGH SO THAT DOUBLING OR HALVING ITS VALUE DOES NOT CHANGE THE READING.

FIGURE 7 — COLLECTOR-EMITTER SATURATION VOLTAGES versus BASE CURRENT

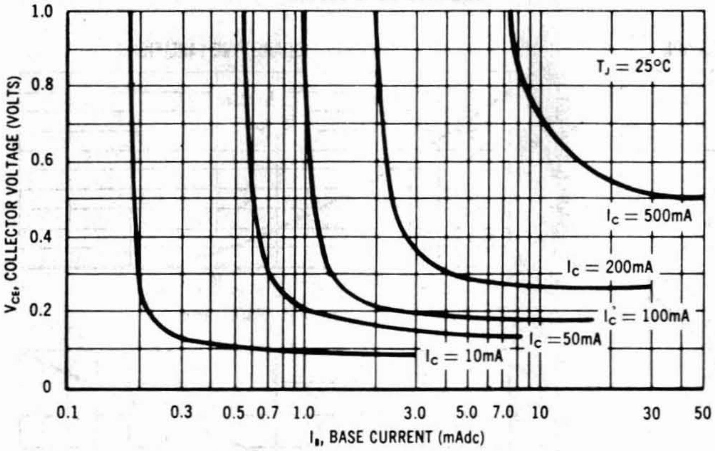


FIGURE 8 — BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT

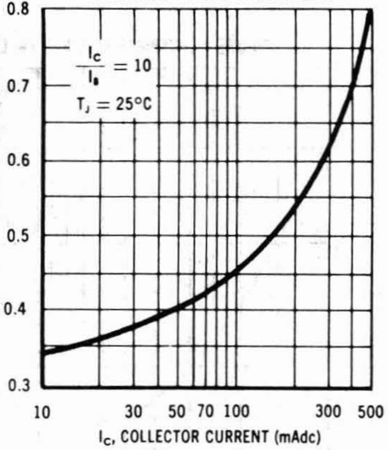


FIGURE 9 — TEMPERATURE COEFFICIENTS

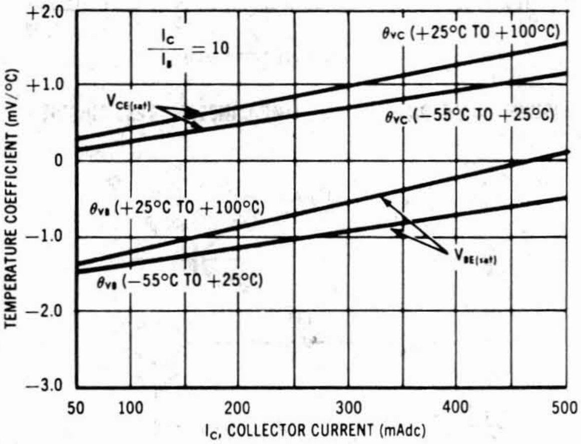


FIGURE 10 — NORMALIZED CURRENT GAIN CHARACTERISTICS

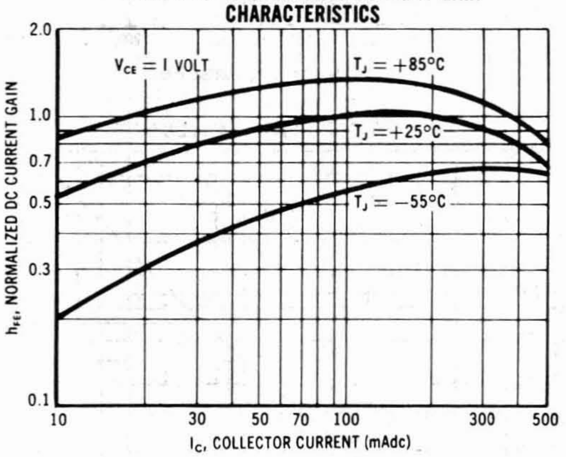
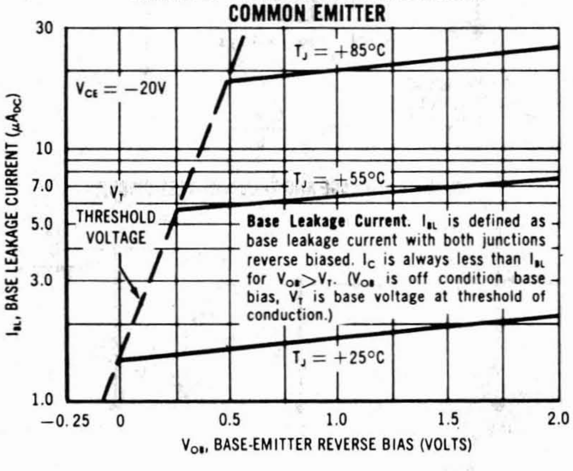
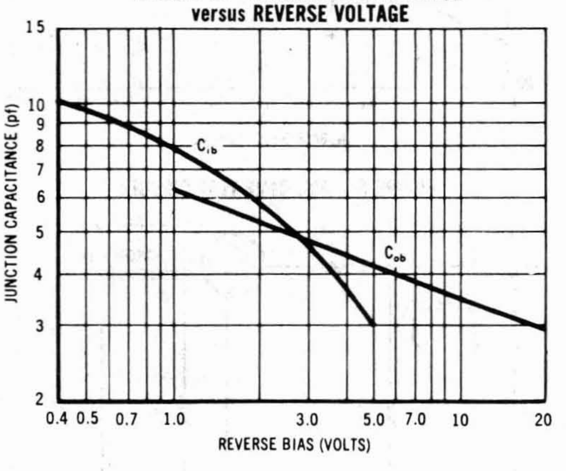


FIGURE 11 — LEAKAGE CHARACTERISTICS COMMON EMITTER



Base Leakage Current. I_{BL} is defined as base leakage current with both junctions reverse biased. I_C is always less than I_{BL} for $V_{OB} > V_T$. (V_{OB} is off condition base bias, V_T is base voltage at threshold of conduction.)

FIGURE 12 — JUNCTION CAPACITANCE versus REVERSE VOLTAGE



2N1358, A (GERMANIUM)

For Specifications, See 2N174 Data.

2N1359 (GERMANIUM)
2N1360
2N1362 thru 2N1365

For Specifications, See 2N375 Data.

2N1408 (GERMANIUM)

CASE 31(1)
(TO-5)

All leads isolated

PNP germanium transistor for high voltage neon driver, solenoid and relay driver circuits.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	50	Volts
Collector-Emitter Voltage	V_{CES}	50	Volts
Emitter-Base Voltage	V_{EB}	10	Volts
Collector Current	I_C	200	mA
Collector Dissipation at $T_A = 25°C$	P_D	150	mW
derating factor		2.0	mW/°C
Junction Temperature Range	T_J	-65 to +100	°C

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Cutoff Current (V_{CB} = 5 Vdc, I_E = 0)	I_{CBO}	---	7.0	μAdc
Emitter-Base Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)	I_{EBO}	---	7.0	μAdc
Collector-Emitter Leakage Current (V_{CB} = 50 Vdc, R_{BE} = 0)	I_{CES}	---	150	μAdc
Collector-Base Breakdown Voltage (I_C = 25 μAdc, I_E = 0)	BV_{CBO}	50	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 25 μAdc, I_C = 0)	BV_{EBO}	10	---	Vdc
Collector-Emitter Punch-Thru Voltage (I_E = 25 μAdc)	V_{pt}	50	---	Vdc
Base-Emitter Input Voltage (I_B = 1.0 mAdc, V_{CE} = 1.0 Vdc)	V_{BE}	---	0.6	Vdc
DC Current Gain (V_{CE} = 1 Vdc, I_B = 1 mAdc)	h_{FE}	10	---	---
Small Signal Current Gain (V_{CE} = 5.0 Vdc, I_E = 1.0 mA, f = 1 kHz)	h_{fe}	10	---	---
Output Admittance (V_{CB} = 5.0 Vdc, I_E = 1.0 mA, f = 1 kHz)	h_{ob}	---	2.0	μmhos

2N1412 (GERMANIUM)
2N1412A

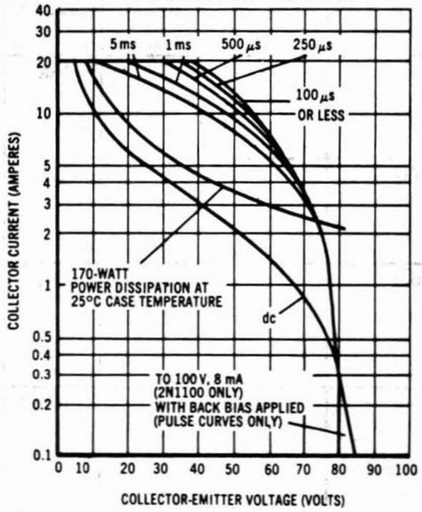
CASE 5
(TO-36)

PNP germanium power transistors for high-voltage power amplifier and switching applications in military and industrial equipment.

MAXIMUM RATINGS

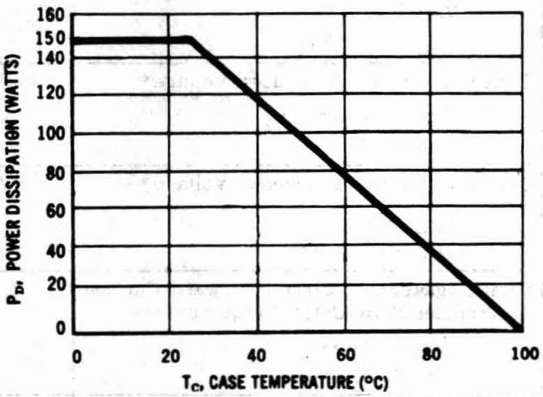
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	100	Vdc
Collector-Emitter Voltage	V_{CES}	80	Vdc
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Emitter-Base Voltage	V_{EB}	60	Vdc
Emitter Current (Continuous)	I_E	15	Amp
Base Current (Continuous)	I_B	4.0	Amp
Junction & Storage Temperature	T_{stg}	-65 to +100	^{o}C
Thermal Resistance	θ_{JC}	0.5	$^{o}C/W$

SAFE OPERATING AREA



The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short.

POWER-TEMPERATURE DERATING CURVE



The maximum continuous power is related to maximum junction temperature by the thermal resistance factor.

This curve has a value of 150 Watts at case temperatures of 25°C and is 0 Watts at 100°C with a linear relation between the two temperatures such that:

$$\text{allowable } P_D = \frac{100° - T_C}{0.5}$$

(Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

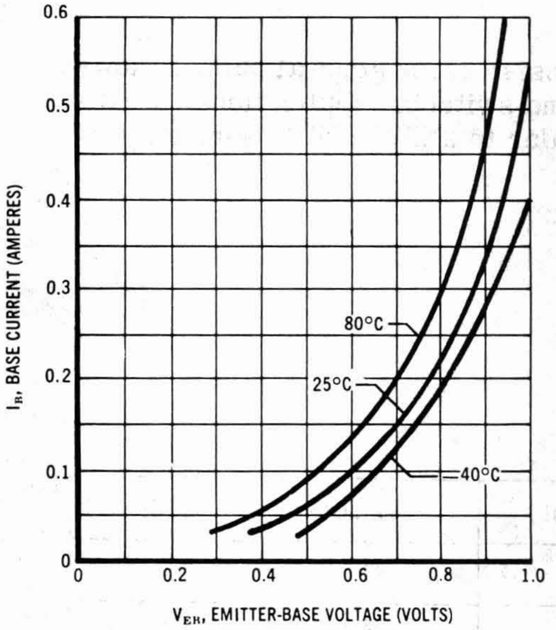
2N1412 (continued)

ELECTRICAL CHARACTERISTICS

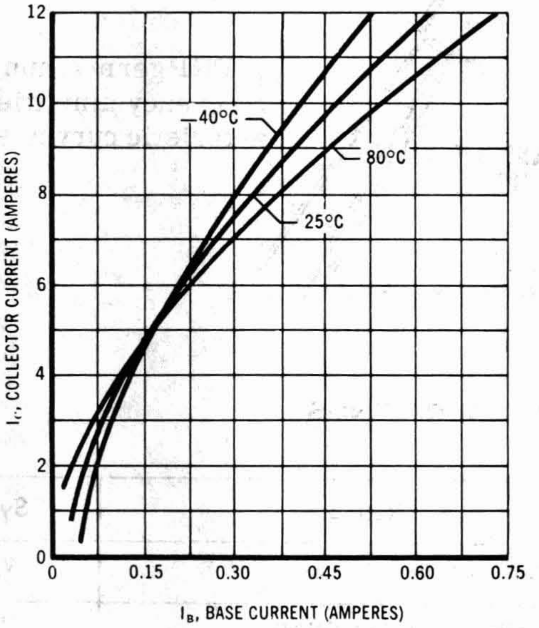
Characteristic	Symbol	Minimum	Maximum	Unit
Emitter Cutoff Current V_{EB} = –2.0 Vdc I_C = 0	I_{EBO}	—	200	μAdc
Emitter Cutoff Current V_{EB} = –60 Vdc I_C = 0	I_{EBO}	—	10	mAdc
Collector Cutoff Current V_{CB} = –2.0 Vdc I_E = 0	I_{CBO}	—	200	μAdc
Collector Cutoff Current V_{CB} = –100 Vdc I_E = 0	I_{CBO}	—	10	mAdc
Emitter-Base Voltage V_{CE} = –2.0 Vdc I_C = –1.2 Adc	V_{EB}		0.5	Vdc
Emitter-Base Voltage V_{CE} = –2.0 Vdc I_C = –5.0 Adc	V_{EB}		0.9	Vdc
Floating Potential V_{CB} = –100 Vdc I_E = 0 (Voltmeter input resistance = 10 Megohm min)	V_{fl}		1.0	Vdc
Collector-Emitter Saturation Voltage I_C = –12 Adc I_B = –2.0 Adc	$V_{CE(SAT)}$		0.7	Vdc
Forward Current Transfer Ratio* V_{CE} = –2.0 Vdc I_C = –15 Adc	h_{FE}	10	—	—
Forward Current Transfer Ratio V_{CE} = –2.0 Vdc I_C = –5.0 Adc	h_{FE}	25	50	—
Collector-Emitter Breakdown Voltage* I_C = –1 Adc I_B = 0	BV_{CEO}	60	—	Vdc
Collector-Emitter Breakdown Voltage* V_{EB} = 0 I_C = 300 mA	BV_{CES}	80	—	Vdc
Small-Signal Short-Circuit Forward-Current Transfer Ratio Cutoff Frequency V_{CE} = –12 Vdc I_C = –5.0 Adc	$f_{\alpha e}$	5.0	—	kHz
High-Temperature Operation Emitter Cutoff Current T_C = +71°C min V_{EB} = –30 Vdc	I_{EBO}	—	6.0	mAdc
Collector Cutoff Current V_{CB} = –30 Vdc I_E = 0	I_{CBO}	—	6.0	mAdc

*Test by sweep method with a short duty cycle (about 1%) to avoid excessive heating.

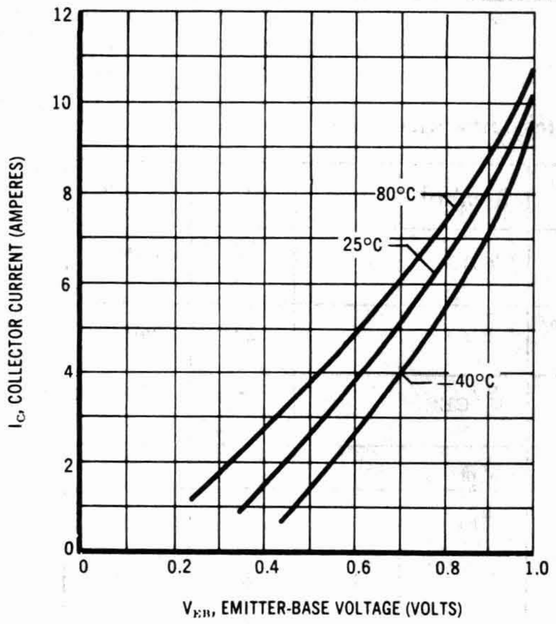
INPUT CHARACTERISTICS



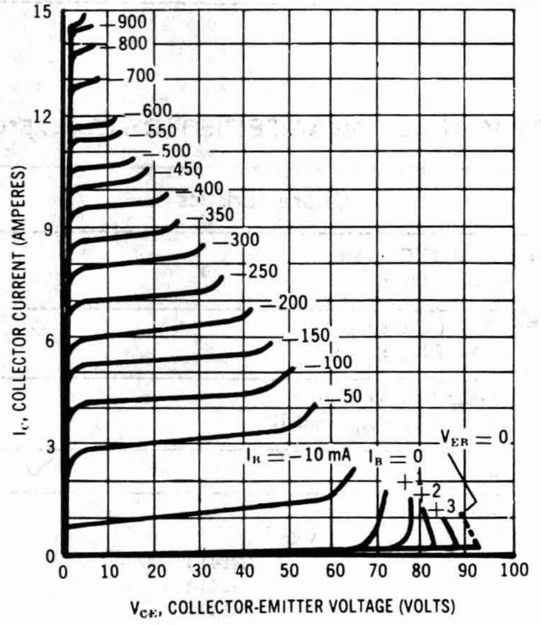
CURRENT TRANSFER CHARACTERISTICS



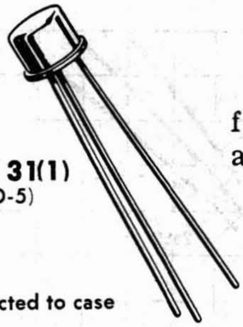
TRANSCONDUCTANCE CHARACTERISTICS



OUTPUT CHARACTERISTICS



2N1413 thru 2N1415 (GERMANIUM)
2N1175



CASE 31(1)
(TO-5)

Base connected to case

PNP germanium transistors for general-purpose low-frequency amplifier and switching applications. Characteristic curves similar to 2N524-2N527 series.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	35	Vdc
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Emitter-Base Voltage	V_{EB}	10	Vdc
Collector Current	I_C	500	mAdc
Junction and Storage Temperature	T_j & T_{stg}	-65 to +100	°C
Power Dissipation at 25°C Ambient	P_D	225	mW

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
Collector Cutoff Current V_{CB} = 30 Vdc, I_E = 0	I_{CBO}	–	12	μAdc
Emitter Cutoff Current V_{EB} = 10 Vdc, I_C = 0	I_{EBO}	–	10	μAdc
Collector-Emitter Voltage I_C = 0.6 mAdc, R_{BE} = 10 K	BV_{CER}	25	–	Vdc
Punch-Thru Voltage	V_{pt}	25	–	Vdc
DC Current Gain I_C = 20 mAdc, V_{CE} = 1 Vdc	h_{FE}			
2N1413		25	42	–
2N1414		34	65	
2N1415		53	90	
2N1175		70	140	

2N1413 thru 2N1415 , 2N1175 (continued)

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
DC Current Gain I_C = 100 mAdc, V_{CE} = 1 Vdc	h_{FE}			
2N1413		23	–	–
2N1414		30	–	
2N1415		47	–	
2N1175		62	–	
Base Input Voltage V_{CE} = 1 Vdc, I_C = 20 mAdc	V_{BE}			
2N1175		–	260	mVdc
Output Capacitance; Input AC Open Circuit V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 MHz	C_{ob}	–	40	pF
Frequency Cutoff V_{CE} = 5 Vdc, I_E = 1 mAdc	$f_{\alpha b}$			
2N1413		0.8	–	MHz
2N1414		1.0	–	
2N1415		1.3	–	
2N1175		1.5	–	
Small-Signal Short-Circuit Forward-Transfer Current Ratio V_{CE} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{fe}			
2N1413		20	41	–
2N1414		30	64	
2N1415		44	88	
2N1175		60	120	
Small-Signal Open Circuit Output Admittance V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{ob}			
2N1413		0.10	1.3	μmh
2N1414		0.10	1.2	
2N1415		0.10	1.0	
2N1175		0.10	0.9	
Small-Signal Open-Circuit Reverse-Transfer Voltate Ratio V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{rb}			
2N1413		1.0	10	$X10^{-4}$
2N1414		1.0	11	
2N1415		1.0	12	
2N1175		1.0	14	
Small-Signal Short-Circuit Input Impedance V_{CB} = 5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{ib}			
2N1413		26	36	ohms
2N1414		26	35	
2N1415		26	33	
2N1175		26	31	

2N1420

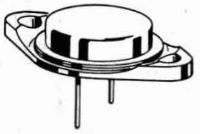
For Specifications, See 2N718 Data.

2N1494, A , 2N1495, 2N1496

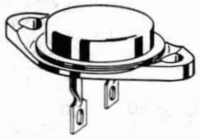
For Specifications, See 2N1204 Data.

2N1529 thru 2N1538 (GERMANIUM)
2N1529A thru 2N1532A, 2N1534A thru 2N1537A

PNP germanium power transistors for switching and amplifier applications in high-reliability equipment.



CASE 11
(TO-3)



CASE 4-04
(TO-41)

For units with solder lugs attached, specify devices MP1529, A etc. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N1529 2N1534	2N1530 2N1535	2N1531 2N1536	2N1532 2N1537	2N1533 2N1538	Units
Collector-Emitter Voltage	V_{CEX}	40	60	80	100	120	Vdc
Collector-Emitter Voltage	V_{CES}	30	45	60	75	90	Vdc
Collector-Emitter Voltage	V_{CEO}	20	30	40	50	60	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	100	120	Vdc
Emitter-Base Voltage	V_{EB}	20	30	40	50	60	Vdc
Collector Current (Continuous)	I_C	5.0					Amp
Collector Current (Peak)	I_C	10					Amp
Junction Temperature Range	T_J	-65 to +110					°C
Total Device Dissipation (25°C Case Temperature)	P_D	106					Watts
Thermal Resistance	θ_{JC}	0.8					°C/W

2N1529 thru 2N1538 (continued)

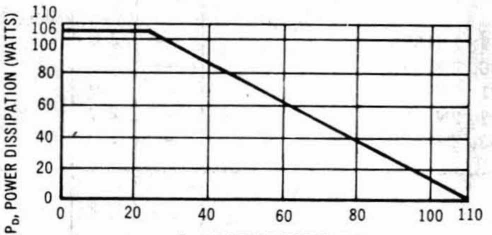
ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise specified.)

Characteristics apply to corresponding "A" type numbers also.

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO1}			mA
(V_{CB} = 25V)	2N1529, 2N1534		—	2.0	
(V_{CB} = 40V)	2N1530, 2N1535		—	2.0	
(V_{CB} = 55V)	2N1531, 2N1536		—	2.0	
(V_{CB} = 65V)	2N1532, 2N1537		—	2.0	
(V_{CB} = 80V)	2N1533, 2N1538		—	2.0	
Collector-Base Cutoff Current		I_{CBO}			mA
(V_{CB} = 2V)			—	0.2	
(V_{CB} = 1 2 BV_{CES} rating; T_C = +90°C)			—	20	
Emitter-Base Cutoff Current (V_{EB} = 12V)		I_{EBO}	—	0.5	mA
Collector-Emitter Breakdown Voltage		BV_{CES}			volts
(I_C = 500 mA, V_{EB} = 0)	2N1529, 2N1534		30	—	
	2N1530, 2N1535		45	—	
	2N1531, 2N1536		60	—	
	2N1532, 2N1537		75	—	
	2N1533, 2N1538		90	—	
Collector-Emitter Leakage Current (V_{BE} = 1V, V_{CE} @ rated BV_{CBO})		I_{CEX}	—	20	mA
Collector-Emitter Breakdown Voltage		BV_{CEO}			volts
(I_C = 500 mA, I_B = 0)	2N1529, 2N1534		20	—	
	2N1530, 2N1535		30	—	
	2N1531, 2N1536		40	—	
	2N1532, 2N1537		50	—	
	2N1533, 2N1538		60	—	
Collector-Base Breakdown Voltage		BV_{CBO}			volts
(I_C = 20 mA)	2N1529, 2N1534		40	—	
	2N1530, 2N1535		60	—	
	2N1531, 2N1536		80	—	
	2N1532, 2N1537		100	—	
	2N1533, 2N1538		120	—	
Current Gain		h_{FE1}			—
(V_{CE} = 2V, I_C = 3A)	2N1529 - 2N1532		20	40	
	2N1534 - 2N1537		35	70	
	2N1529 - 2N1533		20	40	
	2N1534 - 2N1538		35	70	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			volts
(I_C = 3A, I_B = 300 mA)	2N1529 - 2N1532		—	1.7	
	2N1534 - 2N1537		—	1.5	
	2N1529 - 2N1533		—	1.7	
	2N1534 - 2N1538		—	1.5	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			volts
(I_C = 3A, I_B = 300 mA)	2N1529 - 2N1532		—	1.5	
	2N1534 - 2N1537		—	1.2	
	2N1529 - 2N1533		—	1.5	
	2N1534 - 2N1538		—	1.2	
Transconductance		g_{FE}			mhos
(V_{CE} = 2V, I_C = 3A)	2N1529 - 2N1532		1.2	—	
	2N1534 - 2N1537		1.5	—	
	2N1529 - 2N1533		1.2	—	
	2N1534 - 2N1538		1.5	—	

2N1529 thru 2N1538 (continued)

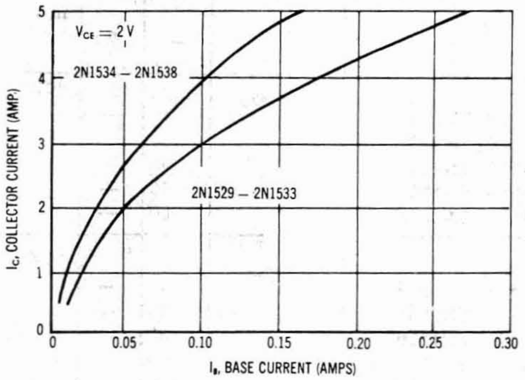
POWER-TEMPERATURE DERATING CURVE



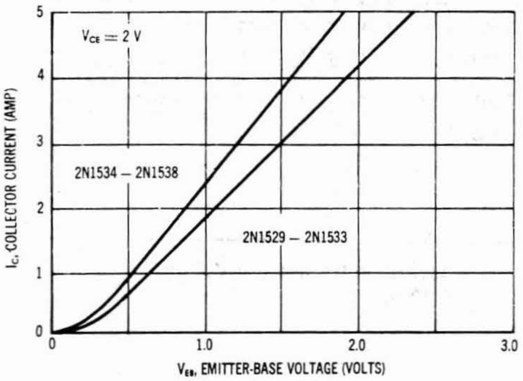
The maximum continuous power is related to maximum junction temperature, by the thermal resistance factor. For dc or frequencies below 25 Hz the transistor must be operated within the constant $P_D = V_C \times I_C$ hyperbolic curve. This curve has a value of 106 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that

$$P_D \text{ allowable} = \frac{110^\circ - T_C}{0.8}$$

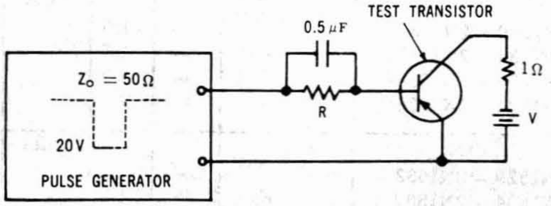
COLLECTOR CURRENT versus BASE CURRENT



COLLECTOR CURRENT versus EMITTER BASE VOLTAGE



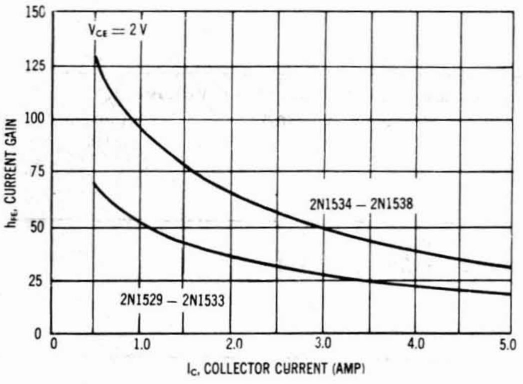
SWITCHING TIME MEASURING CIRCUIT



TYPICAL SWITCHING CHARACTERISTICS

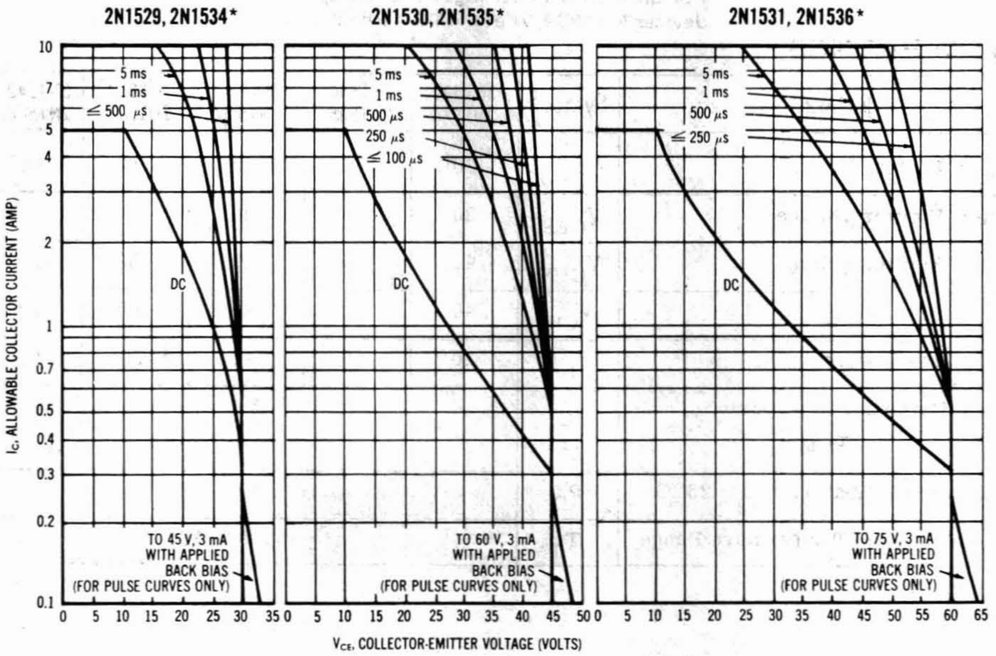
	I_C (AMP)	V (VOLTS)	R (ohms)	$t_d + t_r$ (µs)	t_s (µs)	t_f (µs)
2N1529-33	3	3	65	10	2	5
2N1534-38	3	3	100	8	3	5

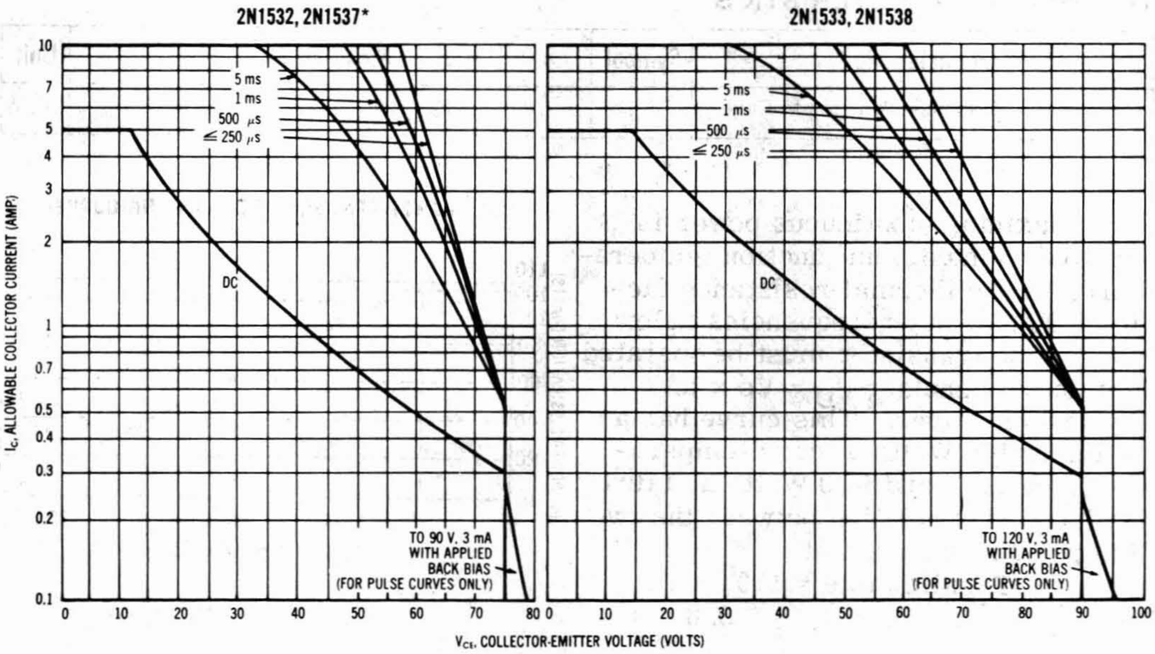
DC CURRENT GAIN versus COLLECTOR CURRENT



SAFE OPERATING AREAS — PULSE CONDITIONS

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

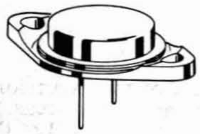




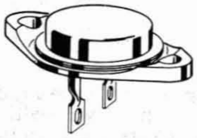
*Characteristics apply to corresponding "A" type numbers also.

2N1539 thru 2N1548 (GERMANIUM)
2N1539A thru 2N1542A, 2N1544A thru 2N1547A

PNP germanium power transistors for switching and amplifier applications in high-reliability equipment.



CASE 11
(TO-3)



CASE 4-04
(TO-41)

For units with solder lugs attached, specify devices MP1539, A etc. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N1539 2N1544	2N1540 2N1545	2N1541 2N1546	2N1542 2N1547	2N1543 2N1548	Unit
Collector-Emitter Voltage	V_{CEO}	20	30	40	50	60	Vdc
Collector-Emitter Voltage	V_{CES}	30	45	60	75	90	Vdc
Collector-Emitter Voltage	V_{CEX}	40	60	80	100	120	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	100	120	Vdc
Emitter-Base Voltage	V_{EB}	20	30	40	50	60	Vdc
Collector Current-Continuous	I_C	5.0					Adc
Peak	I_C	10					Adc
Total Device Dissipation @T_C = 25° C	P_D	106					Watts
Operating Junction Temperature Range	T_J	-65 to +110					°C

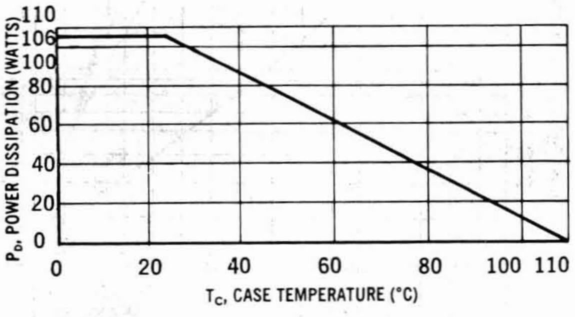
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	°C/W

The maximum continuous power is related to maximum junction temperature, by the thermal resistance factor. For d. c. or frequencies below 25 cps the transistor must be operated within the constant P_D = Vc x Ic hyperbolic curve. This curve has a value of 106 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that

$$P_D \text{ allowable} = \frac{110^{\circ} - Tc}{0.8}$$

POWER-TEMPERATURE DERATING CURVE



ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage‡		BV_{CEO}‡			volts
(I_C = 500 mAdc, I_B = 0)	2N1539, 2N1544		20	-	
	2N1540, 2N1545		30	-	
	2N1541, 2N1546		40	-	
	2N1542, 2N1547		50	-	
	2N1543, 2N1548		60	-	
Collector-Emitter Breakdown Voltage‡		BV_{CES}‡			volts
(I_C = 500 mAdc, V_{BE} = 0)	2N1539, 2N1544		30	-	
	2N1540, 2N1545		45	-	
	2N1541, 2N1546		60	-	
	2N1542, 2N1547		75	-	
	2N1543, 2N1548		90	-	
Collector-Base Breakdown Voltage		BV_{CBO}			volts
(I_C = 20 mAdc, I_E = 0)	2N1539, 2N1544		40	-	
	2N1540, 2N1545		60	-	
	2N1541, 2N1546		80	-	
	2N1542, 2N1547		100	-	
	2N1543, 2N1548		120	-	
Collector Cutoff Current (V_{CE} @ rated V_{CB}, V_{BE} = 1.0 Vdc)		I_{CEX}	-	20	mA
Collector Cutoff Current		I_{CBO}			mA
(V_{CB} = 2.0 Vdc, I_E = 0)			-	0.2	
(V_{CB} = 1/2 V_{CES} rating, T_C = 90°C)			-	20	
Collector Cutoff Current		I_{CBO1}			mA
(V_{CB} = 25 Vdc, I_E = 0)	2N1539, 2N1544		-	2.0	
(V_{CB} = 40 Vdc, I_E = 0)	2N1540, 2N1545		-	2.0	
(V_{CB} = 55 Vdc, I_E = 0)	2N1541, 2N1546		-	2.0	
(V_{CB} = 65 Vdc, I_E = 0)	2N1542, 2N1547		-	2.0	
(V_{CB} = 80 Vdc, I_E = 0)	2N1543, 2N1548		-	2.0	

ON CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
DC Current Gain		h_{FE1}			-
(I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	2N1539-2N1542		50	100	
	2N1544-2N1547		75	150	
	2N1543		50	100	
	2N1548		75	150	
DC Transconductance		g_{FE}			mhos
(I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	2N1539-2N1542		3.0	-	
	2N1544-2N1547		5.0	-	
	2N1543		3.0	-	
	2N1548		5.0	-	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			volts
(I_C = 3.0 Adc, I_B = 300 mAdc)	2N1539-2N1542		-	0.3	
	2N1544-2N1547		-	0.2	
	2N1543		-	0.3	
	2N1548		-	0.2	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			volts
(I_C = 3.0 Adc, I_B = 300 mAdc)	2N1539-2N1542		-	0.7	
	2N1544-2N1547		-	0.5	
	2N1543		-	0.7	
	2N1548		-	0.5	

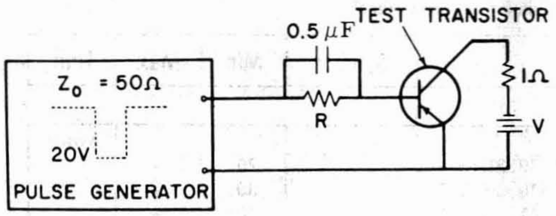
DYNAMIC CHARACTERISTICS

Characteristic	Symbol	Typ	Unit
Common-Emitter Cutoff Frequency (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	$f_{\alpha e}$	4.0	kHz

Characteristics apply to corresponding A type numbers also.

‡To avoid excessive heating of collector junction, perform this test with a sweep method.

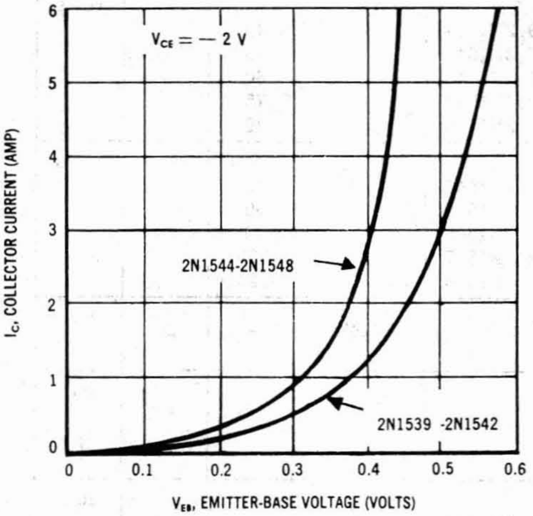
SWITCHING TIME MEASURING UNIT



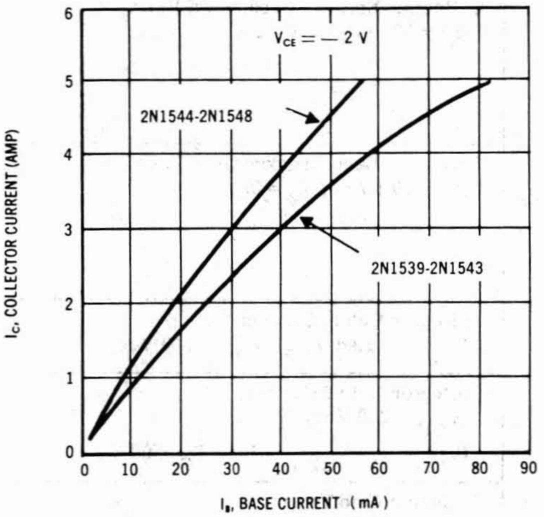
Devices	Conditions*			Typical Switching Times		
	I_C (Amp)	V (Volts)	R (ohms)	$t_d + t_r$ (μs)	t_s (μs)	t_f (μs)
2N1539-43	3	3	165	5	3	5
2N1544-48	3	3	250	5	3	8

*Input Pulse Repetition Rate = 2 kHz,
Pulse Width = 50 μs

COLLECTOR CURRENT versus EMITTER BASE VOLTAGE



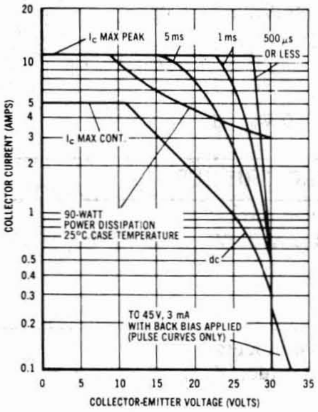
COLLECTOR CURRENT versus BASE CURRENT



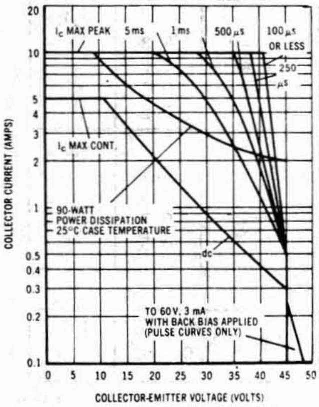
SAFE OPERATING AREAS

The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

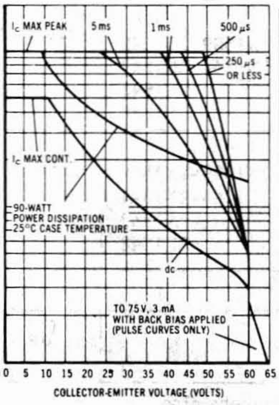
2N1539, 2N1544



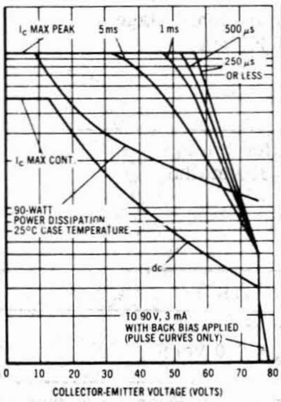
2N1540, 2N1545



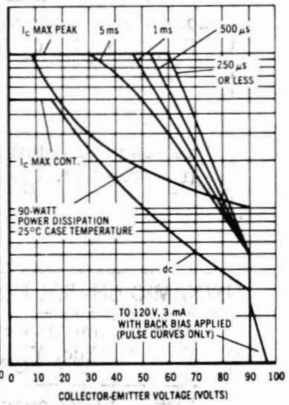
2N1541, 2N1546



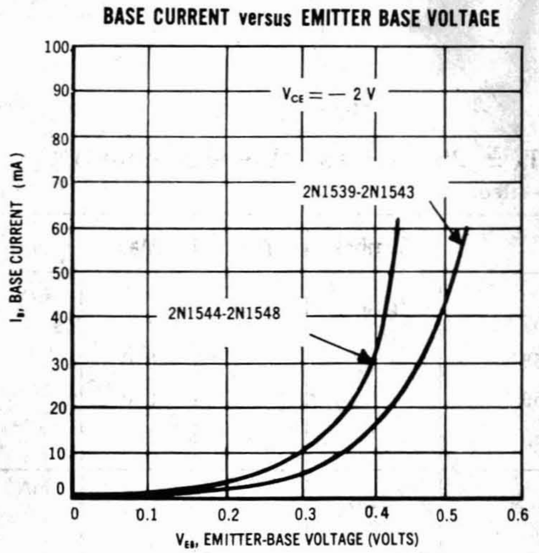
2N1542, 2N1547

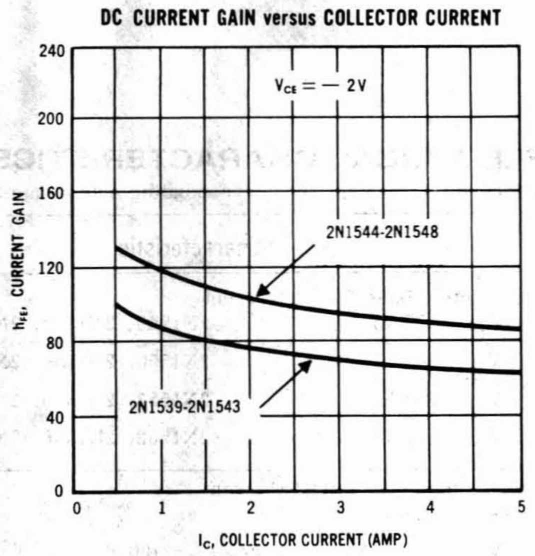


2N1543, 2N1548



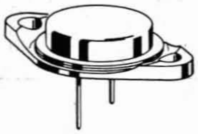
2N1539 thru 2N1548 (continued)


BASE CURRENT versus EMITTER BASE VOLTAGE

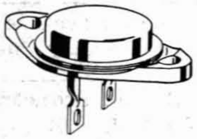

DC CURRENT GAIN versus COLLECTOR CURRENT

2N1549, A thru 2N1560, A (GERMANIUM)

PNP germanium power transistors for switching and amplifier applications in high-reliability equipment.


CASE 11A
(TO-3 modified)

For units with solder lugs attached, specify devices MP1549, A etc. (TO-41 package)


CASE 4-04
(TO-41)

MAXIMUM RATINGS Apply to corresponding "Hi-Rel" Series also

Rating	Symbol	2N1549 2N1553 2N1557	2N1550 2N1554 2N1558	2N1551 2N1555 2N1559	2N1552 2N1556 2N1560	Units
Collector-Emitter Voltage	V_{CEX}	40	60	80	100	Vdc
Collector-Emitter Voltage	V_{CES}*	30	45	60	75	Vdc
Collector-Emitter Voltage	V_{CEO}*	20	30	40	50	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	100	Vdc
Emitter-Base Voltage	V_{EB}	20	30	40	50	Vdc
Collector Current (Continuous)	I_C	15				Amp
Collector Current (Peak)	I_C	20				Amp
Collector Junction Temperature	T_J	-65 to +110				°C
Collector Dissipation (25°C Case Temp.)	P_D	106				Watts
Thermal Resistance	θ_{JC}	0.8				°C/W

*To avoid excessive heating of collector junction, perform this test with a sweep method.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristics apply to corresponding A type numbers also.

Characteristic	Symbol	Min	Max	Unit
Collector-Base Cutoff Current	I_{CBO1}			mA
(V_{CB} = 25 V) 2N1549, 2N1553, 2N1557		-	3.0	
(V_{CB} = 40 V) 2N1550, 2N1554, 2N1558		-	3.0	
(V_{CB} = 55 V) 2N1551, 2N1555, 2N1559		-	3.0	
(V_{CB} = 65 V) 2N1552, 2N1556, 2N1560		-	3.0	
Collector-Base Cutoff Current	I_{CBO}			mA
(V_{CB} = 2 V)		-	0.2	
(V_{CB} = 1/2 BV_{CES} rating; T_C = +90°C)		-	20	
Emitter-Base Cutoff Current (V_{EB} = 12 V)	I_{EBO}	-	0.5	mA
Collector-Emitter Breakdown Voltage (I_C = 300 mA)	BV_{CES}			volts
2N1549, 2N1553, 2N1557		30	-	
2N1550, 2N1554, 2N1558		45	-	
2N1551, 2N1555, 2N1559		60	-	
2N1552, 2N1556, 2N1560		75	-	
Collector-Emitter Leakage Current (V_{BE} = 1.0 V, V_{CE} @ rated BV_{CBO})	I_{CEX}	-	20	mA
Collector-Emitter Breakdown Voltage* (I_C = 300 mA, I_B = 0)	BV_{CEO}*			volts
2N1549, 2N1553, 2N1557		20	-	
2N1550, 2N1554, 2N1558		30	-	
2N1551, 2N1555, 2N1559		40	-	
2N1552, 2N1556, 2N1560		50	-	
Collector-Base Breakdown Voltage (I_C = 20 mA)	BV_{CBO}			volts
2N1549, 2N1553, 2N1557		40	-	
2N1550, 2N1554, 2N1558		60	-	
2N1551, 2N1555, 2N1559		80	-	
2N1552, 2N1556, 2N1560		100	-	
Current Gain (V_{CE} = 2.0 V, I_C = 10 A)	h_{FE1}			-
2N1549 - 2N1552		10	30	
2N1553 - 2N1556		30	60	
2N1557 - 2N1560		50	100	
Base-Emitter Drive Voltage (I_C = 10 A, I_B = 1.0 A)	V_{BE}			volts
2N1549 - 2N1552		-	1.3	
2N1553 - 2N1556		-	1.0	
2N1557 - 2N1560		-	0.7	
Collector Saturation Voltage (I_C = 10 A, I_B = 1.0 A)	$V_{CE(sat)}$			volts
2N1549 - 2N1552		-	1.0	
2N1553 - 2N1556		-	0.7	
2N1557 - 2N1560		-	0.5	

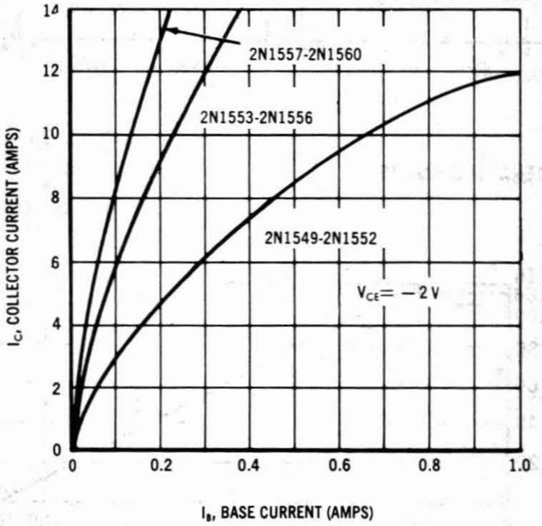
*To avoid excessive heating of collector junction, perform this test with a sweep method.

2N1549 thru 2N1560 (continued)

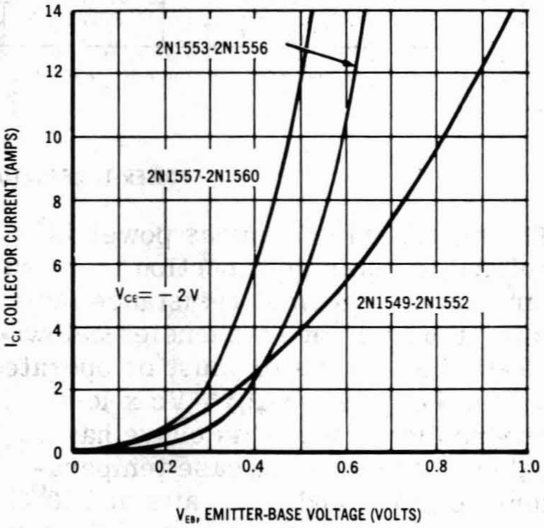
ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Max	Unit
Transconductance (V_{CE} = 2.0 V, I_C = 10 A)	g_{FE}			mhos
2N1549 - 2N1552		6.0	18	
2N1553 - 2N1556		8.0	30	
2N1557 - 2N1560		12	40	
Frequency Cutoff	f_{ae}	Typ		kHz
2N1549 - 2N1552		10		
2N1553 - 2N1556		6.0		
2N1557 - 2N1560		5.0		

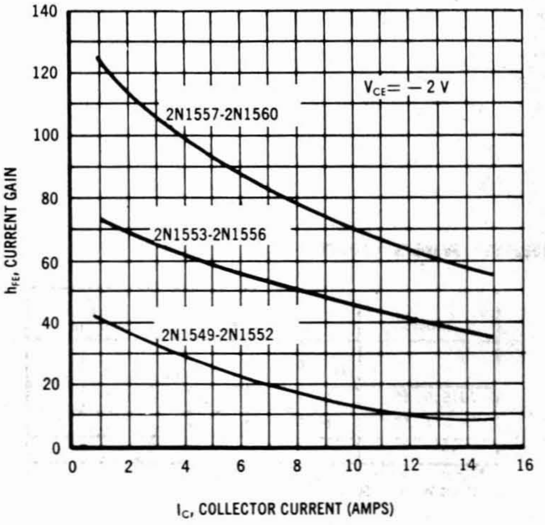
COLLECTOR CURRENT versus BASE CURRENT



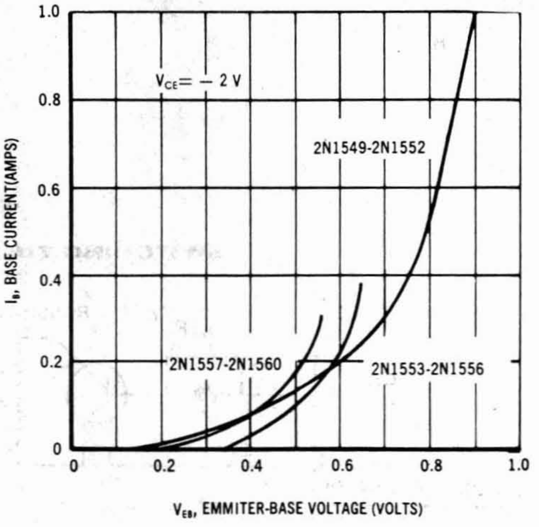
COLLECTOR CURRENT versus EMITTER-BASE VOLTAGE



CURRENT GAIN versus COLLECTOR CURRENT



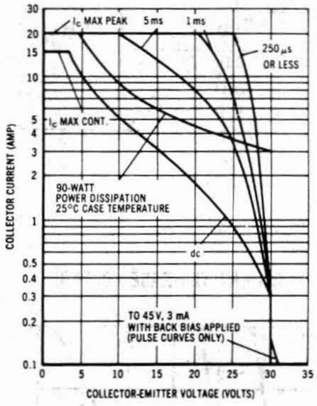
BASE CURRENT versus EMITTER-BASE VOLTAGE



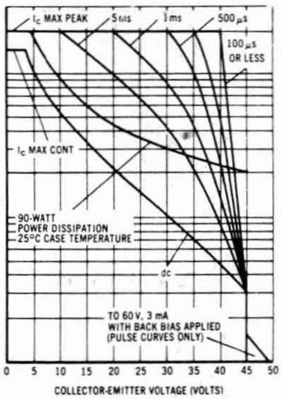
SAFE OPERATING AREAS

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

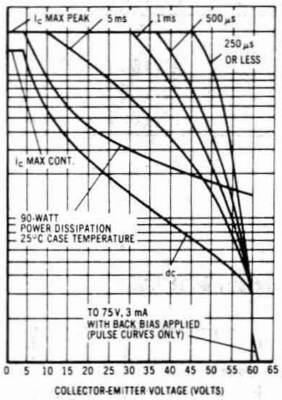
2N1549, 2N1553, 2N1557



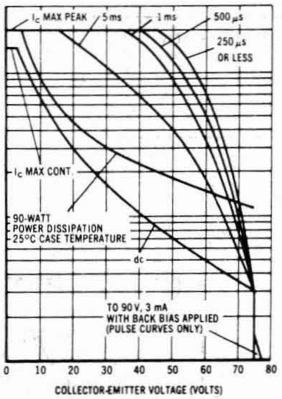
2N1550, 2N1554, 2N1558



2N1551, 2N1555, 2N1559



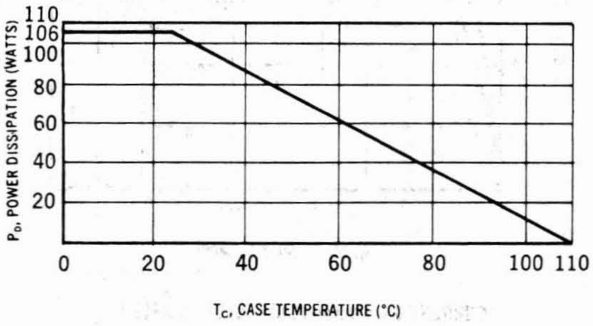
2N1552, 2N1556, 2N1560



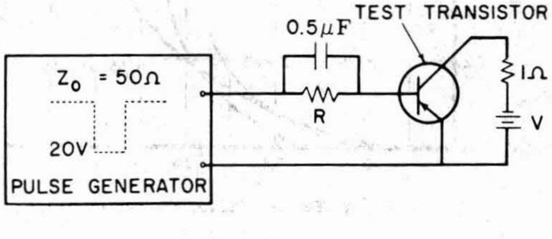
POWER-TEMPERATURE DERATING CURVE

The maximum continuous power is related to maximum junction temperature, by the thermal resistance factor. For dc or frequencies below 25 Hz the transistor must be operated within the constant $P_D = V_C \times I_C$ hyperbolic curve. This curve has a value of 106 watts at case temperatures of 25°C and is 0 watts at 110°C with a linear relation between the two temperatures such that P_D allowable

$$= \frac{110^{\circ} - T_C}{0.8}$$



SWITCHING TIME MEASURING UNIT



Devices	Conditions*			Typical Switching Times		
	I_C (Amp)	V (Volts)	R (ohms)	$t_d + t_r$ (μs)	t_s (μs)	t_f (μs)
2N1549 -52	10	10	10	5	2	10
2N1553 -56	10	10	30	10	5	25
2N1557 -60	10	10	50	10	5	25

* Input Pulse Repetition Rate = 2 kHz, Pulse Width = 50 μs

2N1561 (GERMANIUM)
2N1562
2N1692
2N1693

PNP germanium mesa transistors for VHF power amplifier applications.

Collector connected to case;
stud isolated from case

CASE 23
(TO-107)
2N1561
2N1562

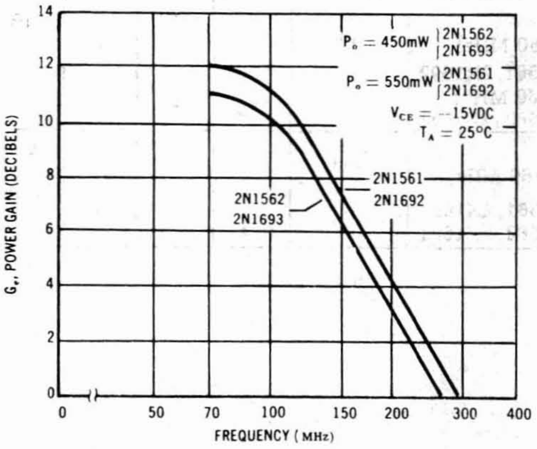
CASE 24
(TO-102)
2N1692
2N1693

MAXIMUM RATINGS

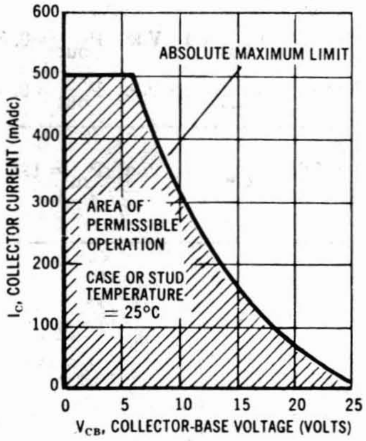
Rating	Symbol	2N1561	2N1562	2N1692	2N1693	Unit
Collector-Emitter Voltage	V_{CE}	25	25	25	25	Vdc
Collector-Base Voltage	V_{CB}	25	25	25	25	Vdc
Emitter-Base Voltage*	V_{EB}*	3	2	3	2	Vdc
Collector Current-Continuous Peak	I_C	250 500	250 500	250 500	250 500	mAdc
Total Device Dissipation @ $T_A = 25^{\circ}C$ Derate above $25^{\circ}C$	P_D	250 3.33	250 3.33	350 4.67	350 4.67	mW mW/°C
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above $25^{\circ}C$	P_D	3 40	3 40	3 40	3 40	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to 100				°C

*May be exceeded provided total rated device dissipation is not exceeded.

POWER GAIN versus FREQUENCY



SAFE OPERATING AREA

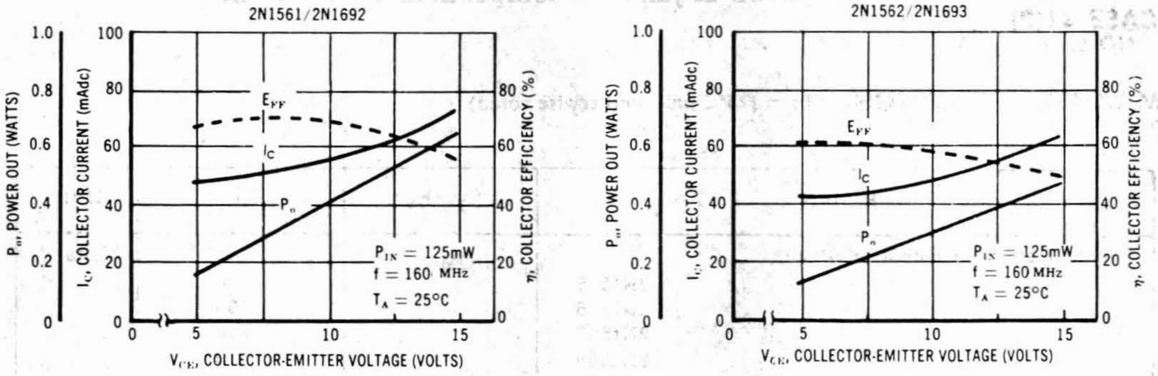


2N1561, 2N1562, 2N1692, 2N1693 (continued)

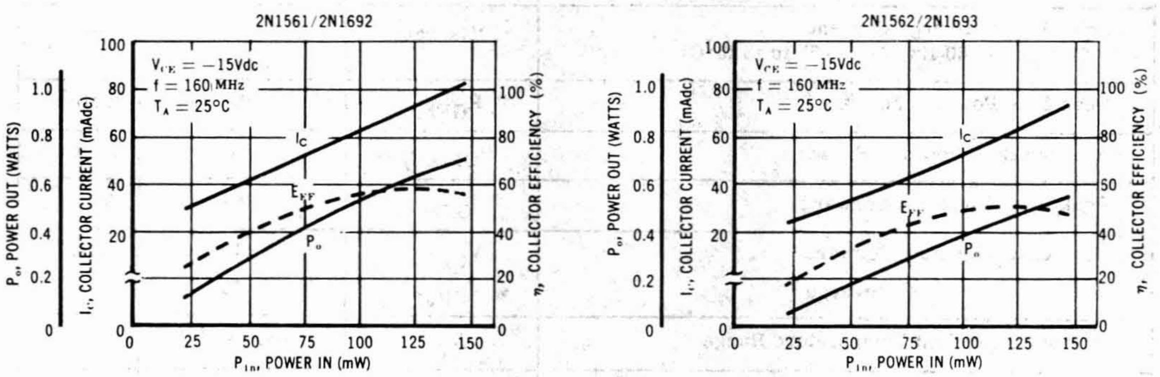
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)		BV_{CES}	25	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	25	-	-	Adc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)		I_{CBO}	-	1.5	10	μAdc
Emitter Cutoff Current (V_{BE} = 0.4 Vdc, I_C = 0)	2N1562, 2N1693	I_{EBO}	-	5.0	-	mAdc
(V_{BE} = 1.0 Vdc, I_C = 0)	2N1561, 2N1692		-	5.0	-	
ON CHARACTERISTICS						
Collector-Emitter Saturation Voltage (I_C = 200 mAdc, I_B = 40 mAdc)	2N1561, 2N1692	$V_{CE(sat)}$	-	-	3.0	Vdc
(I_C = 200 mAdc, I_B = 40 mAdc)	2N1562, 2N1693		-	-	4.0	
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N1561, 2N1692	f_T	-	500	-	MHz
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N1562, 2N1693		-	450	-	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	7	10	pF
Small-Signal Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 160 MHz)	2N1561, 2N1692	h_{fe}	-	10	-	dB
	2N1562, 2N1693		-	9	-	
Extrinsic Base Resistance (I_E = 20 mAdc, V_{CB} = 10 Vdc, f = 300 MHz)		r'_b	-	25	-	Ohms
FUNCTIONAL TEST						
Power Gain (I_C = 100 mAdc, V_{CE} = 15 Vdc, P_{out} = 0.5 W, f = 160 MHz)	2N1561, 2N1692	G_{pe}	6	-	-	dB
(I_C = 100 mAdc, V_{CE} = 15 Vdc, P_{out} = 0.4 W, f = 160 MHz)	2N1562, 2N1693		5	-	-	
Power Output (I_C = 100 mAdc, V_{CE} = 15 Vdc, P_{in} = 125 mW, f = 160 MHz)	2N1561, 2N1692	P_{out}	0.5	-	-	Watt
	2N1562, 2N1693		0.4	-	-	

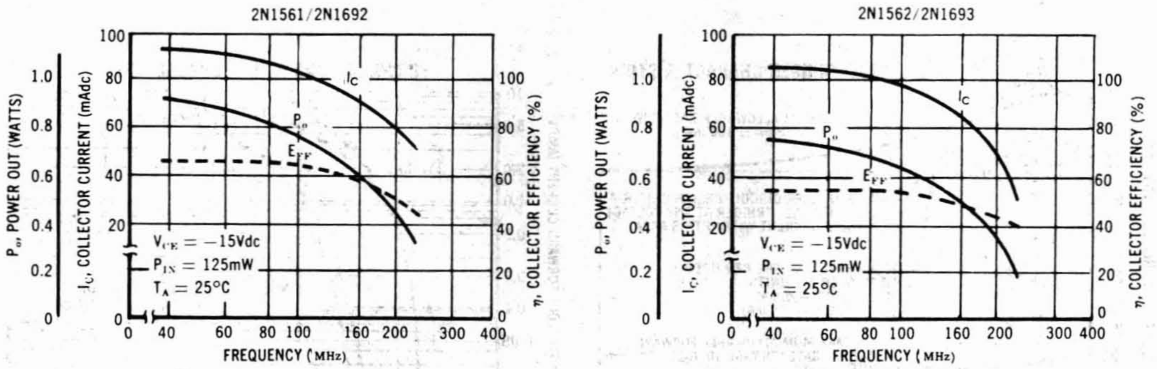
POWER OUT, COLLECTOR CURRENT AND COLLECTOR EFFICIENCY versus COLLECTOR-EMITTER VOLTAGE



POWER OUT, COLLECTOR CURRENT AND COLLECTOR EFFICIENCY versus POWER IN



POWER OUT, COLLECTOR CURRENT AND COLLECTOR EFFICIENCY versus FREQUENCY



2N1595 thru 2N1599 (SILICON)

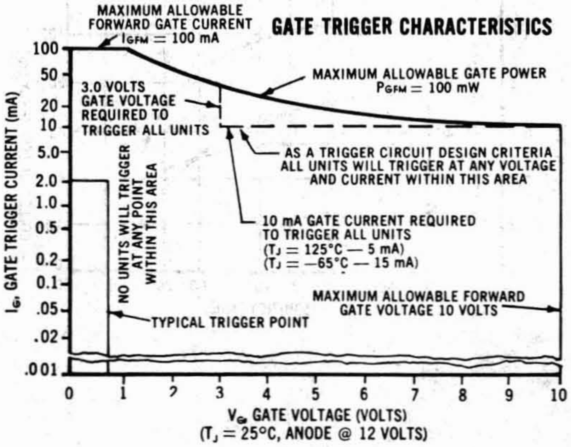
CASE 31(2)
(TO-5)

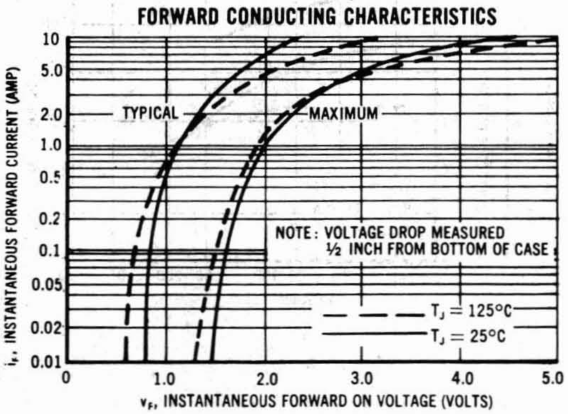
Industrial-type, low-current silicon controlled rectifiers in a three-lead package ideal for printed-circuit applications. Current handling capability of 1.6 amperes at junction temperatures to 125°C.

MAXIMUM RATINGS (TJ = 125°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage* 2N1595 2N1596 2N1597 2N1598 2N1599	$V_{ROM(rep)}$*	 50 100 200 300 400	Volts
Forward Current RMS (All Conduction Angles)	I_f	1.6	Amp
Peak Forward Surge Current (One Cycle, 60 Hz, T_J = -65 to +125°C)	$I_{FM(surge)}$	15	Amp
Peak Gate Power - Forward	P_{GFM}	0.1	Watt
Average Gate Power - Forward	$P_{GF(AV)}$	0.01	Watt
Peak Gate Current - Forward	I_{GFM}	0.1	Amp
Peak Gate Voltage - Forward Reverse	V_{GFM} V_{GRM}	10 10	Volts
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

*V_{ROM} for all types can be applied on a continuous dc basis without incurring damage.


GATE TRIGGER CHARACTERISTICS


FORWARD CONDUCTING CHARACTERISTICS

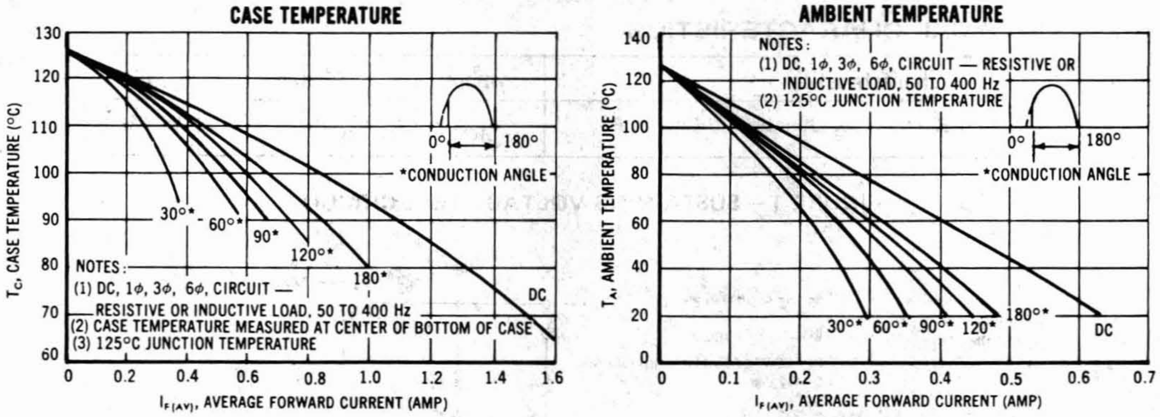
2N1595 thru 2N1599 (continued)

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage* (T_J = 125°C)	2N1595 2N1596 2N1597 2N1598 2N1599	V_{FOM}*	50 100 200 300 400	— — — — —	— — — — —	Volts
Peak Forward Blocking Current (Rated V_{FOM} with gate open, T_J = 125°C)		I_{FOM}	—	—	1.0	mA
Peak Reverse Blocking Current (Rated V_{ROM}, T_J = 125°C)		I_{ROM}	—	—	1.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 12 Ω)		I_{GT}	—	2.0	10.0	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 12 Ω)		V_{GT}	—	0.7	3.0	Volts
(Anode Voltage = Rated V_{FOM}, R_L = 12Ω, T_J = 125°C)		V_{GNT}	0.2	—	—	
Holding Current (Anode Voltage = 7 Vdc, Gate Open)		I_{HO}	—	5.0	—	mA
Forward On Voltage (I_F = 1 Adc)		V_F	—	1.1	2.0	Volts
Turn-On Time (t_d + t_r) (I_G = 10 mA, I_F = 1A)		t_{on}	—	0.8	—	μs
Turn-Off Time (I_F = 1 A, I_R = 1 A, dv/dt = 20 V/μs, T_J = 125°C) (V_{FXM} = rated voltage) (V_{RXM} = rated voltage)		t_{off}	—	10	—	μs

*V_{FOM} for all types can be applied on a continuous dc basis without incurring damage.

CURRENT DERATING

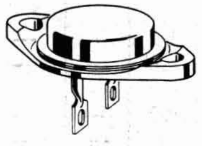


2N1613 (SILICON)

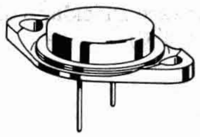
For Specifications, See 2N718A Data.

2N1651 thru 2N1653 (Germanium)

2N2285 thru 2N2287 (Germanium)



CASE 161
(TO-41)
2N1651 thru 2N1653
Collector connected to case



CASE 3A
(TO-3 modified)
2N2285 thru 2N2287

PNP Germanium power transistors designed for high-current switching applications requiring low saturation voltages and fast switching times in addition to good safe operating area.

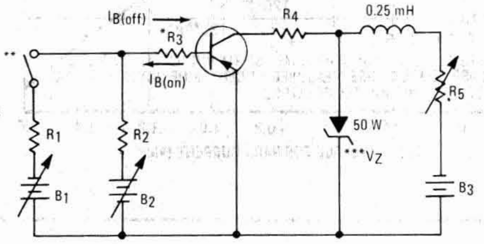
MAXIMUM RATINGS

Rating	Symbol	2N1651 2N2285	2N1652 2N2286	2N1653 2N2287	Unit
Collector-Emitter Voltage	V_{CEO}	30	60	80	Vdc
Collector-Base Voltage	V_{CB}	60	100	120	Vdc
Emitter-Base Voltage	V_{EB}	←	1.5	→	Vdc
Collector Current - Continuous	I_C	←	25	→	Adc
Base Current - Continuous	I_B	←	5.0	→	Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	←	106 1.25	→	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	←	-65 to +110	→	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	°C/W

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT



R_1 = 1.0 Ohm, 20 Watts
R_2 = 7.5 Ohms, 2.0 Watts
R_3 = 0.1 Ohm, 1.0%
$R_4 \leq$ 0.04 Ohm

R_5: I_C Adjust @ $V_{CE} = V_Z$
B_1: Adjust for $I_{B(on)} = \frac{I_C}{10}$
B_2 = 1.5 Vdc, Adjust for $I_{B(off)}$ = 0.2 Adc
B_3 = 12 Vdc

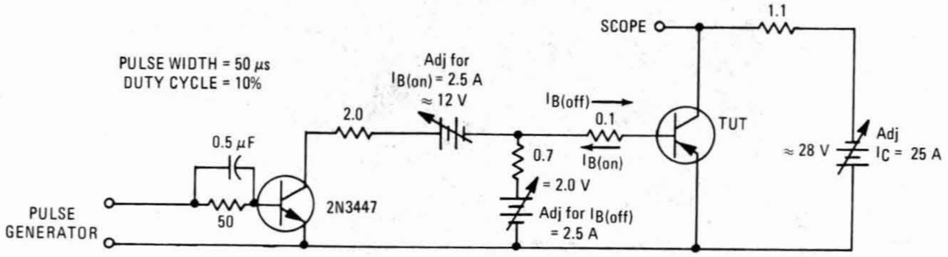
*Not required if current probe is used to read I_{B1}
**PRF ≈ 60 Hz
***Zener selected to establish Sustaining Voltage.
NOTE: Series impedance and inductance must be kept to a minimum.

2N1651 thru 2N1653/2N2285 thru 2N2287 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	2N1651, 2N2285 2N1652, 2N2286 2N1653, 2N2287	BV_{CEO}	30 60 80	- - -	Vdc
Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 25 Adc)	2N1651, 2N2285 2N1652, 2N2286 2N1653, 2N2287	$V_{CE(sus)}$	40 45 50	- - -	Vdc
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)		I_{CBO1}	-	200	µAdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0) (V_{CB} = 80 Vdc, I_E = 0) (V_{CB} = 100 Vdc, I_E = 0)	 2N1651, 2N2285 2N1652, 2N2286 2N1653, 2N2287	I_{CBO2}	- - -	5.0 5.0 5.0	mAdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0, T_C = 100°C) (+0, -3.0°C) (V_{CB} = 80 Vdc, I_E = 0, T_C = 100°C) (+0, -3.0°C) (V_{CB} = 100 Vdc, I_E = 0, T_C = 100°C) (+0, -3.0°C)	 2N1651, 2N2285 2N1652, 2N2286 2N1653, 2N2287	I_{CBO3}	- - -	35 35 35	mAdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) (V_{CB} = 100 Vdc, I_E = 0) (V_{CB} = 120 Vdc, I_E = 0)	 2N1651, 2N2285 2N1652, 2N2286 2N1653, 2N2287	I_{CBO4}	- - -	20 20 20	mAdc
Emitter Cutoff Current (V_{EB} = 1.5 Vdc, I_C = 0)		I_{EBO}	-	50	mAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 10 Adc, V_{CE} = 2.0 Vdc) (I_C = 25 Adc, V_{CE} = 1.5 Vdc)		h_{FE}	35 20	140 -	-
Collector-Emitter Saturation Voltage (I_C = 25 Adc, I_B = 2.5 Adc)		$V_{CE(sat)}$	-	0.30	Vdc
Base-Emitter Saturation Voltage (I_C = 25 Adc, I_B = 2.5 Adc)		$V_{BE(sat)}$	-	0.65	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)		h_{fe}	20	-	-
SWITCHING CHARACTERISTICS					
Rise Time	(I_C = 25 Adc, $I_{B(on)}$ = 2.5 Adc, $I_{B(off)}$ = 2.5 Adc) (See Figure 2)	t_r	-	12	µs
Storage Time		t_s	-	10	µs
Fall Time		t_f	-	8.0	µs

FIGURE 2 – SWITCHING TIME TEST CIRCUIT

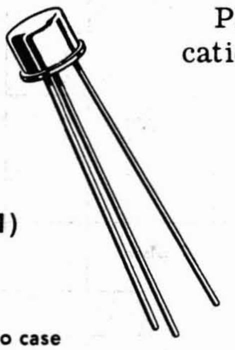


2N1692, 2N1693

For Specifications, See 2N1561 Data.

2N1705 thru 2N1707 (GERMANIUM)

PNP germanium transistors for audio driver applications in transistorized radio receivers.



CASE 31(1)
(TO-5)

Base connected to case

MAXIMUM RATINGS

Rating	Symbol	2N1705	2N1706	2N1707	Unit
Collector-Base Voltage	V_{CB}	18	25	30	Volts
Collector-Emitter Voltage (R_{BE} = 1 K)	V_{CER}	12	18	25	Volts
Emitter-Base Voltage	V_{EB}	5.0	5.0	10	Volts
Collector Current	I_C	400			mA
Collector Dissipation at T_C = 25 °C	P_D	200			mW
Junction Temperature Range	T_J	-65 to +100			°C

2N1705 thru 2N1707 (continued)

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current		I_{CBO}				μAdc
(V_{CB} = -10 Vdc)	2N1705		---	5.0	10	
	2N1706		---	---	10	
(V_{CB} = -25 Vdc)	2N1707		---	---	15	
Emitter-Base Cutoff Current		I_{EBO}				μAdc
(V_{EB} = -5 Vdc)	2N1705		---	4.0	20	
	2N1706		---	---	20	
(V_{EB} = -10 Vdc)	2N1707		---	---	10	
Collector-Emitter Voltage		BV_{CER}				Vdc
(I_C = 1 mAdc, R_{BE} = 1 K)	2N1705		12	---	---	
	2N1706		18	---	---	
	2N1707		25	---	---	
Base-Emitter Voltage		V_{BE}				V
(I_C = 10 mA, V_{CE} = 5 V)	2N1706		0.15	---	0.35	
(I_C = 20 mA, V_{CE} = 1 V)	2N1705		0.2	---	0.4	
DC Current Gain		h_{FE}				---
(I_C = 10 mAdc, V_{CE} = -5 V)	2N1707		40	90	150	
(I_C = 20 mAdc, V_{CE} = -1 V)	2N1706		60	---	120	
Small Signal Current Gain		h_{fe}				---
(I_C = 1 mA, V_{CE} = -6 V, f = 1 kHz)	2N1705		70	110	150	
(I_C = 10 mA, V_{CE} = -5 V, f = 1 kHz)	2N1706		50	90	150	
	2N1707		30	---	150	
Output Admittance Conductance		h_{ob}				μmhos
(I_C = 1 mA, V_{CB} = -6 V, f = 1 kHz)	2N1705		---	0.5	---	
(I_C = 10 mA, V_{CE} = -5 V, f = 1 kHz)	2N1706, 2N1707		---	3.0	---	
Input Impedance		h_{ib}				ohms
(I_C = 1 mA, V_{CE} = -6 V, f = 1 kHz)	2N1705		---	30	---	
(I_C = 10 mA, V_{CE} = -5 V, f = 1 kHz)	2N1706, 2N1707		---	4.0	---	
Voltage Feedback Ratio						
(I_C = 1 mA, V_{CB} = -6 V, f = 1 kHz)	2N1705	h_{rb}	---	3.0	---	$X10^{-4}$
(I_C = 10 mA, V_C = -5 V, f = 1 kHz)	2N1706	h_{re}	---	0.69	---	$X10^{-3}$
	2N1707	h_{rb}	---	4.5	---	$X10^{-4}$
Frequency Cutoff		$f_{\alpha b}$				MHz
(I_C = 1 mA, V_C = -6 V)	2N1706, 2N1707		---	3.0	---	
	2N1705		---	4.0	---	
Output Capacitance		C_{ob}				pF
(I_C = 1 mA, V_{CB} = -6 V, f = 1 MHz)			---	20	---	
Noise Figure		NF				dB
(I_C = 1 mA, V_{CB} = -6 V, R_s = 1 K, f = 1 kHz)	2N1705		---	6.0	---	

2N1708 (SILICON)

CASE 26
(TO-46)

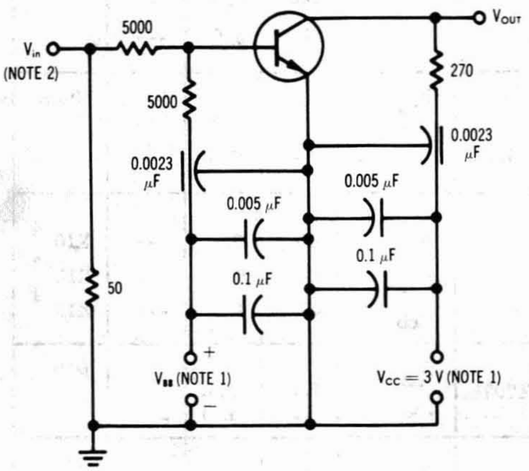
Collector electrically
connected to case

NPN silicon transistor designed for very high-speed, low-power saturated switching applications for computers in military and industrial service.

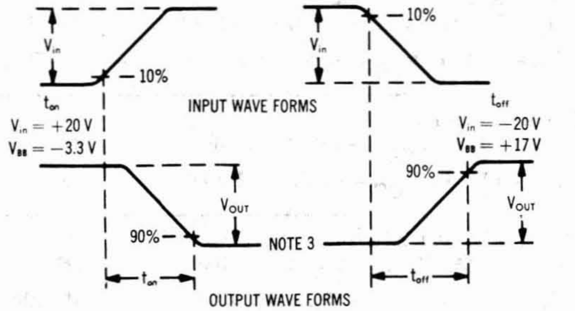
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 2.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.0 6.67	Watt mW/°C
Operating Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT



V_OUT
5000
V_in
(NOTE 2)
5000
270
0.0023 µF
0.0023 µF
0.005 µF
0.005 µF
0.1 µF
0.1 µF
50
+
V_BB (NOTE 1)
−
V_CC = 3 V (NOTE 1)



V_in
10%
t_on
V_in = +20 V
V_BB = −3.3 V
INPUT WAVE FORMS
10%
V_in
t_off
V_in = −20 V
V_BB = +17 V
V_OUT
90%
NOTE 3
90%
V_OUT
t_on
t_off
OUTPUT WAVE FORMS

NOTE 1: With certain types of power supplies, it may be necessary to connect 25 µF decoupling capacitors across the power-supply terminals for V_{CC} and V_{BB}.

NOTE 2: Input voltage (V_{in}) obtained from a pulse generator having an output impedance of 50 ohms. V_{in} rise time ≦ 1.0 ns, pulse duration ≧ 300 ns, and duty factor ≦ 2.0%.

NOTE 3: Input and output waveforms, shown above, monitored by means of an oscilloscope having a rise time ≦ 0.5 ns, input capacitance of probe ≦ 2.5 pF with shunt resistance ≧ 3000 ohms.

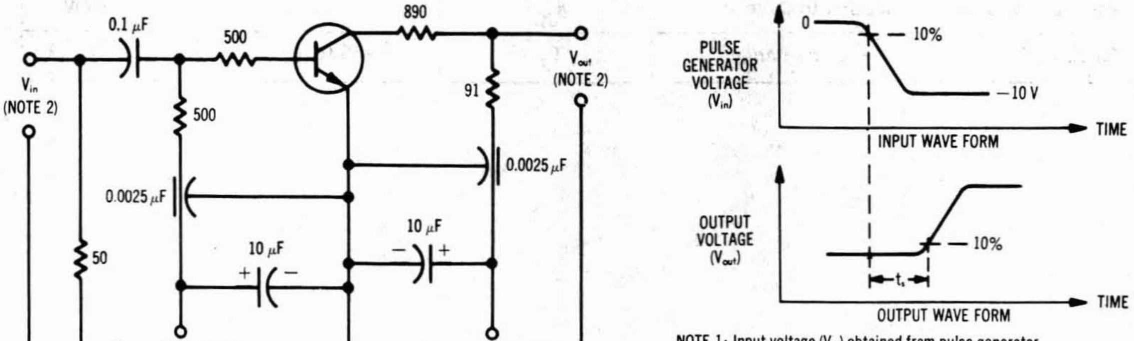
2N1708 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	12	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	25	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3.0	-	Vdc
Collector-Cutoff Current (V_{CE} = 10 Vdc, V_{BE} = 0.25 Vdc, T_A = 100°C)	I_{CEX}	-	15	μAdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.025 15	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	20	-	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$	- -	0.22 0.35	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	0.7	0.9	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	200	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	6.0	pF
Turn-On Time (Figure 1) (I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc)	t_{on}	-	40	ns
Turn-Off Time (Figure 1) (V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc)	t_{off}	-	75	ns
Storage Time (Figure 2) (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc)	t_s	-	25	ns

* Pulse Test: Pulse Length ≦ 6.0 ms, Duty Cycle ≦ 30%.

FIGURE 2 — STORAGE TIME TEST CIRCUIT



0.1 μF
500
890
Vin
(NOTE 2)
Vout
(NOTE 2)
500
91
0.0025 μF
0.0025 μF
10 μF
10 μF
50
VBB = 11 V (NOTE 1)
VCC = 10 V (NOTE 1)
PULSE GENERATOR VOLTAGE (Vin)
0
10%
−10 V
TIME
INPUT WAVE FORM
OUTPUT VOLTAGE (Vout)
10%
ts
TIME
OUTPUT WAVE FORM

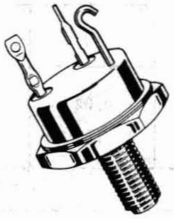
NOTE 1: Input voltage (V_{in}) obtained from pulse generator having an output impedance of 50 ohms. V_{in} rise time < 1 ns, pulse duration ≧ 300 ns, and duty factor ≦ 2.0%.

NOTE 2: Input and output wave forms monitored by means of an oscilloscope having a rise time ≦ 0.5 ns; input capacitance of probe ≦ 2.5 pF with shunt resistance ≧ 1000 ohms.

2N1711

For Specifications, See 2N718A Data.

2N1724 (SILICON)
2N1725



CASE 9
(TO-61)

NPN silicon power transistors designed for switching and amplifier applications.

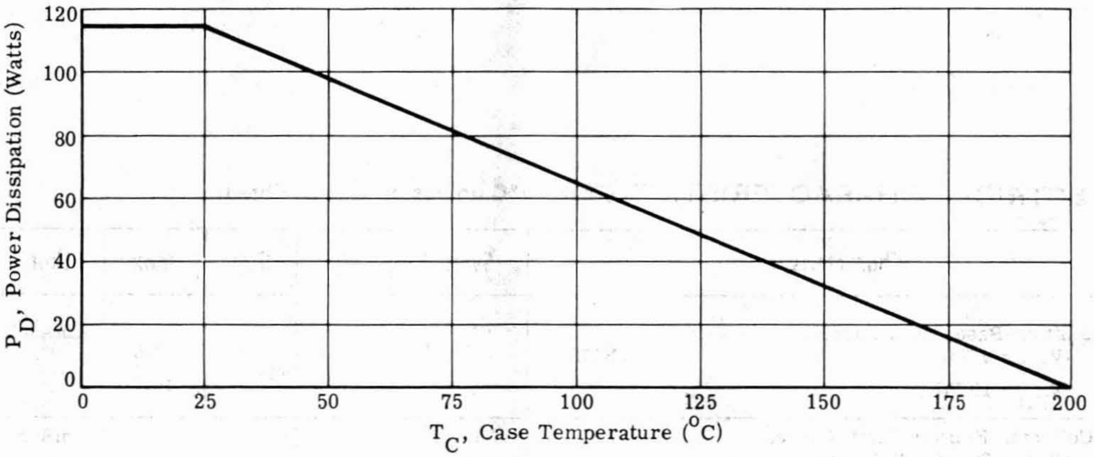
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	120	Vdc
Collector-Emitter Voltage	V_{CE}	80	Vdc
Emitter-Base Voltage	V_{EB}	10	Vdc
Collector Current (Continuous)	I_C	5.0	Adc
Power Dissipation	P_D	117	Watts
Thermal Resistance, Junction to Case	θ_{JC}	1.5	°C/W
Junction Operating Temperature Range	T_J	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Emitter-Base Cutoff Current	I_{EBO}				mAdc
(V_{EB} = 9 Vdc) 2N1725		-	-	0.5	
(V_{EB} = 10 Vdc)		-	-	10.0	
Collector-Emitter Cutoff Current	I_{CES}				mAdc
(V_{CE} = 60 Vdc, V_{BE} = 0)		-	-	1.0	
(V_{CE} = 60 Vdc, V_{BE} = 0, T_C = 150°C)		-	-	2.0	
(V_{CE} = 120 Vdc, V_{BE} = 0, T_C = 150°C)		-	-	10.0	
Collector-Base Cutoff Current (V_{CB} = 3 Vdc, I_E = 0)	I_{CBO}	-	-	0.1	mAdc
Collector-Emitter Sustaining Voltage (I_C = 200 mAdc, I_B = 0)	$V_{CEO(sus)}$	80	-	-	Vdc
DC Current Gain	h_{FE}				
(V_{CE} = 15 Vdc, I_C = 2 Adc) 2N1724		20	40	90	
2N1725		50	90	150	
(V_{CE} = 15 Vdc, I_C = 2 Adc, T_A = -55°C) 2N1724		12	-	-	
2N1725		25	-	-	
(V_{CE} = 15 Vdc, I_C = 0.1 Adc) 2N1724		20	-	-	
2N1725		50	-	-	
Collector-Emitter Saturation Voltage (I_C = 2 Adc, I_B = 200 mAdc)	$V_{CE(sat)}$		0.5	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 2 Adc, I_B = 200 mAdc)	$V_{BE(sat)}$		1.2	2.0	Vdc
High Frequency Current Gain (V_{CE} = 15 Vdc, I_C = 0.5 Adc, f = 10 MHz)	h_{fe}	1.0	1.6	-	
Common Base Output Capacitance (V_{CB} = 10 Vdc, f = 0.1 MHz)	C_{ob}		260	550	pF
Switching Times (I_C = 2 Adc, I_{B1} = $-I_{B2}$ = 0.2 Adc)					µs
Delay time plus Rise time	$t_d + t_r$	-	0.15	-	
Storage time	t_s	-	1.3	-	
Fall time	t_f		0.14		

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



SAFE OPERATING AREAS

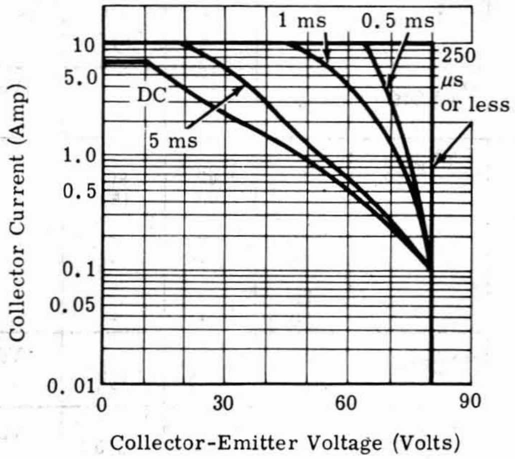
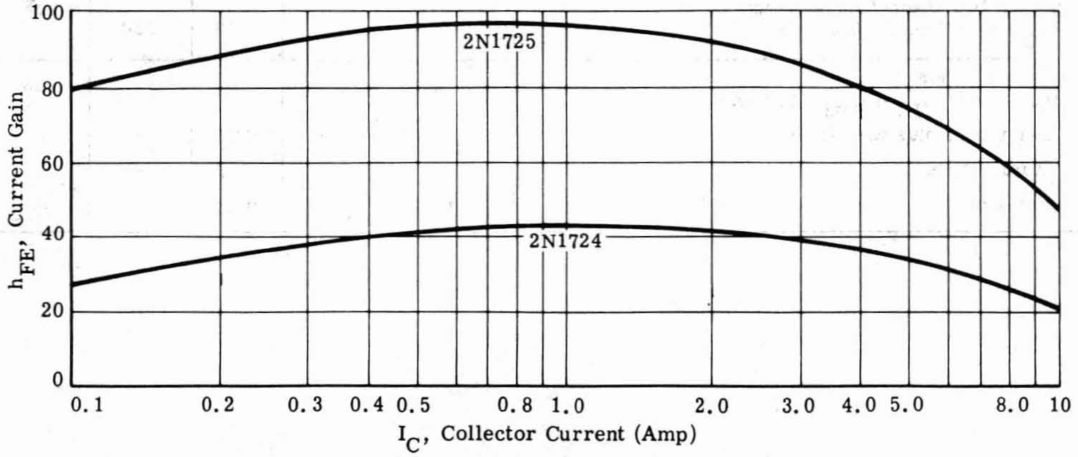


FIGURE 2 — 2N1724, 2N1725

In using these curves the average power derating curve (Fig. 1) must be observed to ensure operation below the maximum junction temperature.

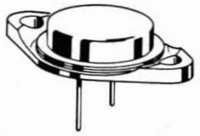
FIGURE 3 — DC CURRENT GAIN versus COLLECTOR CURRENT



2N1742

For Specifications, See 2N499 Data.

2N1751 (GERMANIUM)



Collector Connected to Case

CASE 3A

(TO-3 modified)

PNP Germanium power transistor designed for high-current switching applications requiring low saturation voltages, short switching times and good sustaining voltage capability.

- Alloy-Diffused Epitaxial Construction
- Low Saturation Voltages –
  $V_{CE(sat)}$ = 0.3 Vdc (Max) @ I_C = 20 Adc
  $V_{BE(sat)}$ = 0.7 Vdc (Max) @ I_C = 20 Adc

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
*Collector-Base Voltage	V_{CB}	80	Vdc
*Emitter-Base Voltage	V_{EB}	2.5	Vdc
*Collector Current - Continuous	I_C	25	Adc
Base Current - Continuous	I_B	5.0	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	106 1.25	Watts W/°C
*Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
*Thermal Resistance, Junction to Case	θ_{JC}	0.8	°C/W

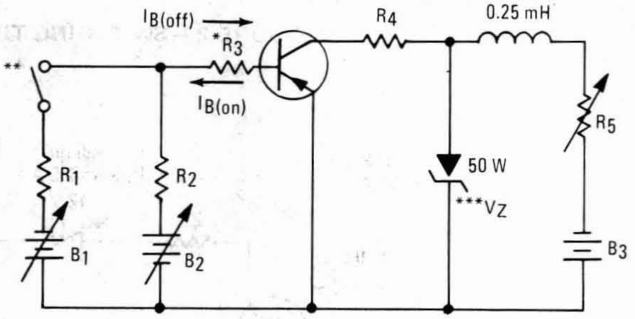
* Indicates JEDEC Registered Data.

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT

R_1 = 1.0 Ohm, 20 Watts
R_2 = 10 Ohms, 2.0 Watts
R_3 = 0.1 Ohm, 1.0%
$R_4 \leq$ 0.04 Ohm

R_5: I_C Adjust @ $V_{CE} = V_Z$
B_1: Adjust for $I_{B(on)} = \frac{I_C}{10}$
B_2 = 2.0 Vdc, Adjust for $I_{B(off)}$ = 0.2 Adc
B_3 = 12 Vdc

*Not required if current probe is used to read I_B
**PRF ≈ 60 Hz
***Zener selected to establish Sustaining Voltage.
NOTE: Series impedance and inductance must be kept to a minimum. Adjust input pulse width for I_C = 25 A condition.

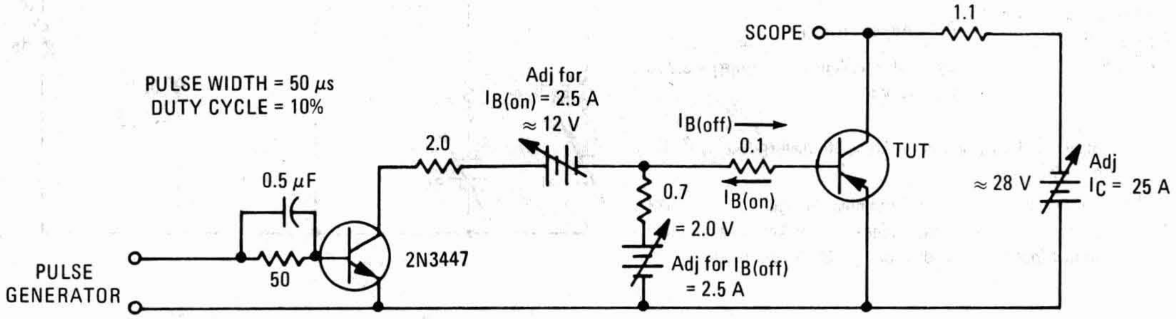


ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	BV_{CEO}	60	-	Vdc
Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 25 Adc)	$V_{CE(sus)}$	45	-	Vdc
*Floating Potential (V_{CB} = 80 Vdc, I_E = 0)	V_{EBF}	-	1.0	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 80 Vdc, R_{BE} = 50 Ohms)	I_{CER}	-	50	mAdc
Collector Cutoff Current (V_{CE} = 80 Vdc, V_{BE} = 0)	I_{CES}	-	5.0	mAdc
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)	I_{CBO1}	-	200	µAdc
Collector Cutoff Current *(V_{CB} = 80 Vdc, I_E = 0) (V_{CB} = 80 Vdc, I_E = 0, T_C = 100°C, +0, -3°C)	I_{CBO2}	- -	5.0 25	mAdc
*Emitter Cutoff Current (V_{EB} = 2.5 Vdc, I_C = 0)	I_{EBO}	-	50	mAdc
ON CHARACTERISTICS				
*DC Current Gain (I_C = 20 Adc, V_{CE} = 1.5 Vdc)	h_{FE}	30	90	-
Collector-Emitter Saturation Voltage (I_C = 20 Adc, I_B = 2.5 Adc)	$V_{CE(sat)}$	-	0.3	Vdc
Base-Emitter Saturation Voltage (I_C = 20 Adc, I_B = 2.5 Adc)	$V_{BE(sat)}$	-	0.7	Vdc
SMALL-SIGNAL CHARACTERISTICS				
*Common-Base Cutoff Frequency (I_C = 0.5 Adc, V_{CB} = 10 Vdc)	$f_{\alpha b}$	1.5	-	MHz
*Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)	h_{fe}	20	-	-
SWITCHING CHARACTERISTICS				
Rise Time (I_C = 25 Adc, $I_{B(on)}$ = 2.5 Adc, $I_{B(off)}$ = 2.5 Adc) (See Figure 2)	t_r	-	12	µs
Storage Time	t_s	-	10	µs
Fall Time	t_f	-	8.0	µs

*Indicates JEDEC Registered Data.

FIGURE 2 – SWITCHING TIME TEST CIRCUIT



SCOPE
1.1
PULSE WIDTH = 50 µs
DUTY CYCLE = 10%
Adj for
$I_{B(on)}$ = 2.5 A
≈ 12 V
$I_{B(off)}$
2.0
0.1
TUT
Adj
≈ 28 V
I_C = 25 A
0.5 µF
0.7
$I_{B(on)}$
= 2.0 V
Adj for $I_{B(off)}$
= 2.5 A
2N3447
50
PULSE
GENERATOR

2N1842 thru 2N1850 (SILICON)

CASE 64
(TO-48)

Industrial-type, silicon controlled rectifiers in a stud package with current handling capability to 16 amperes at junction temperatures to 100°C.

MAXIMUM RATINGS (T_J = 100°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*	$V_{ROM(rep)}$*		Volts
2N1842		25	
2N1843		50	
2N1844		100	
2N1845		150	
2N1846		200	
2N1847		250	
2N1848		300	
2N1849		400	
2N1850		500	
Peak Reverse Blocking Voltage	$V_{ROM(non-rep)}$		Volts
(Transient) 2N1842		35	
(Non-Recurrent 5 ms max.) 2N1843		75	
2N1844		150	
2N1845		225	
2N1846		300	
2N1847		350	
2N1848		400	
2N1849		500	
2N1850		600	
Forward Current RMS (All Conduction Angles)	I_f	16	Amp
Circuit Fusing Considerations (T_J = -40 to +100°C, t ≦ 8.3 ms)	I^2t	60	A^2s
Peak Forward Surge Current (One Cycle, 60 Hz, T_J = -40 to +100°C)	$I_{FM(surge)}$	125	Amp
Peak Gate Power - Forward	P_{GFM}	5.0	Watts
Average Gate Power Forward	$P_{GF(AV)}$	0.5	Watt
Peak Gate Current - Forward	I_{FGM}	2.0	Amp
Peak Gate Voltage - Forward	V_{GFM}	10	Volts
Reverse	V_{GRM}	5.0	
Operating Junction Temperature Range	T_J	-40 to +100	°C
Storage Temperature Range	T_{stg}	-40 to +125	°C
Stud Torque	—	30	in. lb.

*$V_{ROM(rep)}$ for all types can be applied on a continuous dc basis without incurring damage.

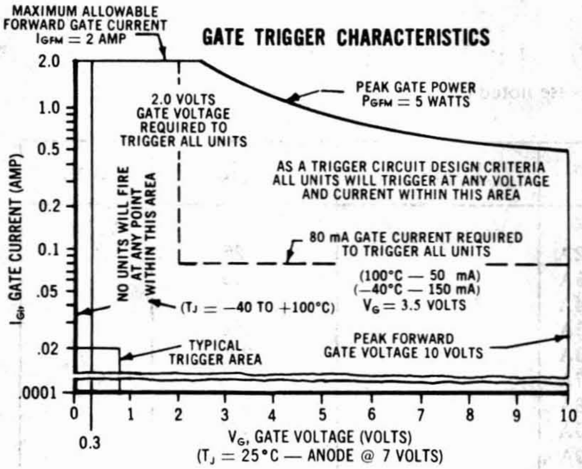
Ratings apply for zero or negative gate voltage.

2N1842 thru 2N1850 (continued)

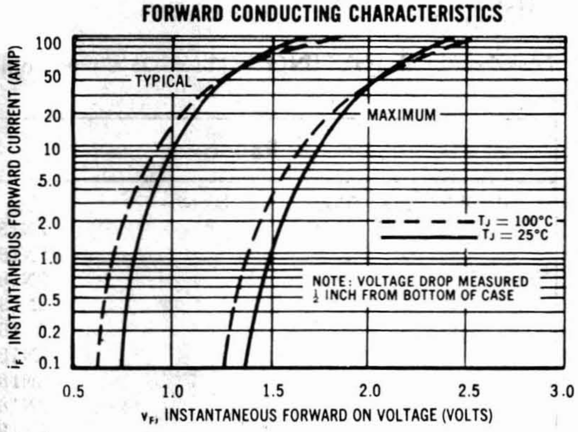
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage* (T_J = 100°C)	2N1842	V_{FOM}*	25	—	—	Volts
	2N1843		50	—	—	
	2N1844		100	—	—	
	2N1845		150	—	—	
	2N1846		200	—	—	
	2N1847		250	—	—	
	2N1848		300	—	—	
	2N1849		400	—	—	
	2N1850		500	—	—	
Peak Forward or Reverse Blocking Current (Rated V_{FOM} or V_{ROM} gate open, T_J = 100°C)		I_{FOM} I_{ROM}	—	—	6.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50 Ω)		I_{GT}	—	15	80	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50 Ω)		V_{GT}	—	0.8	2.0	Volts
(Anode Voltage = Rated V_{FOM}, R_L = 50Ω, T_J = 100°C)		V_{GNT}	0.3	—	—	
Holding Current (Anode Voltage = 7 Vdc, Gate Open)		I_{HO}	—	20	—	mA
Forward On Voltage (I_F = 16 Adc)		V_F	—	1.1	1.8	Volts
Turn-On Time ($t_d + t_r$) (I_G = 50 mA, I_F = 10 A)		t_{on}	—	1.0	—	μs
Turn-Off Time (I_F = 10 A, I_R = 10 A; dv/dt = 20 V/μs, T_J = 100°C) (V_{FXM} = rated voltage) (V_{RXM} = rated voltage)		t_{off}	—	25	—	μs
Forward Voltage Application Rate (Gate open, T_J = 100°C)		dv/dt	—	30	—	V/μs
Thermal Resistance (Junction to Case)		θ_{JC}	—	1.0	2.0	°C/W

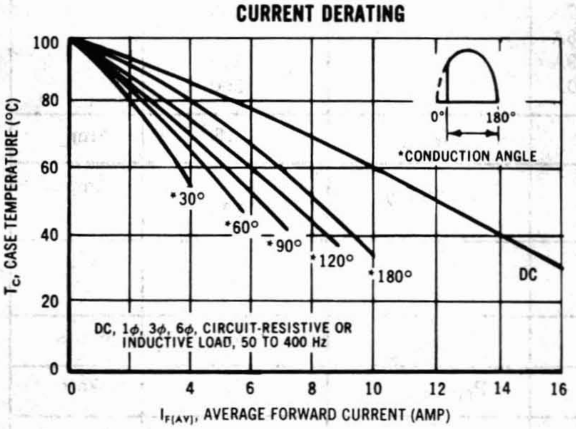
*V_{FOM} for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for zero or negative voltage.



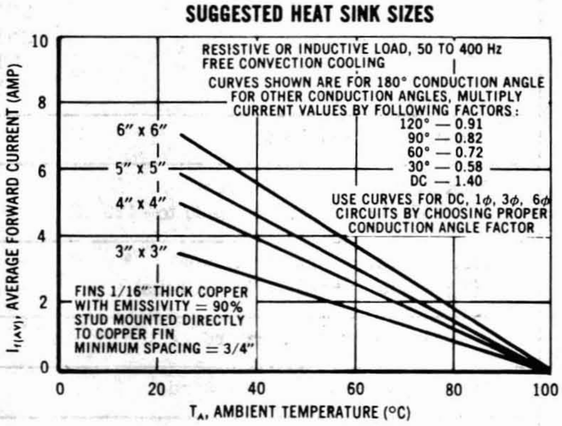
GATE TRIGGER CHARACTERISTICS



FORWARD CONDUCTING CHARACTERISTICS



CURRENT DERATING



SUGGESTED HEAT SINK SIZES

2N1842A thru 2N1850A (SILICON)

CASE 64
(TO-48)

Industrial-type, silicon controlled rectifiers in a stud package with current handling capability to 16 amperes at junction temperatures to 125°C.

MAXIMUM RATINGS (T_J = 125°C unless otherwise noted)

Rating		Symbol	Value	Unit
Peak Reverse Blocking Voltage*		$V_{ROM(rep)}$*		Volts
	2N1842A		25	
	2N1843A		50	
	2N1844A		100	
	2N1845A		150	
	2N1846A		200	
	2N1847A		250	
	2N1848A		300	
	2N1849A		400	
	2N1850A		500	
Peak Reverse Blocking Voltage (Transient) (Non-Recurrent 5 ms max.)		$V_{ROM(non-rep)}$		Volts
	2N1842A		35	
	2N1843A		75	
	2N1844A		150	
	2N1845A		225	
	2N1846A		300	
	2N1847A		350	
	2N1848A		400	
	2N1849A		500	
	2N1850A		600	
Forward Current RMS		I_f	16	Amp
Peak Forward Surge Current (One Cycle, 60 Hz, T_J = -65 to +125°C)		$I_{FM(surge)}$	125	Amp
Circuit Fusing Considerations (T_J = -65 to +125°C, t ≦ 8.3 ms)		I^2t	60	A^2s
Peak Gate Power - Forward		P_{GFM}	5.0	Watts
Average Gate Power - Forward		$P_{GF(AV)}$	0.5	Watt
Peak Gate Current - Forward		I_{GFM}	2.0	Amp
Peak Gate Voltage - Forward		V_{GFM}	10	Volts
Reverse		V_{GRM}	5.0	
Operating Junction Temperature Range		T_J	-65 to +125	°C
Storage Temperature Range		T_{stg}	-65 to +150	°C
Stud Torque		—	30	in. lb.

*$V_{ROM(rep)}$ for all types can be applied on a continuous dc basis without incurring damage.

Ratings apply for zero or negative gate voltage.

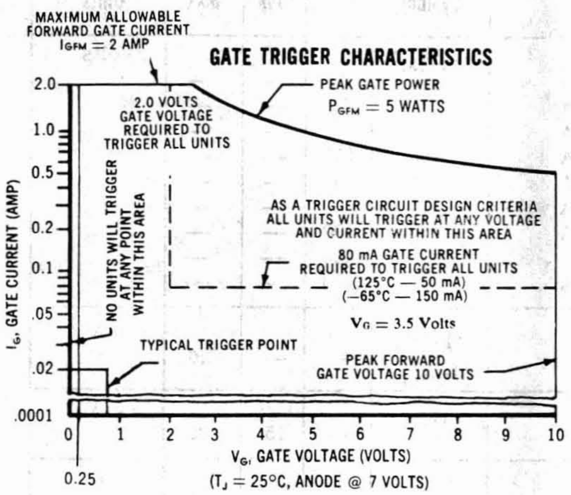
2N1842 A thru 2N1850A (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

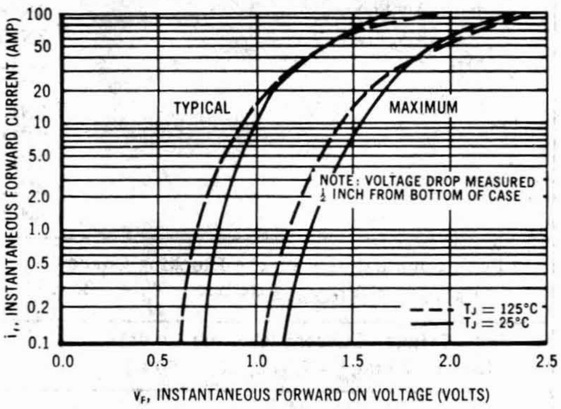
Characteristic	Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage* (T_J = 125°C) 2N1842A	V_{FOM}*	25	—	—	Volts
2N1843A		50	—	—	
2N1844A		100	—	—	
2N1845A		150	—	—	
2N1846A		200	—	—	
2N1847A		250	—	—	
2N1848A		300	—	—	
2N1849A		400	—	—	
2N1850A		500	—	—	
Peak Forward or Reverse Blocking Current (V_{FOM}, OR V_{ROM}, gate open, T_J = 125°C)	I_{FOM} I_{ROM}	—	—	6.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50 Ω)	I_{GT}	—	15	80	mA
Gate Trigger Voltage (Anode Voltage = 7 Vdc, R_L = 50 Ω)	V_{GT}	—	0.8	2.0	Volts
(Anode Voltage = Rated V_{FOM}, R_L = 50 Ω, T_J = 125°C)	V_{GNT}	0.25	—	—	
Holding Current (Anode Voltage = 7 Vdc, Gate Open)	I_{HO}	—	20	—	mA
Forward On Voltage (I_F = 16 Adc)	V_F	—	1.1	1.6	Volts
Turn-On Time ($t_d + t_r$) (I_G = 50 mA, I_F = 10 A)	t_{on}	—	1.0	—	μs
Turn-Off Time (I_F = 10 A, I_R = 10 A, dv/dt = 20 V/μs, T_J = 125°C)	t_{off}	—	30	—	μs
Forward Voltage Application Rate (Gate Open, T_J = 125°C)	dv/dt	—	30	—	V/μs
Thermal Resistance (Junction to Case)	θ_{JC}	—	1.0	2.0	°C/W

*V_{FOM} for all types can be applied on a continuous dc basis without incurring damage.

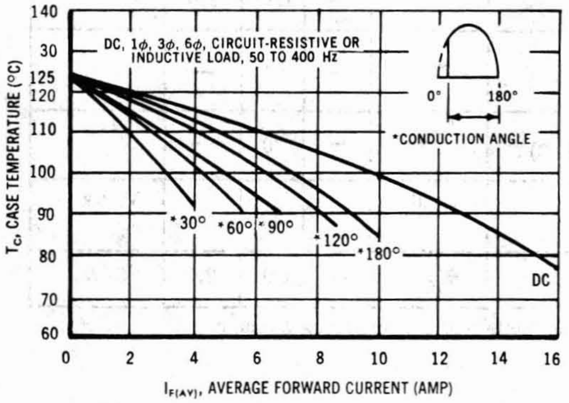
Ratings apply for zero or negative gate voltage.


GATE TRIGGER CHARACTERISTICS

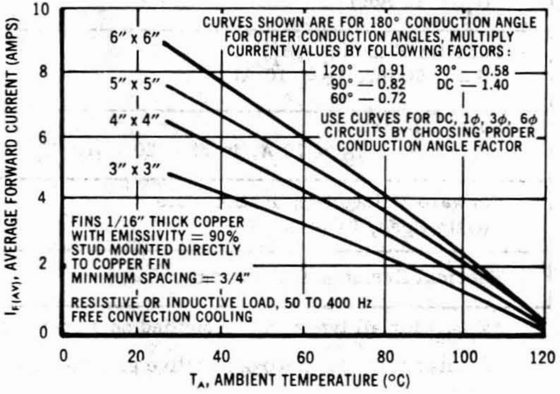
FORWARD CONDUCTING CHARACTERISTICS



CURRENT DERATING



SUGGESTED HEAT SINK SIZES



2N1893 (SILICON)
2N2405

NPN silicon annular transistors designed for medium-power amplifier and switching applications.

Collector connected to case

CASE 31
(TO-5)

MAXIMUM RATINGS

Rating	Symbol	2N1893	2N2405	Unit
Collector-Emitter Voltage	V_{CEO}	80	90	Vdc
Collector-Emitter Voltage	V_{CER}	100	140	Vdc
Collector-Base Voltage	V_{CB}	120		Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Collector Current	I_C	0.5	1.0	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.8 4.57	1.0 5.71	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	3.0 17.2	5.0 28.6	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	2N1893	2N2405	Unit
Thermal Resistance, Junction to Case	θ_{JC}	58.3	35	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	219	175	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage*		$BV_{CEO(sus)}$*			Vdc
(I_C = 30 mAdc, I_B = 0)	2N1893		80	-	
(I_C = 100 mAdc, I_B = 0)	2N2405		90	-	
Collector-Emitter Sustaining Voltage (I_C = 100 mAdc, R_{BE} = 10 ohms)	2N1893 2N2405	$BV_{CER(sus)}$	100 140	- -	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	120	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 90 Vdc, I_E = 0)			-	0.01	
(V_{CB} = 90 Vdc, I_E = 0, T_A = 150°C)	2N1893 2N2405		- -	15 10	
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	0.01	μAdc

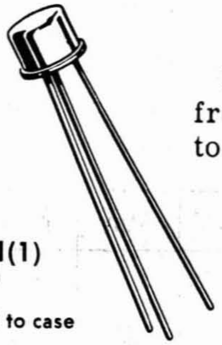
2N1893, 2N2405 (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Max	Unit
ON CHARACTERISTICS					
DC Current Gain*		h_{FE}*			-
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N1893		20	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N1893		35	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N1893		20	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N1893		40	120	
	2N2405		60	200	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 5.0 mAdc)	2N1893		-	1.2	
(I_C = 150 mAdc, I_B = 15 mAdc)	2N1893		-	5.0	
	2N2405		-	0.5	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 5.0 mAdc)	2N1893		-	0.9	
(I_C = 150 mAdc, I_B = 15 mAdc)	2N1893		-	1.3	
	2N2405		-	1.1	
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product		f_T			MHz
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N1893		50	-	
Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, I_E = 0, 100 kHz ≤ f ≤ 1.0 MHz)			-	15	
Input Capacitance		C_{ib}			pF
(V_{BE} = 0.5 Vdc, I_C = 0, 100 kHz ≤ f ≤ 1.0 MHz)	2N1893		-	85	
Input Impedance		h_{ib}			ohms
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N1893		20	30	
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	2N1893, 2N2405		4.0	8.0	
Voltage Feedback Ratio		h_{rb}			X 10^{-4}
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N1893		-	1.25	
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	2N1893		-	1.5	
	2N2405		-	3.0	
Small-Signal Current Gain		h_{fe}			-
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N1893		30	100	
(I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N2405		50	275	
(I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N1893		45	-	
Output Admittance		h_{ob}			μmho
(I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N1893		-	0.5	
(I_C = 5.0 mAdc, V_{CB} = 10 Vdc, f = 1.0 kHz)	2N1893, 2N2405		-	0.5	

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N1924 thru 2N1926 (GERMANIUM)



CASE 31(1)
(TO-5)

Base connected to case

PNP germanium transistors for general purpose, low-frequency applications. Characteristics curves similar to 2N524-2N527 series.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Emitter-Base Voltage	V_{EB}	25	Vdc
Collector Current	I_C	500	mAdc
Junction and Storage Temperature	T_J & T_{stg}	-65 to +100	°C
Power Dissipation at 25°C Ambient	P_D	225	mW

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
Collector Cutoff Current V_{CB} = -45 Vdc, I_E = 0	I_{CBO}	–	10	μAdc
Emitter Cutoff Current V_{EB} = -25 Vdc, I_C = 0	I_{EBO}	–	10	μAdc
Collector-Base Voltage I_C = 200 μAdc, I_E = 0	V_{CBO}	60	–	Vdc
Collector-Emitter Voltage I_C = 50 μAdc, V_{BE} = +1.5 Vdc, R_{BE} = 10 K	V_{CEX}	50	–	Vdc
Collector-Emitter Voltage I_C = 0.6 mAdc, R_{BE} = 10 K	V_{CER}	40	–	Vdc
Punch-Thru Voltage **(V_{EB} = 1 Vdc, VTVM Z ≥ 1 Megohm)**	V_{pt}	50	–	Vdc

ELECTRICAL CHARACTERISTICS (continued)

Characteristics	Symbol	Min	Max	Unit
DC Current Gain I_C = 20 mAdc, V_{CE} = -1 Vdc	h_{FE}			
2N1924		34	65	–
2N1925		53	90	
2N1926		72	121	
DC Current Gain I_C = 100 mAdc, V_{CE} = -1 Vdc	h_{FE}			
2N1924		30	–	–
2N1925		47	–	
2N1926		65	–	
Collector-Emitter Saturation Voltage	$V_{CE(SAT)}$			
I_B = 1.33 mAdc, I_C = 20 mAdc 2N1924		50	110	mVdc
I_B = 1.0 mAdc, I_C = 20 mAdc 2N1925		55	110	
I_B = 0.67 mAdc, I_C = 20 mAdc 2N1926		60	110	
Base Input Voltage V_{CE} = -1 Vdc, I_C = 20 mAdc	V_{BE}			
2N1924		200	300	mVdc
2N1925		190	290	
2N1926		180	280	
Output Capacitance; Input AC Open Circuit V_{CB} = -5 Vdc, I_E = 1 mAdc, f = 1 MHz	C_{ob}	–	30	pF
Frequency Cutoff V_{CB} = -5 Vdc, I_E = 1 mAdc	$f_{\alpha b}$			
2N1924		1.0	–	MHz
2N1925		1.3	–	
2N1926		1.5	–	
Small-Signal Short-Circuit Forward-Transfer Current Ratio V_{CE} = -5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{fe}			
2N1924		30	64	–
2N1925		44	88	
2N1926		60	120	
Small-Signal Open Circuit Output Admittance V_{CE} = -5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{oe}			
2N1924		15	60	µmho
2N1925		20	65	
2N1926		25	70	
Small-Signal Open-Circuit Reverse-Transfer Voltage Ratio V_{CE} = -5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{re}			
2N1924		2.0	8.0	$X10^{-4}$
2N1925		3.0	9.0	
2N1926		4.0	10	
Small-Signal Short-Circuit Input Impedance V_{CE} = -5 Vdc, I_E = 1 mAdc, f = 1 kHz	h_{ie}			
2N1924		700	2200	ohms
2N1925		1200	3200	
2N1926		1500	4200	

2N1959 (SILICON)

CASE 31
(TO-5)

Collector connected to case

NPN silicon annular transistor designed for high-speed, medium-power saturated switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage R_{BE} = 10 ohms	V_{CER}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	600 4.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	2.0 1.3	Watts mW/°C
Operating Junction Temperature Range	T_J	-65to + 175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

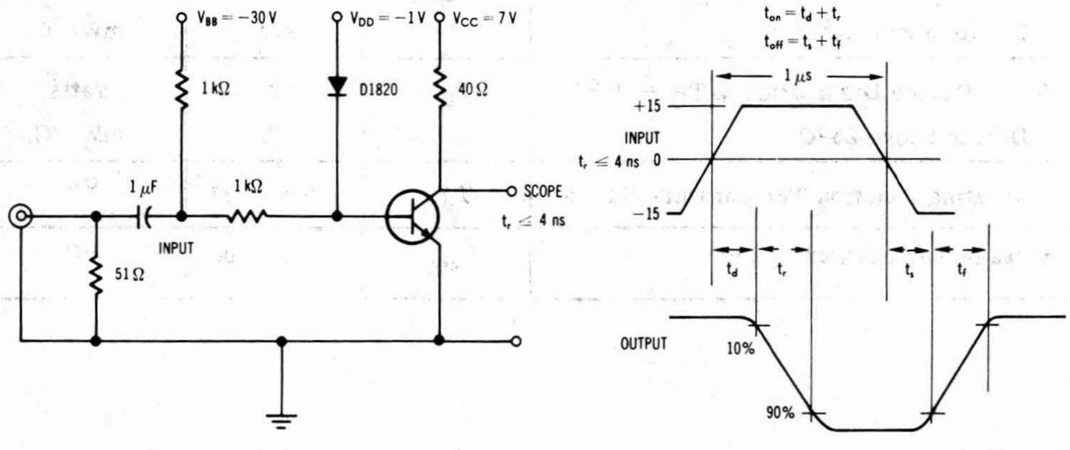
2N1959 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise specified)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 50 μAdc, R_{BE} = 10 ohms)	BV_{CER}	40	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	— —	0.5 300	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 150 mAdc, V_{CE} = 10 Vdc)	h_{FE}	40	120	—
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$	—	0.45	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	—	1.3	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 25 mAdc, V_{CB} = 10 Vdc, f = 100 MHz)	f_T	100	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	18	pF
Turn-On Time — Figure 1 (V_{CC} = 7 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc,	t_{on}	—	65	ns
Turn-Off Time	t_{off}	—	45	ns
Storage Time	t_s	—	25	ns

*t_{on}, t_{off}, and t_s measured from 50% point of input pulse.

FIGURE 1 — SWITCHING TIME TEST CIRCUIT


V_{BB} = −30 V
V_{DD} = −1 V
V_{CC} = 7 V
1 kΩ
D1820
40 Ω
1 μF
1 kΩ
INPUT
SCOPE
$t_r \leq$ 4 ns
51 Ω
$t_{on} = t_d + t_r$
$t_{off} = t_s + t_f$
1 μs
+15
INPUT
$t_r \leq$ 4 ns
0
−15
t_d
t_r
t_s
t_f
OUTPUT
10%
90%

2N1970 (GERMANIUM)

2N1980 thru 2N1982

CASE 5
(TO-36)

PNP germanium power transistors for general purpose amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N1970	2N1980	2N1981	2N1982	Unit
Collector-Base Voltage	V_{CB}	100	50	70	90	Volts
Collector-Emitter Voltage	V_{CEO}	50	30	40	50	Volts
Emitter-Base Voltage	V_{EB}	40	20	20	20	Volts
Collector Current	I_C	15				Amp
Power Dissipation at $T_C = 25^oC$	P_D	170				Watts
Junction Temperature Range	T_J	-65 to +110				^oC

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = -100 Vdc)	2N1970		—	4.0	
(V_{CB} = -50 Vdc)	2N1980		—	6.0	
(V_{CB} = -70 Vdc)	2N1981		—	6.0	
(V_{CB} = -90 Vdc)	2N1982		—	6.0	
(V_{CB} = -2 Vdc)	2N1980-2N1982		—	0.3	
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = -40 Vdc)	2N1970		—	4.0	
(V_{EB} = -20 Vdc)	2N1980-2N1982		—	5.0	
(V_{EB} = -2 Vdc)	2N1980-2N1982		—	0.3	
Collector-Emitter Breakdown Voltage		BV_{CEO}			Vdc
(I_C = 1 Adc, I_B = 0)	2N1970		50	—	
	2N1980		30	—	
	2N1981		40	—	
	2N1982		50	—	
Base-Emitter Voltage		V_{BE}			Vdc
(V_{CE} = -2 Vdc, I_C = 5 Adc)	2N1970		—	0.9	
Emitter Floating Potential		V_{EBF}			Vdc
(V_{CB} = -50 Vdc)	2N1980		—	1.0	
(V_{CB} = -70 Vdc)	2N1981		—	1.0	
(V_{CB} = -90 Vdc)	2N1982		—	1.0	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 12 Adc, I_B = 2 Adc)	2N1970		—	1.0	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N1980-2N1982		—	0.5	
DC Current Gain		h_{FE}			—
(I_C = 5 Adc, V_{CE} = -2 Vdc)	2N1970		17	40	
	2N1980-2N1982		50	100	
(I_C = 12 Adc, V_{CE} = -2 Vdc)	2N1970		10	—	
Common Emitter Cutoff Frequency		$f_{\alpha e}$			kHz
(V_{CE} = -4 V, I_C = 5 A)	2N1970		5.0	—	
(V_{CE} = -5 V, I_C = 2 A)	2N1980-2N1982		3.0	—	

2N1983 (SILICON)
2N1984

NPN silicon annular small-signal transistor.

CASE 31
(TO-5)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Base Voltage	V_{CB}	50	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	1.0	Adc
Total Device Dissipation @ T_A = 25° C Derate above 25° C	P_D	0.6 4.8	Watt mW/° C
Total Device Dissipation @ T_C = 25° C Derate above 25° C	P_D	2.0 16	Watts mW/° C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	62.5	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	208	°C/W

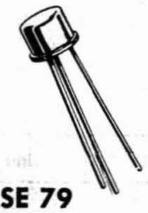
2N1983, 2N1984 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	25	-	Vdc
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, $R_{BE} \leqq$ 10 ohms)	$BV_{CER(sus)}$*	30	-	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)	I_{CBO}	-	5.0	μAdc
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)		-	200	
Emitter-Cutoff Current ($V_{EB(off)}$ = 2.0 Vdc, I_C = 0)	I_{EBO}	-	100	μAdc
ON CHARACTERISTICS				
Collector-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 0.5 mAdc)	$V_{CE(sat)}$	-	0.25	Vdc
Base-Emitter On Voltage (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	$V_{BE(on)}$	-	0.85	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	40	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)	C_{ob}	-	45	pF
Input Impedance (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc) 2N1983	h_{ie}	-	2.0	k ohm
2N1984		-	1.2	
Input Resistance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20	30	ohm
(I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)		4.0	8.0	
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N1983	h_{rb}	-	7.0	X 10^{-4}
2N1984		-	5.0	
(I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N1983		-	7.0	
2N1984		-	5.0	
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N1983	h_{fe}	70	210	-
2N1984		35	100	
(I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N1983		80	240	
2N1984		40	120	
Output Admittance (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc) 2N1983	h_{oe}	-	200	-
2N1984		-	100	
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	1.0	μmho
(I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)		-	1.5	

* Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

2N1990 (SILICON)



CASE 79
(TO-39)

NPN silicon transistor designed for driving neon display tubes.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	100	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current-Continuous	I_C	1.0	Adc
Total Device Dissipation $T_A = 25°C$ Derate above 25°C	P_D	0.6 4.8	W mW/°C
Total Device Dissipation $T_C = 2.5°C$ @ $T_C = 100°C$	P_D	2.0 1.0	W
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	62.5	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	208	°C/W

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector Cutoff Current ($V_{CE} = 75$ Vdc, $I_B = 10$ μAdc) ($V_{CE} = 75$ Vdc, $I_B = 250$ μAdc, $T_A = 150°C$	I_{CEX}	 - -	 10 250	 μAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 30$ mAdc, $V_{CE} = 10$ Vdc)	h_{FE}	 20	 -	-
Collector-Emitter Saturation Voltage ($I_C = 2.0$ mAdc, $I_B = 0.2$ mAdc)	$V_{CE(sat)}$	 -	 0.5	Vdc
Base-Emitter Saturation Voltage ($I_C = 2.0$ mAdc, $I_B = 0.2$ mAdc)	$V_{BE(sat)}$	 -	 1.0	Vdc

2N1991 (SILICON)

For Specifications, See 2N1131 Data.

2N2042, 2N2043 (GERMANIUM)

CASE 31(1)
(TO-5)

PNP germanium transistors suitable for high-voltage audio switching and amplifier applications. Suitable for high-reliability projects.

All leads isolated from case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	105	Vdc
Collector-Emitter Voltage	V_{CES}	105	Vdc
Emitter-Base Voltage	V_{EB}	75	Vdc
Collector Current (Continuous)	I_C	200	mAdc
Operating Junction Temperature Range	T_J	-65 to +100	°C
Storage Temperature Range	T_{stg}	-65 to +100	°C
Collector Dissipation, Ambient Derate above 25°C	P_D	200 2.67	mW mW/°C
Thermal Resistance (Junction to Ambient)	θ_{JA}	0.375	°C/mW
Thermal Resistance (Junction to Case)	θ_{JC}	0.250	°C/mW

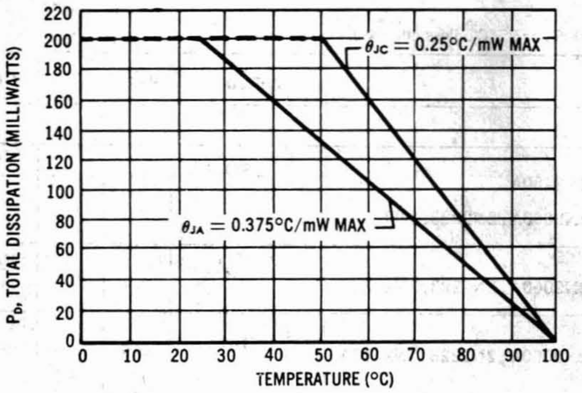
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 105 V, I_E = 0)			–	25	
(V_{CB} = 2.5 V, I_E = 0)			–	10	
(V_{CB} = 105 V, I_E = 0, T_A = +71°C)			–	500	
Emitter-Base Cutoff Current		I_{EBO}			μAdc
(V_{EB} = 75 V, I_C = 0)			–	50	
(V_{EB} = 2.5 V, I_C = 0)			–	10	
Collector-Emitter Cutoff Current		I_{CER}			μAdc
(V_{CE} = 55 V, R_{BE} = 10 K)			–	600	
Collector-Emitter Cutoff Current		I_{CES}			mAdc
(V_{CE} = 105 V, V_{BE} = 0)			–	1.0	
DC Collector-Emitter Punch-Through Voltage		V_{pt}			Vdc
(V_{fl} = 1.0 V, VTVM R_{in} 10-12 megohm)			105	–	
DC Current Gain		h_{FE}			–
(I_C = 5 mA, V_{CE} = 0.35 V)	2N2042		20	50	
	2N2043		40	100	
Common Base, Small-Signal Input Impedance		h_{ib}			Ohms
(V_{CB} = 6 V, I_E = 1 mA, f = 1 kHz)			30	50	

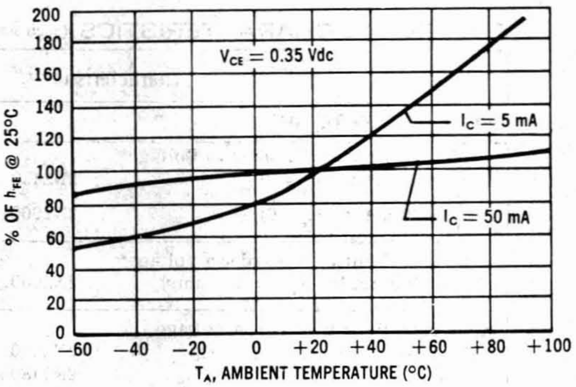
ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Max	Unit
Common Base, Small-Signal Output Admittance (V_{CB} = 6 V, I_E = 1 mA, f = 1 kHz)		h_{ob}	0.1	1.0	μmho
Common Emitter, Small-Signal Current Transfer Ratio (V_{CE} = 6 V, I_C = 1 mA, f = 1 kHz)	2N2042 2N2043	h_{fe}	20 45	80 180	–
Base-Emitter Saturation Voltage (I_C = 5 mA, I_B = 0.25 mA)		$V_{BE(sat)}$	–	0.30	Vdc
Collector-Emitter Saturation Voltage (I_C = 5 mA, I_B = 0.25 mA) (I_C = 100 mA, I_B = 10 mA)		$V_{CE(sat)}$	– –	0.25 0.75	Vdc
Collector Output Capacitance (V_{CB} = 6 V, I_E = 0)		C_{ob}	–	25	pF
Common-Base, Small-Signal Forward Current Transfer Ratio Cutoff Frequency (V_{CB} = 6 V, I_E = 1 mA)	2N2042 2N2043	$f_{\alpha b}$	0.50 0.75	– –	MHz

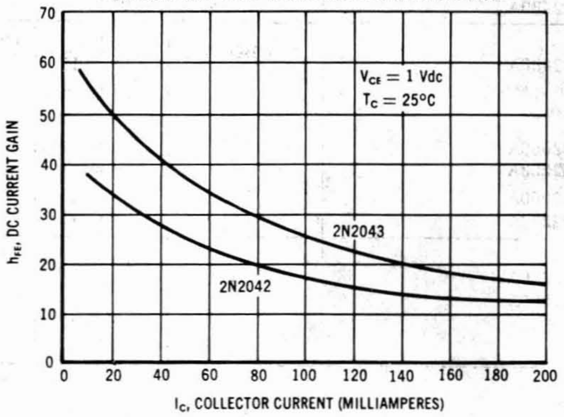
POWER-TEMPERATURE DERATING CURVE



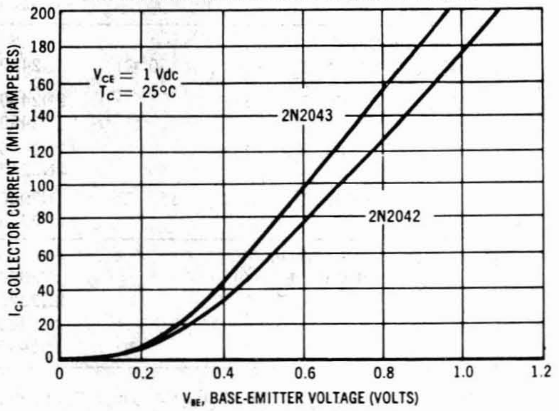
LARGE SIGNAL CURRENT GAIN versus TEMPERATURE



DC CURRENT GAIN versus COLLECTOR CURRENT

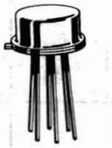


COLLECTOR CURRENT versus BASE-DRIVE VOLTAGE

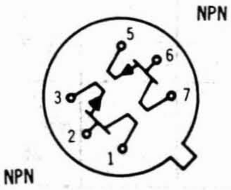


2N2060, A
2N2223, A
2N2480, A

NPN silicon annular Star dual transistors for differential amplifiers and other applications requiring a matched pair with a high degree of parameter uniformity.



CASE 32C



PINS 4 AND 8 OMITTED
Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	2N2060 2N2060A 2N2223 2N2223A	2N2480	2N280A	Unit
Collector-Emitter Voltage	V_{CEO}	60	40	40	Vdc
Collector-Emitter Voltage	V_{CER}	80	-	-	Vdc
Collector-Base Voltage	V_{CB}	100	75	80	Vdc
Emitter-Base Voltage	V_{EB}	7.0	5.0	5.0	Vdc
Collector Current	I_C	←500→			mAdc
Operating Junction Temperature	T_J	←200→			°C
Storage Temperature Range	T_{stg}	←-65 to +200→			°C
		One Side	**Both Sides**		
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.5 2.86	0.6 3.43		Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.6 9.1	3.0 17.2		Watts mW/°C

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage*		$BV_{CEO}{}^*$			Vdc
(I_C = 20 mAdc, I_B = 0)	2N2480, 2N2480A		40	-	
(I_C = 30 mAdc, I_B = 0)	2N2060, 2N2060A, 2N2223, 2N2223A		60	-	
Collector-Emitter Breakdown Voltage*		$BV_{CER}{}^*$			Vdc
(I_C = 100 mAdc, $R_{BE} \leq$ 10 ohms)	2N2060, 2N2060A, 2N2223, 2N2223A		80	-	
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 100 μAdc, I_E = 0)	2N2060, 2N2060A, 2N2223, 2N2223A		100	-	
	2N2480		75	-	
	2N2480A		80	-	
Emitter-Base Breakdown Voltage		BV_{EBO}			Vdc
(I_E = 100 μAdc, I_C = 0)	2N2060, 2N2060A, 2N2223, 2N2223A		7.0	-	
	2N2480, 2N2480A		5.0	-	
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	2N2480, 2N2480A		-	15	
(V_{CB} = 60 Vdc, I_E = 0)	2N2480		-	0.050	
	2N2480A		-	0.020	
(V_{CB} = 80 Vdc, I_E = 0)	2N2060, 2N2060A		-	0.002	
	2N2223, 2N2223A		-	0.010	
(V_{CB} = 80 Vdc, I_E = 0, T_A = 150°C)	2N2060, 2N2060A		-	10	
	2N2223, 2N2223A		-	15	
Emitter Cutoff Current		I_{EBO}			nAdc
(V_{BE} = 5.0 Vdc, I_C = 0)	2N2060, 2N2060A		-	2.0	
	2N2223, 2N2223A		-	10	
	2N2480		-	50	
	2N2480A		-	20	

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

ELECTRICAL CHARACTERISTICS (continued)

ON CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
DC Current Gain (I_C = 10 μAdc, V_{CE} = 5.0 Vdc)	2N2060, 2N2060A	h_{FE}	25	75	-
	2N2223, 2N2223A		15	-	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	2N2060, 2N2060A		30	90	
	2N2223, 2N2223A		25	150	
	2N2480		20	-	
	2N2480A		35	-	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	2N2060, 2N2060A		40	120	
	2N2480		30	350	
	2N2480A		50	200	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc)*	2N2060, 2N2060A		50	150	
	2N2223, 2N2223A		50	200	
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 5.0 mAdc)	2N2060A	$V_{CE(sat)}$	-	0.6	Vdc
	2N2060, 2N2223, 2N2223A, 2N2480A		-	1.2	
	2N2480		-	1.3	
Base-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 5.0 mAdc)	2N2060, 2N2060A, 2N2223, 2N2223A, 2N2480A	$V_{BE(sat)}$	-	0.9	Vdc
	2N2480		-	1.0	

SMALL-SIGNAL CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Current-Gain–Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N2223, 2N2223A, 2N2480, 2N2480A	f_T	50	-	MHz
	2N2060, 2N2060A		60	-	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	2N2060, 2N2060A, 2N2223, 2N2223A	C_{ob}	-	15	pF
	2N2480A		-	18	
	2N2480		-	20	
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	2N2060, 2N2060A, 2N2223, 2N2223A, 2N2480A	C_{ib}	-	85	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N2060, 2N2060A	h_{ie}	1000	4000	ohms
	2N2480A		1000	5000	
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N2060, 2N2060A, 2N2223, 2N2223A	h_{ib}	20	30	ohms
	2N2480A		20	35	
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N2223, 2N2223A	h_{rb}	-	3.0	$X 10^{-4}$
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N2060, 2N2060A	h_{fe}	50	150	-
	2N2223, 2N2223A		40	120	
	2N2480A		50	300	
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N2060, 2N2060A, 2N2480A	h_{oe}	4.0	16	μmhos
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	2N2223, 2N2223A	h_{ob}	-	0.5	μmhos
Noise Figure (I_C = 0.3 mAdc, V_{CE} = 10 Vdc, R_S = 510 ohms, f = 1.0 kHz, BW = 1.0 Hz)	2N2480, 2N2480A	NF	-	8.0	dB
(I_C = 0.3 mAdc, V_{CE} = 10 Vdc, R_S = 510 ohms, f = 1.0 kHz, BW = 200 Hz)	2N2060, 2N2060A		-	8.0	
(I_C = 0.3 mAdc, V_{CE} = 10 Vdc, R_S = 1.0 k ohm, f = 1.0 kHz, BW = 15.7 kHz†)			-	8.0	

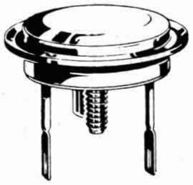
†Amplifier: 3.0 dB points at 25 Hz and 10 kHz with a roll-off of 6.0 dB per octave.

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Max	Unit
MATCHING CHARACTERISTICS				
DC Current Gain Ratio**	h_{FE1}/h_{FE2}**			
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N2060, 2N2060A, 2N2223A		0.9	1.0	
2N2223, 2N2480, 2N2480A		0.8	1.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N2060, 2N2060A		0.9	1.0	
2N2480, 2N2480A		0.8	1.0	
Base Voltage Differential	$\lvert V_{BE1}-V_{BE2} \rvert$			mVdc
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N2060A		-	3.0	
2N2060, 2N2223A, 2N2480A		-	5.0	
2N2480		-	10	
2N2223		-	15	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N2060, 2N2060A, 2N2480A		-	5.0	
2N2480		-	10	
Base Voltage Differential Change	$\Delta(V_{BE1}-V_{BE2})$			mVdc
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55 to +25°C) 2N2060A		-	0.4	
2N2060		-	0.8	
2N2223, 2N2223A		-	2.0	
2N2480, 2N2480A		-	1.2	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = +25 to +125°C) 2N2060		-	1.0	
2N2060A		-	0.5	
2N2223, 2N2223A		-	2.5	
2N2480, 2N2480A		-	1.5	

**The lowest h_{FE} reading is taken as h_{FE1} for this ratio.

2N2075 thru 2N2082 (GERMANIUM)
2N2075A thru 2N2082A



CASE 5
(TO-36)

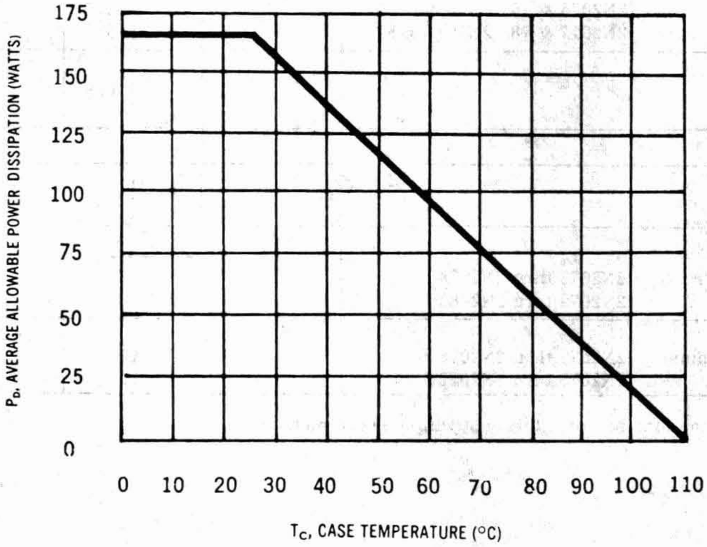
PNP germanium power transistors for high-power applications in high-reliability equipment.

MAXIMUM RATINGS

Rating	Symbol	2N2078 2N2082	2N2077 2N2081	2N2076 2N2080	2N2075 2N2079	Unit
Collector-Emitter Voltage	V_{CEO}	25	45	55	65	Vdc
Collector-Emitter Voltage	V_{CES}	40	50	70	80	Vdc
Collector-Base Voltage	V_{CB}	40	50	70	80	Vdc
Emitter-Base Voltage	V_{EB}	20	25	35	40	Vdc
Collector Current	I_C	15				Adc
Total Device Dissipation @ $T_C = 25°C$	P_D	170				Watts
Operating Junction Temperature Range	T_J	-65 to +110				

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.5	°C/W



POWER-TEMPERATURE DERATING CURVE

The maximum average power is related to maximum junction temperature by the thermal resistance factor.

This curve has a value of 170 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that:

$$\text{allowable } P_D = \frac{110° - T_C}{0.5}$$

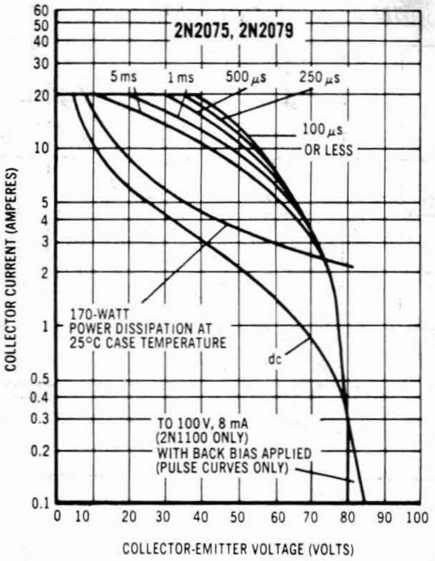
2N2075 thru 2N2082 (continued)

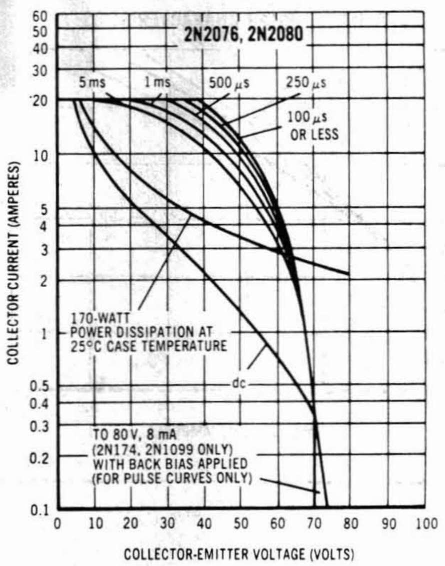
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

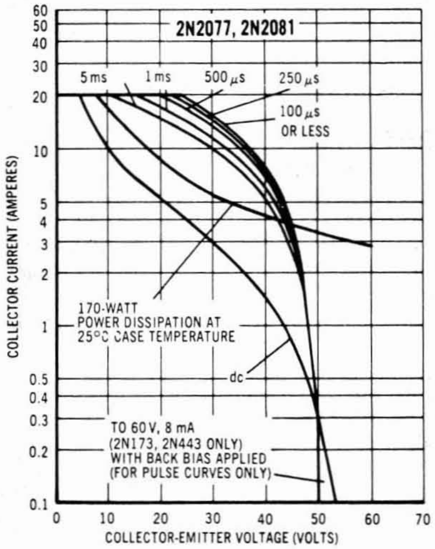
Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage		BV_{CEO}			Vdc
(I_C = 1.0 Adc, I_B = 0)	2N2078, 2N2082		25	-	
	2N2077, 2N2081		45	-	
	2N2076, 2N2080		55	-	
	2N2075, 2N2079		65	-	
Collector-Emitter Breakdown Voltage*		BV_{CES}			Vdc
(I_C = 300 mAdc, V_{BE} = 0)	2N2078, 2N2082		40	-	
	2N2077, 2N2081		50	-	
	2N2076, 2N2080		70	-	
	2N2075, 2N2079		80	-	
Floating Potential		V_{EBF}			Vdc
(V_{CB} = 40 Vdc, I_E = 0)	2N2078, 2N2082		-	1.0	
(V_{CB} = 50 Vdc, I_E = 0)	2N2077, 2N2081		-	1.0	
(V_{CB} = 70 Vdc, I_E = 0)	2N2076, 2N2080		-	1.0	
(V_{CB} = 80 Vdc, I_E = 0)	2N2075, 2N2079		-	1.0	
Collector Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 2.0 Vdc, I_E = 0)			-	0.2	
(V_{CB} = $V_{CB(max)}$, V_{EB} = 1.5 Vdc)			-	4.0	
(V_{CB} = $V_{CB(max)}$, I_E = 0, T_C = +71°C)			-	15	
Emitter Cutoff Current		I_{EBO}			mAdc
(V_{BE} = $V_{BE(max)}$, I_C = 0)			-	4.0	
(V_{BE} = $V_{BE(max)}$, I_C = 0, T_C = +71°C)			-	15	
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			-
(I_C = 1.2 Adc, V_{CE} = 2.0 Vdc)	2N2075 thru 2N2078		25	100	
	2N2079 thru 2N2082		40	160	
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	2N2075 thru 2N2078		20	40	
	2N2079 thru 2N2082		35	70	
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc, T_C = -55°C)	2N2075 thru 2N2078		15	-	
	2N2079 thru 2N2082		25	-	
(I_C = 12 Adc, V_{CE} = 2.0 Vdc)	2N2075 thru 2N2078		8	-	
	2N2079 thru 2N2082		12	-	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 13 Adc, I_B = 2.0 Adc)	2N2075 & 76, 2N2079 & 80		-	0.7	
	2N2077 & 78, 2N2081 & 82		-	0.9	
Base-Emitter On Voltage		$V_{BE(on)}$			Vdc
(I_C = 5.0 Adc, V_{CE} = 12 Vdc)			-	0.9	
DYNAMIC CHARACTERISTICS					
Common-Emitter Cutoff Frequency		$f_{\alpha e}$			kHz
(I_C = 5.0 Adc, V_{CE} = 6.0 Vdc)			5.0	-	
Rise Time		t_r	Typ		μs
(V_{CE} = 12 Vdc, $I_{C(on)}$ = 12 Adc, I_B = 2.0 Adc)	2N2075 thru 2N2078		9.0		
	2N2079 thru 2N2082		6.0		
Fall Time		t_f			μs
(V_{BE} = 6.0 Vdc, $I_{C(off)}$ = 0, R_{BE} = 10 ohms)	2N2075 thru 2N2078		12		
	2N2079 thru 2N2082		13		

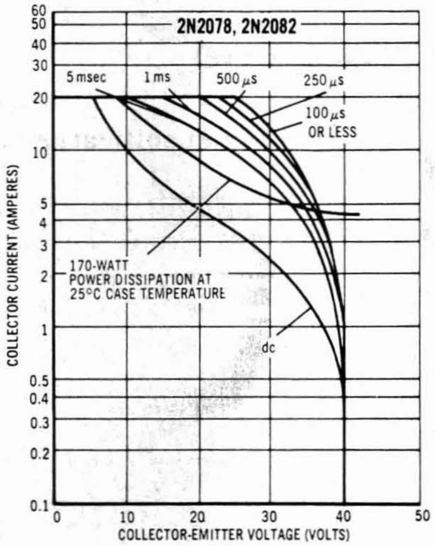
*To avoid excessive heating of collector junction, perform this test with a sweep method.

SAFE OPERATING AREAS





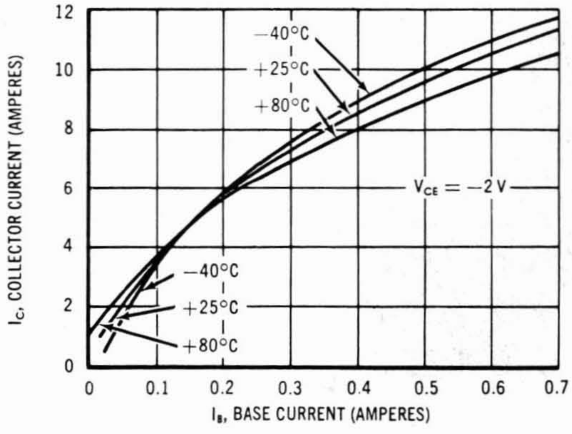




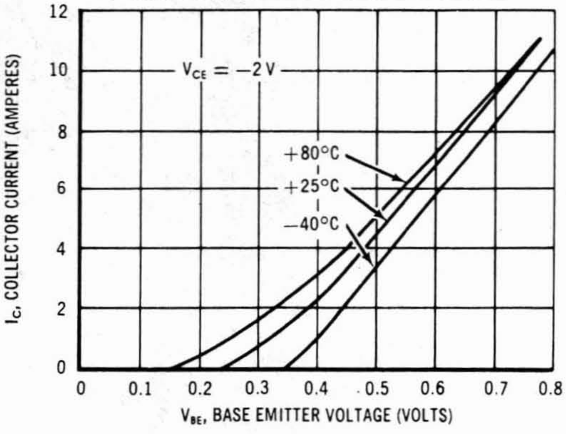
The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N2075-2N2078

CURRENT TRANSFER CHARACTERISTICS

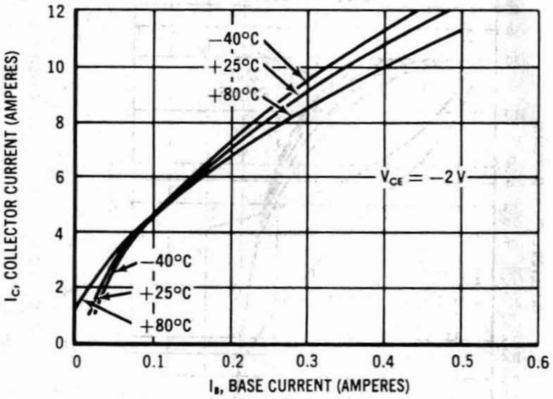


TRANSCONDUCTANCE CHARACTERISTICS

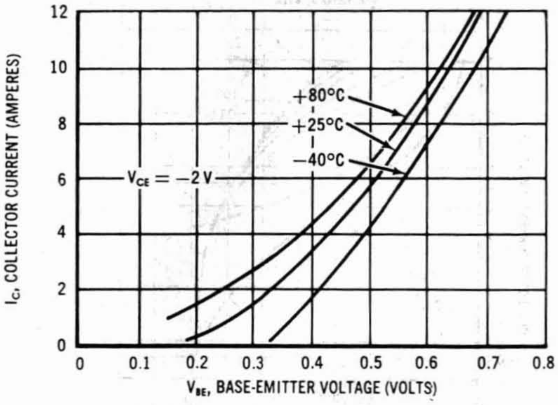


2N2079-2N2082

CURRENT TRANSFER CHARACTERISTICS



TRANSCONDUCTANCE CHARACTERISTICS

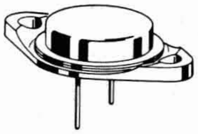


2N2096 (GERMANIUM)
2N2097
2N2099
2N2100

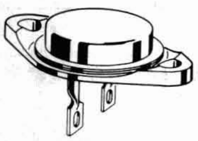
For Specifications, See 2N1204 Data.

2N2137 thru 2N2146 (GERMANIUM)
2N2137A thru 2N2146A

PNP germanium industrial power transistors for driver applications in high reliability equipment.



CASE 11
(TO-3)



CASE 4-04
(TO-41)

For units with solder lugs attached, specify devices MP2137,A etc. (TO-41 package)

MAXIMUM RATINGS

Apply also to standard, non-A series

Rating	Symbol	2N2137A 2N2142A	2N2138A 2N2143A	2N2139A 2N2144A	2N2140A 2N2145A	2N2141A 2N2146A	Unit
Collector-Base Voltage	V_{CB}	30	45	60	75	90	Vdc
Collector-Emitter Voltage	V_{CES}	30	45	60	75	90	Vdc
Collector-Emitter Voltage	V_{CEO}	20	30	45	60	65	Vdc
Emitter-Base Voltage	V_{EB}	15	25	30	40	45	Vdc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	70 0.833					Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110					°C

ELECTRICAL CHARACTERISTICS

*Characteristics apply also to corresponding, non-A type numbers.

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage**		BV_{CEO}**				Vdc
(I_C = 500 mAdc, I_B = 0)	2N2137A, 2N2142A*		20	-	-	
	2N2138A, 2N2143A*		30	-	-	
	2N2139A, 2N2144A*		45	-	-	
	2N2140A, 2N2145A*		60	-	-	
	2N2141A, 2N2146A*		65			
Collector-Emitter Breakdown Voltage**		BV_{CES}**				Vdc
(I_C = 300 mAdc, V_{BE} = 0)	2N2137A, 2N2142A*		30	-	-	
	2N2138A, 2N2143A*		45	-	-	
	2N2139A, 2N2144A*		60	-	-	
	2N2140A, 2N2145A*		75	-	-	
	2N2141A, 2N2146A*		90	-	-	
Floating Potential		V_{EBF}				Vdc
(V_{CB} = 30 Vdc, I_E = 0)	2N2137A, 2N2142A*		-	-	1.0	
(V_{CB} = 45 Vdc, I_E = 0)	2N2138A, 2N2143A*		-	-	1.0	
(V_{CB} = 60 Vdc, I_E = 0)	2N2139A, 2N2144A*		-	-	1.0	
(V_{CB} = 75 Vdc, I_E = 0)	2N2140A, 2N2145A*		-	-	1.0	
(V_{CB} = 90 Vdc, I_E = 0)	2N2141A, 2N2146A*		-	-	1.0	
Collector-Base Cutoff Current		I_{CBO}				mAdc
(V_{CB} = 2.0 Vdc, I_E = 0)			-	0.018	0.05	
(V_{CB} = $V_{CB(max)}$, I_C = 0, T_C = +71°C)			-	0.75	5.0	
Collector-Base Cutoff Current (V_{CB} = $V_{CB(max)}$, I_E = 0)		I_{CBO1}	-	0.1	2.0	mAdc
Emitter-Base Cutoff Current		I_{EBO}				mAdc
(V_{BE} = $V_{BE(max)}$, I_C = 0)			-	0.08	2.0	
(V_{BE} = $V_{BE(max)}$, I_C = 0, T_C = +71°C)			-	0.5	5.0	
ON CHARACTERISTICS						
DC Current Gain		h_{FE1}				-
(I_C = 0.5 Adc, V_{CE} = 2.0 Vdc)	2N2137A-2N2141A*		30	45	60	
	2N2142A-2N2146A*		50	70	100	
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	2N2137A-2N2141A*	h_{FE}	15	22	-	
	2N2142A-2N2146A*		25	33	-	
Collector-Emitter Saturation Voltage (I_C = 2.0 Adc, I_B = 200 mAdc)		$V_{CE(sat)}$	-	0.12	0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 2.0 Adc, I_B = 200 mAdc)		$V_{BE(sat)}$	-	0.75	1.2	Vdc
DYNAMIC CHARACTERISTICS						
Common Emitter Cutoff Frequency (I_C = 2.0 Adc, V_{CE} = 6.0 Vdc)		$f_{\alpha e}$	12	20	-	kHz

**Sweep method: 1/2 cycle sine wave, 60 Hz .

FIGURE 1 — POWER TEMPERATURE DERATING CURVE

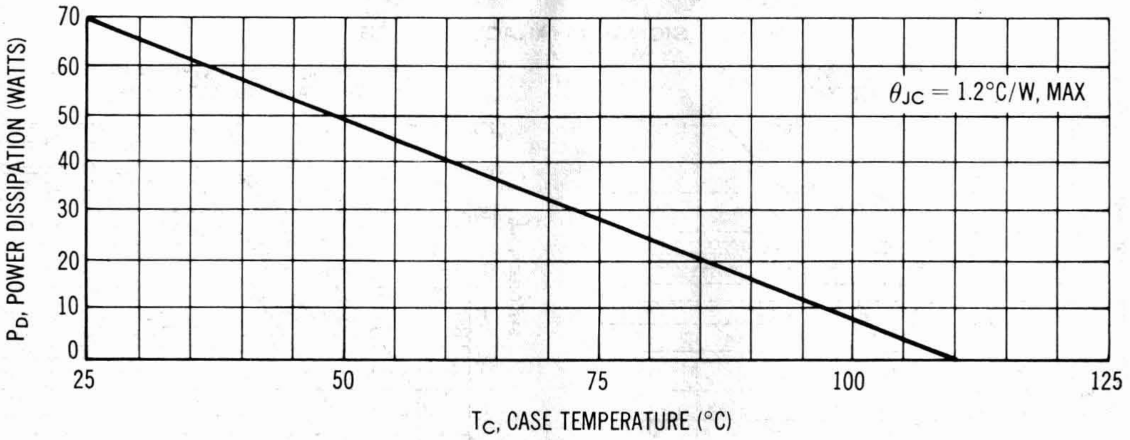
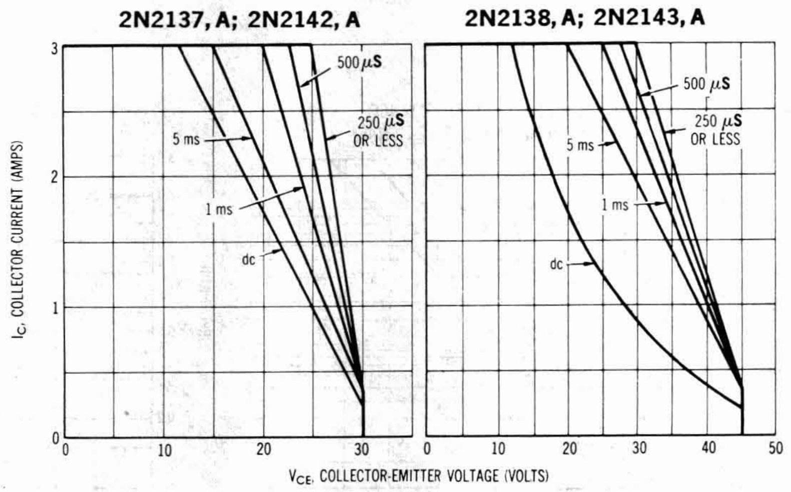
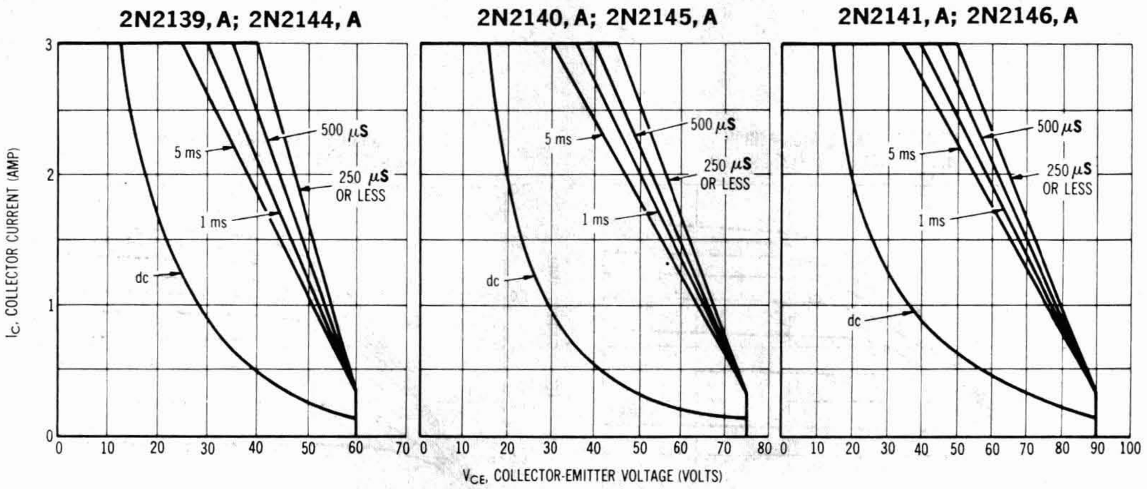


FIGURE 2 — ACTIVE REGION SAFE OPERATING AREAS

The active region safe operating area curves indicate I_C-V_{CE} limits to be observed in order to avoid secondary breakdown. (Secondary breakdown is independent of temperature and duty cycle.) These curves do not define operation in the avalanche region. To insure operation below the maximum junction temperature, power derating must be observed for both steady state and pulse conditions.





LARGE SIGNAL CHARACTERISTICS

FIGURE 3 — TRANSCONDUCTANCE
(ALL TYPES)

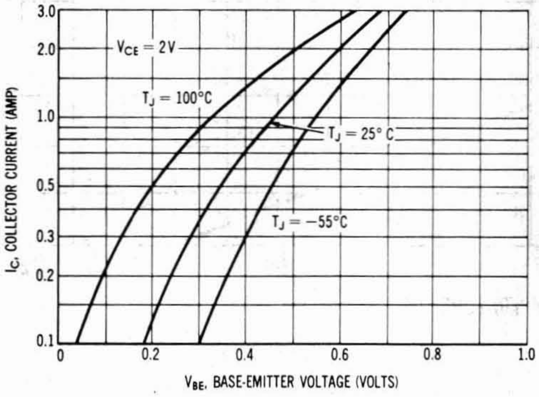


FIGURE 4 — INPUT ADMITTANCE
(2N2137A-2N2141A, 2N2137-2N2141)

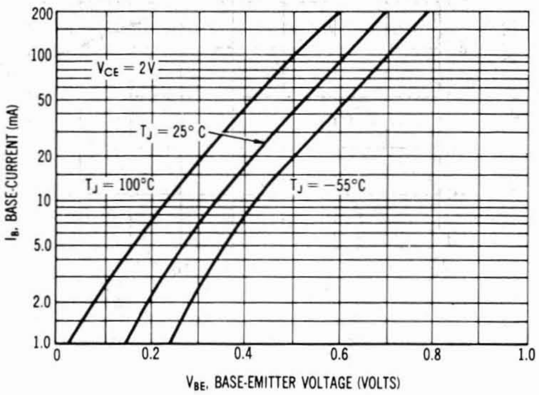


FIGURE 5 — INPUT ADMITTANCE
(2N2142A-2N2146A, 2N2142-2N2146)

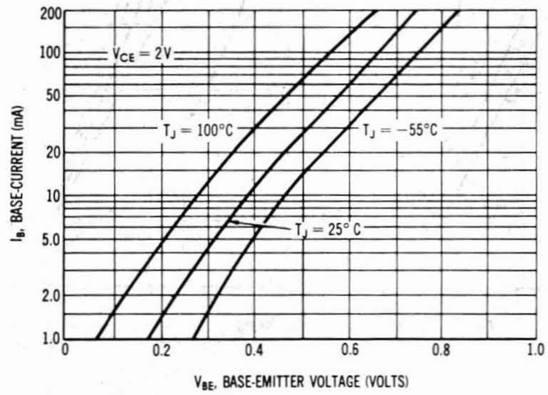


FIGURE 6 — NORMALIZED DC CURRENT GAIN
(ALL TYPES)

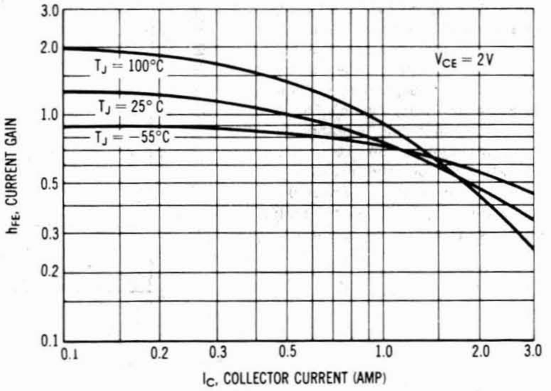


FIGURE 7 — SATURATION REGION
(2N2137A-2N2141A, 2N2137-2N2141)

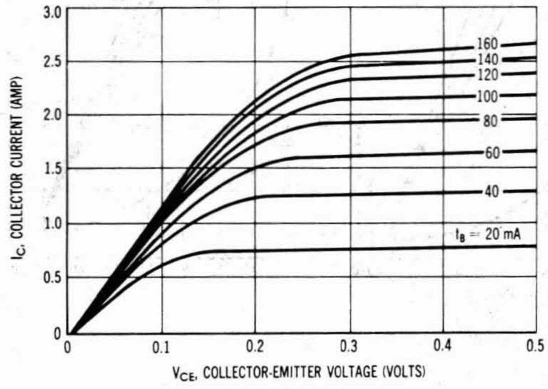
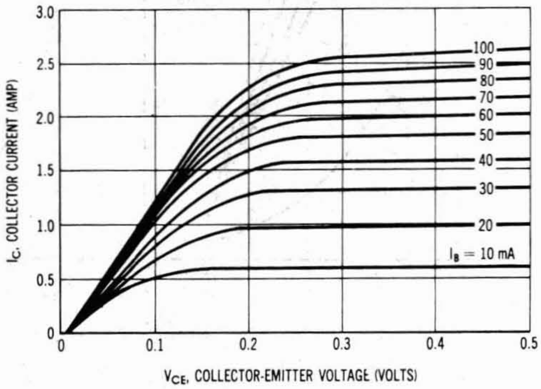


FIGURE 8 — SATURATION REGION
(2N2142A-2N2146A, 2N2142-2N2146)

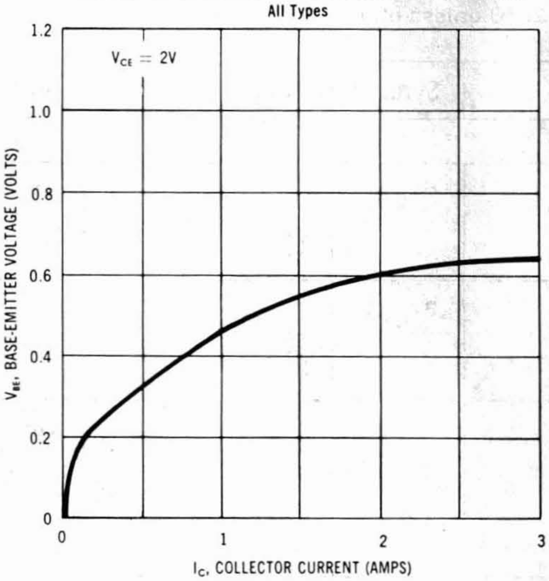


2N2137 thru 2N2146 (continued)

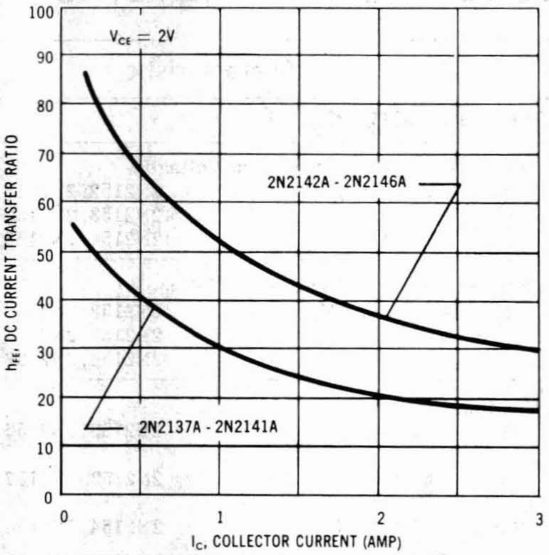
INPUT & TRANSFER CHARACTERISTICS

BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT

All Types



DC CURRENT TRANSFER RATIO versus COLLECTOR CURRENT



2N2152 thru 2N2154 (GERMANIUM)
2N2156 thru 2N2158

CASE 5
(TO-36)

PNP germanium power transistors for high-power, high-gain applications in high-reliability industrial equipment.

MAXIMUM RATINGS

Rating	Symbol	2N2152 2N2156	2N2153 2N2157	2N2154 2N2158	Unit
Collector-Emitter Voltage	V_{CEO}	30	45	60	Vdc
Collector-Emitter Voltage	V_{CES}	45	60	75	Vdc
Collector-Base Voltage	V_{CB}	45	60	75	Vdc
Emitter-Base Voltage	V_{EB}	25	30	40	Vdc
Collector Current	I_C		30		Adc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D		170 0.5		Watts $W/^oC$
Operating Junction Temperature Range	T_J		-65 to +110		^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.5	$^oC/W$

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

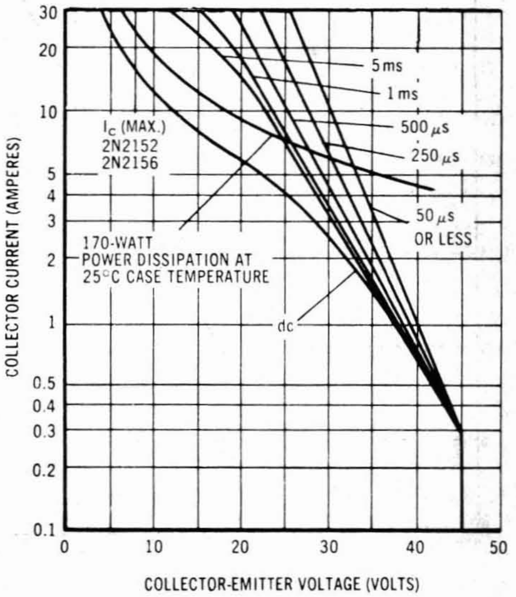
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage*	BV_{CEO}*				Vdc
(I_C = 1.0 Adc, I_B = 0) 2N2152, 2N2156		30	-	-	
2N2153, 2N2157		45	-	-	
2N2154, 2N2158		60	-	-	
Collector-Emitter Breakdown Voltage*	BV_{CES}*				Vdc
(I_C = 300 mAdc, V_{BE} = 0) 2N2152, 2N2156		45	-	-	
2N2153, 2N2157		60	-	-	
2N2154, 2N2158		75	-	-	
Floating Potential	V_{EBF}				Vdc
(V_{CB} = 45 Vdc, I_E = 0) 2N2152, 2N2156		-	-	1.0	
(V_{CB} = 60 Vdc, I_E = 0) 2N2153, 2N2157		-	-	1.0	
(V_{CB} = 75 Vdc, I_E = 0) 2N2154, 2N2158		-	-	1.0	
Collector Cutoff Current	I_{CBO}				mAdc
(V_{CB} = 2V, I_E = 0)		-	0.08	0.2	
(V_{CB} = 45 Vdc, I_E = 0) 2N2152, 2N2156		-	0.9	4.0	
(V_{CB} = 60 Vdc, I_E = 0) 2N2153, 2N2157		-	0.9	4.0	
(V_{CB} = 75 Vdc, I_E = 0) 2N2154, 2N2158		-	0.9	4.0	
(V_{CB} = $V_{CB(max)}$, I_E = 0, T_C = 71°C)		-	4.0	15	
Emitter Cutoff Current	I_{EBO}				mAdc
(V_{BE} = 25 Vdc, I_C = 0)		-	0.2	4.0	
(V_{BE} = 30 Vdc, I_C = 0)		-	0.2	4.0	
(V_{BE} = 40 Vdc, I_C = 0)		-	0.2	4.0	
(V_{BE} = $V_{EB(max)}$, I_C = 0, T_C = 71°C)		-	2.7	15	
ON CHARACTERISTICS					
DC Current Gain	h_{FE}				-
(I_C = 5.0 Adc, V_{CB} = 2 Vdc) 2N2152, 2N2153, 2N2154		50	75	100	
2N2156, 2N2157, 2N2158		80	105	160	
(I_C = 15 Adc, V_{CB} = 2 Vdc) 2N2152, 2N2153, 2N2154		25	47	-	
2N2156, 2N2157, 2N2158		40	63	-	
(I_C = 25 Adc, V_{CB} = 2 Vdc)		15	38	-	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$				Vdc
(I_C = 5.0 Adc, I_B = 500 mAdc)		-	0.06	0.1	
(I_C = 25 Adc, I_B = 2 Adc)		-	0.2	0.3	
Base-Emitter On Voltage	$V_{BE(on)}$				Vdc
(I_C = 5.0 Adc, I_B = 500 mAdc)		-	0.65	1.0	
(I_C = 25 Adc, I_B = 2 Adc)		-	1.0	2.0	
SMALL SIGNAL CHARACTERISTICS					
Common-Emitter Cutoff Frequency (I_C = 5.0 Adc, V_{CE} = 6.0 Vdc)	$f_{\alpha e}$	2.0	2.7	-	kHz

*To avoid excessive heating of the collector junction, perform these tests with an oscilloscope.

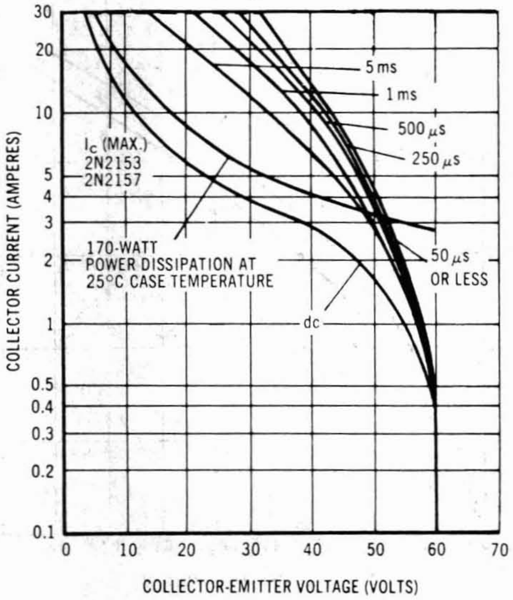
SAFE OPERATING AREAS

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

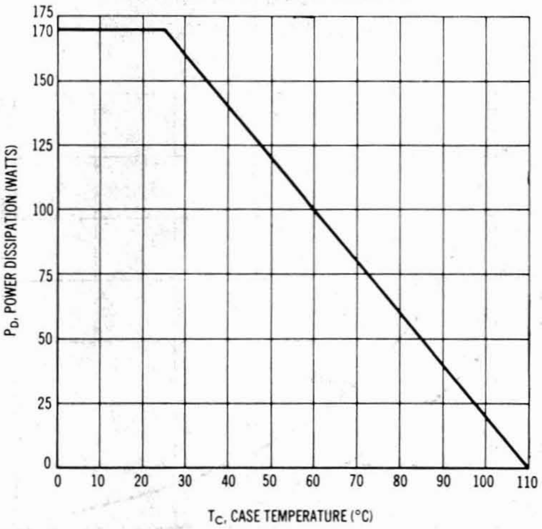
2N2152, 2N2156



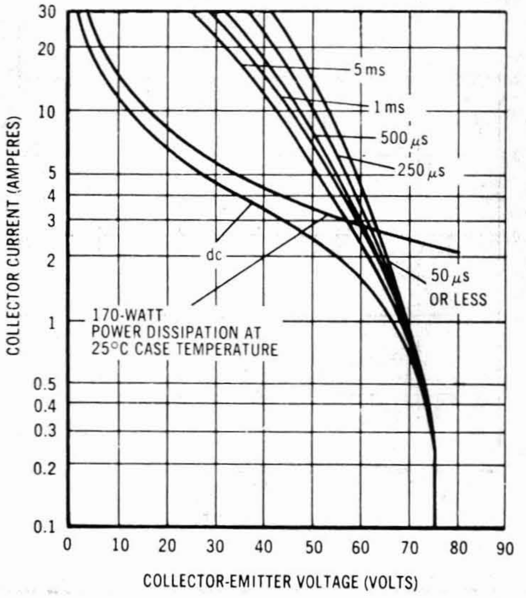
2N2153. 2N2157



POWER-TEMPERATURE DERATING CURVE



2N2154, 2N2158



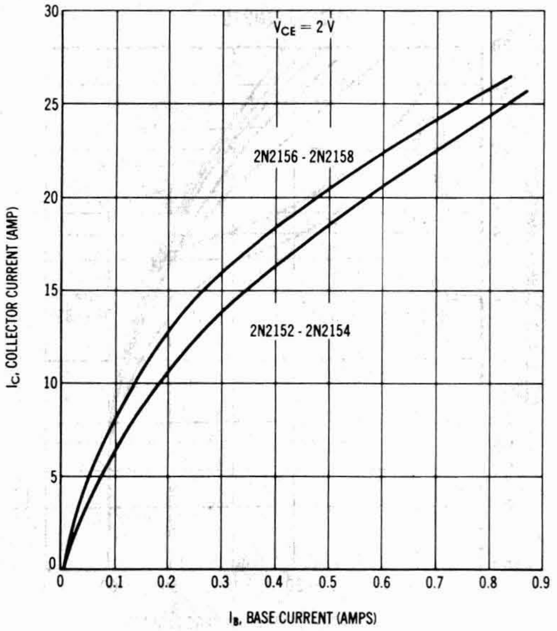
The maximum continuous power is related to maximum junction temperature by the thermal resistance factor. This curve has a value of 170 Watts at case temperatures of 25°C and is 0 Watts at 110^{0} C with a linear relation between the two temperatures such that:

$$\text{allowable } P_D = \frac{110^{O} - Tc}{0.5}$$

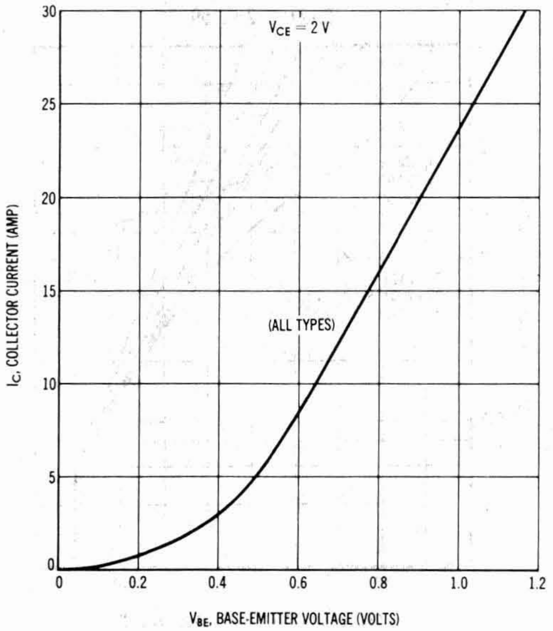
2N2152 thru 2N2154 , 2N2156 thru 2N2158 (continued)

TYPICAL INPUT AND TRANSFER CHARACTERISTICS

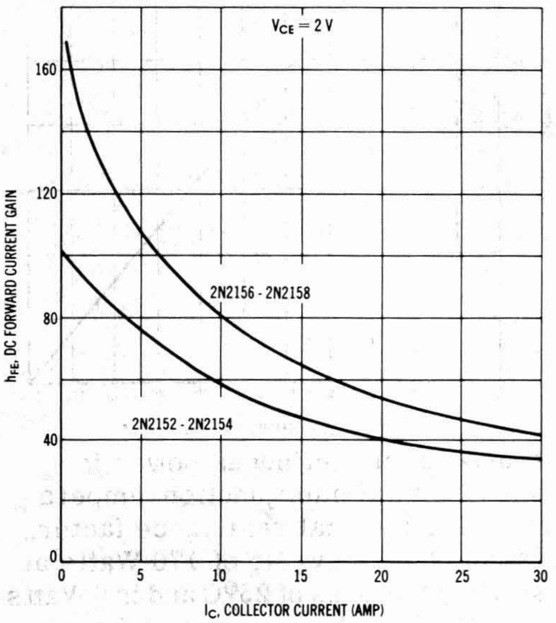
COLLECTOR CURRENT
versus BASE CURRENT



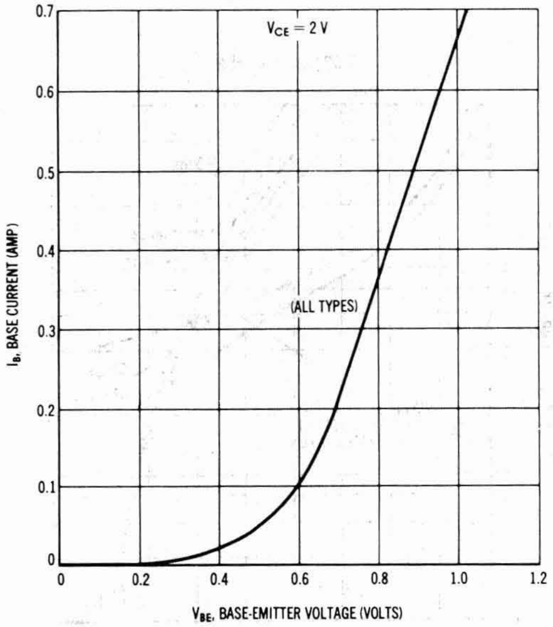
COLLECTOR CURRENT
versus BASE-EMITTER VOLTAGE



DC CURRENT GAIN
versus COLLECTOR CURRENT



BASE CURRENT versus
BASE-EMITTER VOLTAGE



2N2171

FOR SPECIFICATIONS, SEE 2N381 DATA.

2N2192, A, B thru 2N2195, A, B
(SILICON)

NPN silicon annular transistors for high-current switching and amplifier applications.

CASE 31
(TO-5)

Collector connected to case

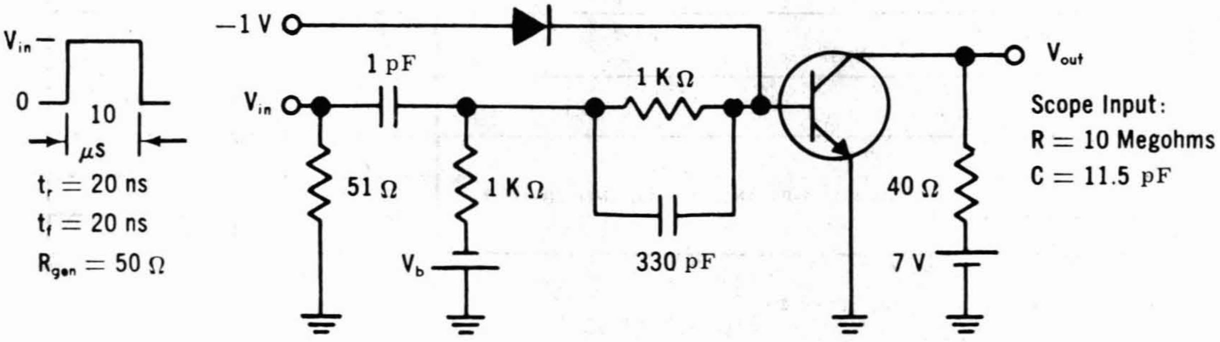
MAXIMUM RATINGS

Rating	Symbol	2N2192 2N2192A 2N2192B 2N2194 2N2194A 2N2194B	2N2193 2N2193A 2N2193B	2N2195 2N2195A 2N2195B	Unit
Collector-Base Voltage	V_{CB}	60	80	45	Vdc
Collector-Emitter Voltage	V_{CEO}	40	50	25	Vdc
Emitter-Base Voltage	V_{EB}	5	8	5	Vdc
Collector Current	I_C	1.0	1.0	1.0	Adc
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	0.8 4.56	0.8 4.56	0.6 3.43	Watt mW/°C
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	← 2.8 → ← 16 →			Watts mW/°C
Junction Temperature, Operating	T_J	-65 to +200			°C
Storage Temperature Range	T_{stg}	-65 to +200			°C

FIGURE 1

2N2193, A, B }
2N2194, A, B } V_{in} = 15 V, V_b = 15 V

2N2192, A, B — V_{in} = 7.5 V, V_b = 7.5 V



V_{in}
0
10 μs
t_r = 20 ns
t_f = 20 ns
R_{gen} = 50 Ω
−1 V
1 pF
V_{in}
51 Ω
1 KΩ
V_b
1 KΩ
330 pF
40 Ω
7 V
V_{out}
Scope Input:
R = 10 Megohms
C = 11.5 pF

2N2192,A,B thru 2N2195,A,B (continued)

ELECTRICAL CHARACTERISTICS (at 25°C unless otherwise specified)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N2192, A, B, 2N2194, A, B	BV_{CBO}	60	-	Vdc
	2N2193, A, B		80	-	
	2N2195, A, B		45		
Collector Emitter-Open Base Sustain Voltage* (I_C = 25 mA pulsed, I_B = 0)	2N2192, A, B, 2N2194, A, B	$V_{CEO(sus)}$*	40	-	Vdc
	2N2193, A, B		50	-	
	2N2195, A, B		25	-	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	2N2192, A, B, 2N2194, A, B,	BV_{EBO}	5	-	Vdc
	2N2195, A, B		5	-	
	2N2193, A, B		8	-	
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)	2N2192, A, B, 2N2194, A B	I_{CBO}	-	.010	μAdc
	2N2195, A, B			.100	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)	2N2192, A, B		-	15	
	2N2194, A, B		-	25	
	2N2195, A, B		-	50	
(V_{CB} = 60 Vdc, I_E = 0)	2N2193, A, B		-	.010	
(V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)	2N2193, A, B		-	25	
Emitter Cutoff Current (V_{EB} = 3 Vdc, I_C = 0)	2N2192, A, B, 2N2194, A, B	I_{EBO}	-	.050	μAdc
	2N2195, A, B		-	.100	
(V_{EB} = 5 Vdc, I_C = 0)	2N2193, A, B		-	.050	
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	2N2192 thru 2N2195	$V_{CE(sat)}$	-	0.35	Vdc
	2N2192A thru 2N2195A		-	0.25	
	2N2192B thru 2N2195B		-	0.18	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$	-		Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			-	1.3	
DC Current Gain* (I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N2192, A, B, 2N2193, A, B	h_{FE}*	15	-	-
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N2192, A, B		75	-	
	2N2193, A, B		30	-	
	2N2194, A, B		15	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N2192, A, B		35	-	
	2N2193, A, B		20	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N2192, A, B		100	300	
	2N2193, A, B		40	120	
	2N2194, A, B		20	60	
	2N2195, A, B		20	-	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)	2N2192, A, B		70	-	
	2N2193, A, B		30	-	
	2N2194, A, B		15	-	
	2N2195, A, B		10	-	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)	2N2192, A, B		35	-	
	2N2193, A, B		20	-	
	2N2194, A, B		12	-	
(I_C = 1.0 Adc, V_{CE} = 10 Vdc)	2N2192, A, B, 2N2193, A, B		15	-	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)		C_{ob}	-	20	pF
Small Signal Current Gain (I_C = 50 mA, V_{CE} = 10 V, f = 20 MHz)		h_{fe}	2.5	-	-
Rise Time	2N2192-94, 2N2192A-94A, 2N2192B-94B	t_r	-	70	ns
Storage Time		t_s	-	150	ns
Fall Time		t_f	-	50	ns

*Pulse Test: PW ≤ 300 μs Duty Cycle ≤ 2%

2N2212

PNP GERMANIUM POWER TRANSISTORS

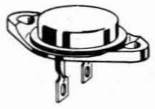
. . . designed for high-current switching applications requiring low saturation voltages, short switching times and good collector-emitter sustaining capability.

- Alloy-Diffused Epitaxial Construction
- Low Saturation Voltage –
  $V_{CE(SAT)}$ = 0.5 Vdc (Max) @I_C = 5.0 Adc

10 AMPERE

PNP ADE GERMANIUM
POWER TRANSISTORS

120 VOLTS
102 WATTS



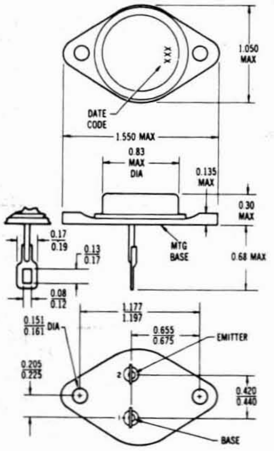
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
*Collector-Emitter Voltage	V_{CER}	120	Vdc
*Collector-Base Voltage	V_{CB}	120	Vdc
*Emitter-Base Voltage	V_{EB}	1.5	Vdc
*Collector Current - Continuous	I_C	10	Adc
*Base Current - Continuous	I_B	3.0	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	102 1.2	Watts W/°C
*Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
*Thermal Resistance, Junction to Case	θ_{JC}	0.83	°C/W

*Indicates JEDEC Registered Data.

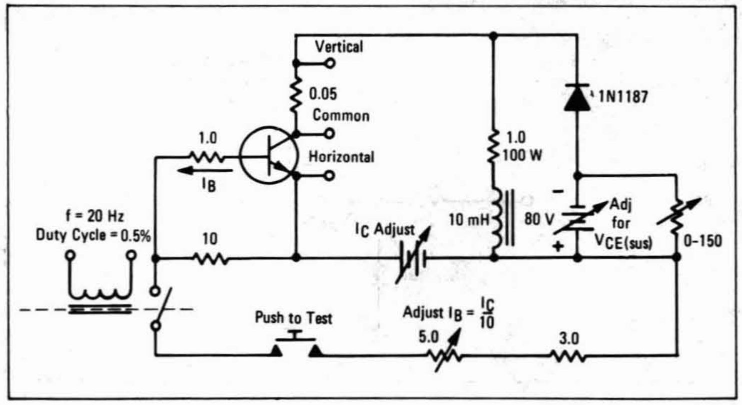


XXX
DATE CODE
1.050 MAX
1.550 MAX
0.83 MAX DIA
0.135 MAX
0.30 MAX
0.17 / 0.19
0.13 / 0.17
MTG BASE
0.68 MAX
0.08 / 0.12
1.177 / 1.197
0.151 / 0.161 DIA
0.655 / 0.675
EMITTER
0.205 / 0.225
2
0.420 / 0.440
1
BASE

Collector Connected to Case

CASE 4–04
(TO-41)

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT



Vertical
0.05
Common
1.0
Horizontal
I_B
1N1187
1.0
100 W
f = 20 Hz
Duty Cycle = 0.5%
10
I_C Adjust
10 mH
80 V
-
+
Adj for $V_{CE(sus)}$
0-150
Push to Test
Adjust $I_B = \frac{I_C}{10}$
5.0
3.0

2N2212 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	BV_{CEO}	60	-	Vdc
Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 5.0 Adc, I_B = 0)	$V_{CE(sus)}$	60	-	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 120 Vdc, R_{BE} = 100 Ohms)	I_{CER}	-	50	mAdc
*Collector Cutoff Current (V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C)	I_{CEX}	-	20	mAdc
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0) *(V_{CB} = 100 Vdc, I_E = 0)	I_{CBO}	- -	200 2.0	μAdc mAdc
Emitter Cutoff Current (V_{EB} = 0.75 Vdc, I_C = 0)	I_{EBO}	-	25	mAdc

ON CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
*DC Current Gain (I_C = 0.6 Adc, V_{CE} = 1.0 Vdc) (I_C = 1.2 Adc, V_{CE} = 1.0 Vdc) (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	50 60 50	200 200 120	-
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)	$V_{CE(sat)}$	-	0.5	Vdc
*Base-Emitter On Voltage (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	$V_{BE(on)}$	-	1.0	Vdc

SMALL-SIGNAL CHARACTERISTICS

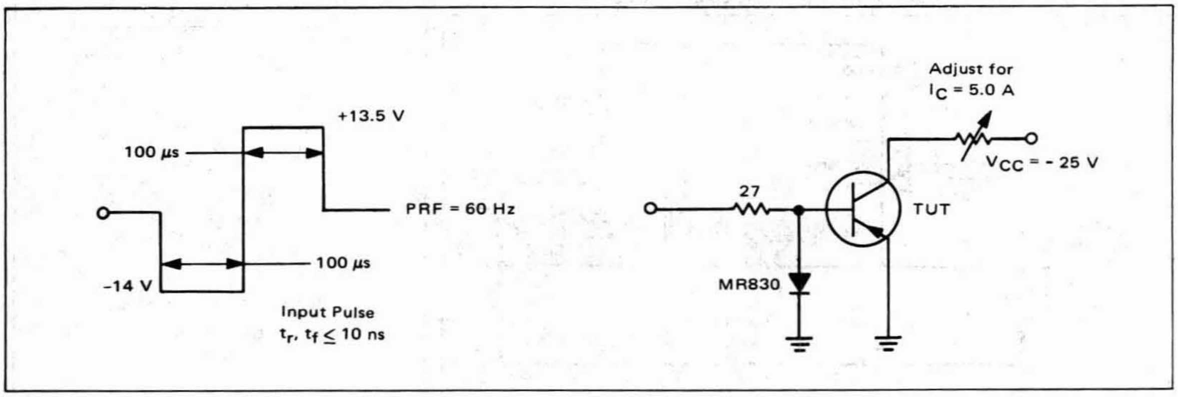
Characteristic	Symbol	Min	Max	Unit
*Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)	h_{fe}	15	-	-

SWITCHING CHARACTERISTICS

Characteristic	Conditions	Symbol	Min	Max	Unit
Rise Time	(I_C = 5.0 Adc, I_{B1} = 0.5 Adc, I_{B2} = 0.5 Adc) (See Figure 2)	t_r	-	7.0	μs
Storage Time		t_s	-	10	μs
Fall Time		t_f	-	8.0	μs

*Indicates JEDEC Registered Data.

FIGURE 2 – SWITCHING TIME TEST CIRCUIT



2N2218 (SILICON)
2N2219
2N2221
2N2222
2N2904 thru 2N2907

CASE 22
(TO-18)

2N2221
2N2222
2N2906
2N2907

CASE 31
(TO-5)

2N2218, 2N2219,
2N2904, 2N2905

Silicon annular star transistors for high-speed switching and DC to UHF amplifier applications. NPN types 2N2218 thru 2N2222 are complementary to PNP types 2N2904 thru 2N2907.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	NPN	PNP	Unit
Collector - Base Voltage	V_{CB}	60	60	Vdc
Collector - Emitter Voltage	V_{CEO}	30	40	Vdc
Emitter - Base Voltage	V_{EB}	5	5	Vdc
Collector Current	I_C	800	600	mAdc
Total Device Dissipation @ 25°C Case Temperature	P_D			
To - 5: 2N2218, 2N2219		3		W
Derate Above 25°C		20		mW/°C
2N2904, 2N2905			3	W
Derate Above 25°C			17.2	mW/°C
To - 18: 2N2221, 2N2222		1.8		W
Derate Above 25°C		12		mW/°C
2N2906, 2N2907			1.8	W
Derate Above 25°C			10.3	mW/°C
Total Device Dissipation @ 25°C Ambient Temperature	P_D			
To - 5: 2N2218, 2N2219		0.8		W
Derate Above 25°C		5.33		mW/°C
2N2904, 2N2905			0.6	W
Derate Above 25°C			3.43	mW/°C
To - 18: 2N2221, 2N2222		0.5		W
Derate Above 25°C		3.33		mW/°C
2N2906, 2N2907			0.4	W
Derate Above 25°C			2.28	mW/°C
Operating Junction Temperature	T_J	-65 to +175	-65 to+200	°C
Storage Temperature	T_{stg}	-65 to + 200	-65 to +200	°C

2N2218 SERIES, 2N2904 SERIES (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Static Characteristic		Fig. No.	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)		---	BV_{CBO}	60	---	Vdc
Collector-Emitter Breakdown Voltage• (I_C = 10 mAdc, I_B = 0)	2N2218-19, 2N2221-22 2N2904 thru 2N2907	9	BV_{CEO}•	30 40	--- ---	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)		---	BV_{EBO}	5	---	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0)	2N2218-19, 2N2221-22 2N2904 thru 2N2907	---	I_{CBO}	--- ---	.01 .02	µAdc
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	2N2218-19, 2N2221-22 2N2904 thru 2N2907			--- ---	10 20	
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)	2N2904 thru 2N2907	---	I_{CEX}	---	50	nAdc
Base Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)	2N2904 thru 2N2907	---	I_{BL}	---	50	nAdc
Collector-Emitter Saturation Voltage• (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)		12, 15	$V_{CE\,(sat)}$•	--- ---	0.4 1.6	Vdc
Base-Emitter Saturation Voltage• (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)		13, 16	$V_{BE\,(sat)}$•	--- ---	1.3 2.6	Vdc
DC Forward Current Transfer Ratio (I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N2218, 2N2221, 2N2904, 2N2906 2N2219, 2N2222, 2N2905, 2N2907	10 11	h_{FE}	20 35	--- ---	---
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	2N2218, 2N2221, 2N2904, 2N2906 2N2219, 2N2222, 2N2905, 2N2907			25 50	--- ---	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N2218, 2N2221, 2N2904, 2N2906 2N2219, 2N2222, 2N2905, 2N2907			35 75	--- ---	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)•	2N2218, 2N2221, 2N2904, 2N2906 2N2219, 2N2222, 2N2905, 2N2907			40 100	120 300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)•	2N2218, 2N2221, 2N2904, 2N2906 2N2219, 2N2222, 2N2905, 2N2907			20 30	--- ---	

Dynamic Characteristic		Fig. No.	Symbol	Min	Typ	Max	Unit
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		4	C_{ob}	---	---	8	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz) (V_{BE} = 2 Vdc, I_C = 0, f = 100 kHz)	2N2218-19, 2N2221-22 2N2904 thru 2N2907	4	C_{ib}	--- ---	--- ---	30 30	pF
Current Gain - Bandwidth Product (I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz) (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N2218-19, 2N2221-22 2N2904 thru 2N2907	8	f_T	250 200	--- ---	--- ---	MHz
Delay Time	2N2904 thru 2N2907	1	t_d	---	6	10	ns
Rise Time	2N2904 thru 2N2907	1	t_r	---	20	40	ns
Turn-On Time	2N2218-19, 2N2221-22 2N2904 thru 2N2907	1	t_{on}	--- ---	26 26	--- 45	ns
Storage Time	2N2904 thru 2N2907	2	t_s	---	50	80	ns
Fall Time	2N2904 thru 2N2907	2	t_f	---	20	30	ns
Turn-Off Time	2N2218-19, 2N2221-22 2N2904 thru 2N2907	2	t_{off}	--- ---	70 70	--- 100	ns
Total Switching Time		3	t_{total}	---	12	---	ns

•Pulse Test, Pulse Width ≤ 300 µs Duty Cycle ≤ 2%

PNP SWITCHING-TIME CIRCUITS

For NPN Switching Tests, reverse diodes, polarities, and input pulses.

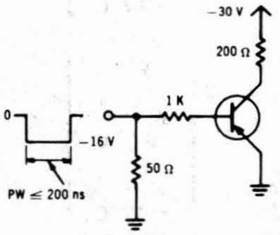


FIGURE 1 — SATURATED TURN-ON SWITCHING-TIME TEST CIRCUIT

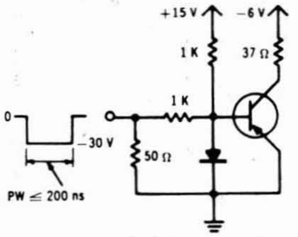


FIGURE 2 — SATURATED TURN-OFF SWITCHING-TIME TEST CIRCUIT

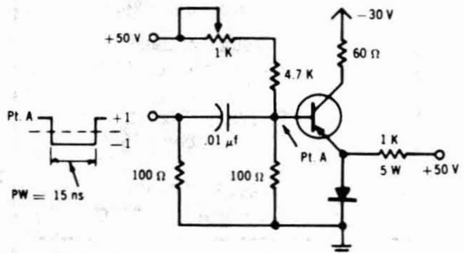


FIGURE 3 — NON-SATURATED SWITCHING-TIME TEST CIRCUIT

FIGURE 4 — CAPACITANCE VARIATIONS versus VOLTAGE

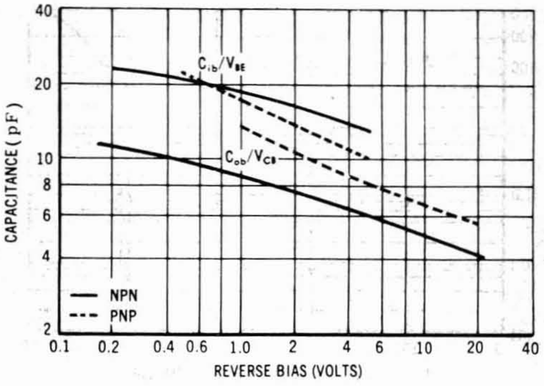


FIGURE 5 — ACTIVE REGION TIME CONSTANT versus COLLECTOR CURRENT

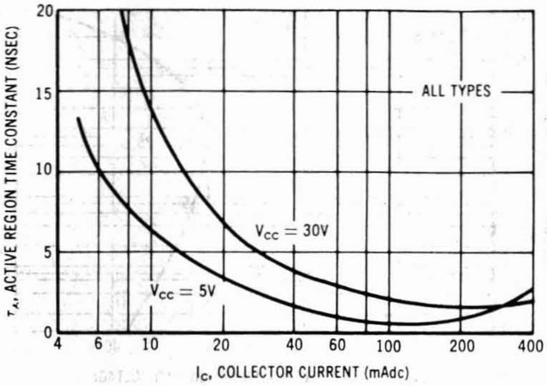


FIGURE 6 — TOTAL CONTROL CHARGE versus BASE CURRENT

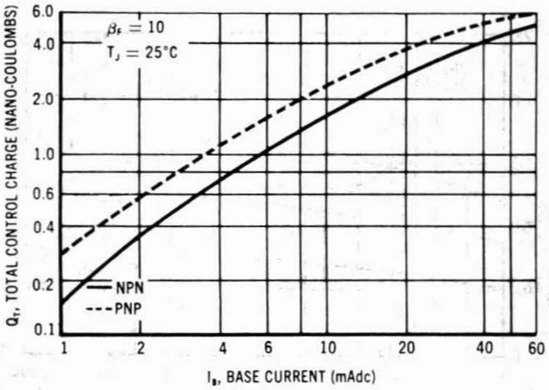
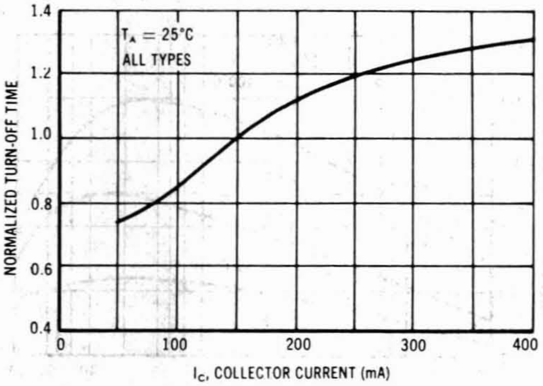


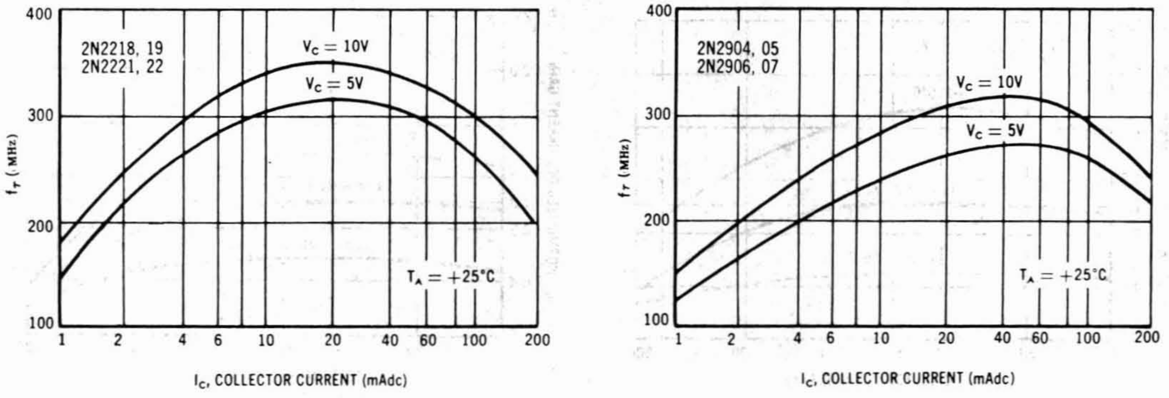
FIGURE 7 — NORMALIZED TURN-OFF TIME versus COLLECTOR CURRENT



NPN

PNP

FIGURE 8 — CURRENT-GAIN — BANDWIDTH PRODUCT versus COLLECTOR CURRENT



NPN **PNP**

FIGURE 9 — COLLECTOR CURRENT versus MINIMUM COLLECTOR-EMITTER BREAKDOWN VOLTAGE

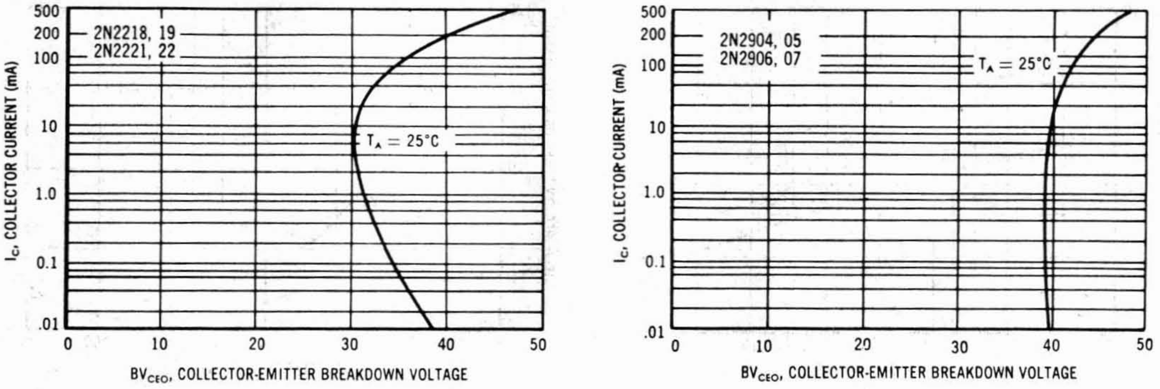


FIGURE 10 — LOW CURRENT GAIN

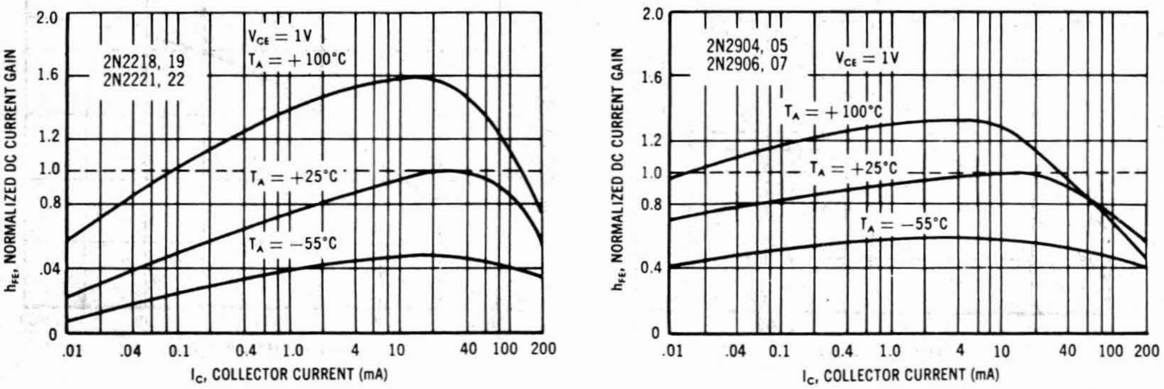
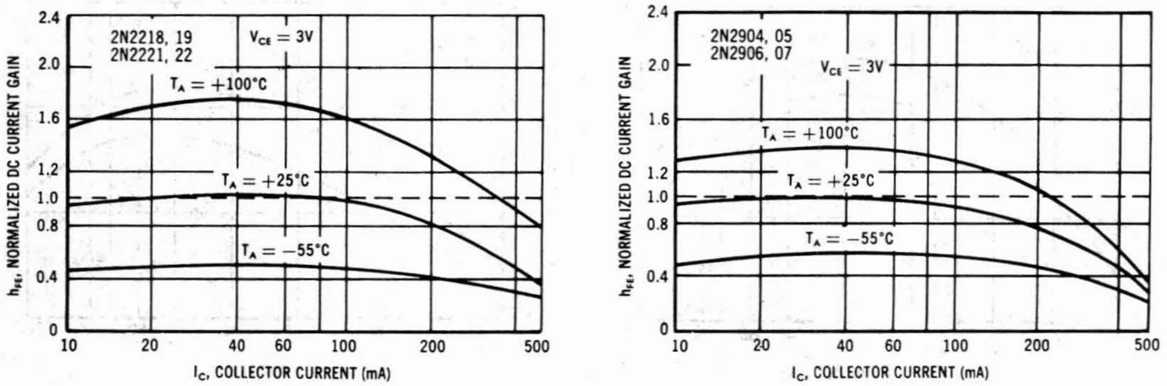


FIGURE 11 — HIGH CURRENT GAIN



NPN

FIGURE 12 — COLLECTOR SATURATION VOLTAGE versus BASE CURRENT

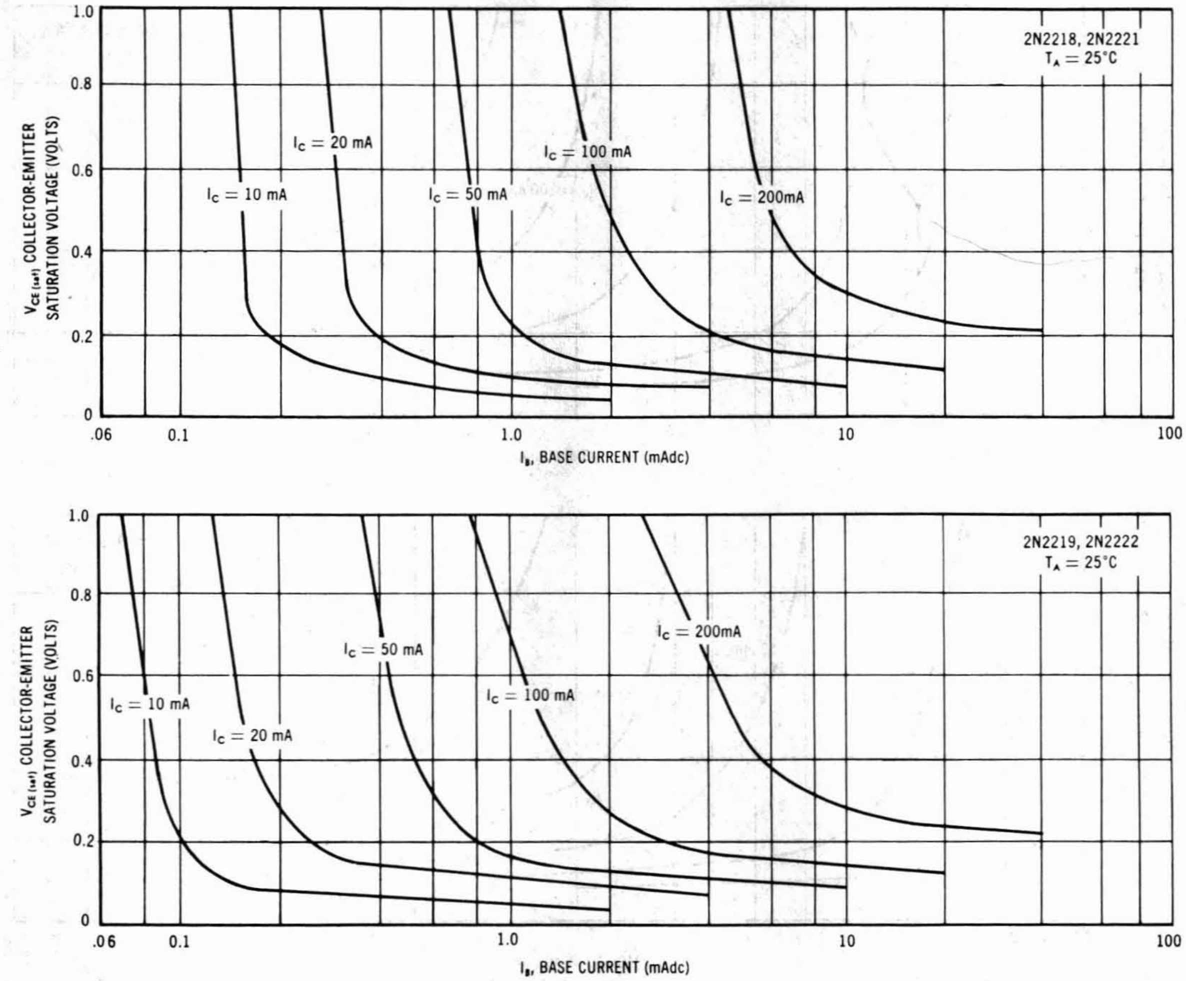


FIGURE 13 — BASE SATURATION VOLTAGE versus BASE CURRENT

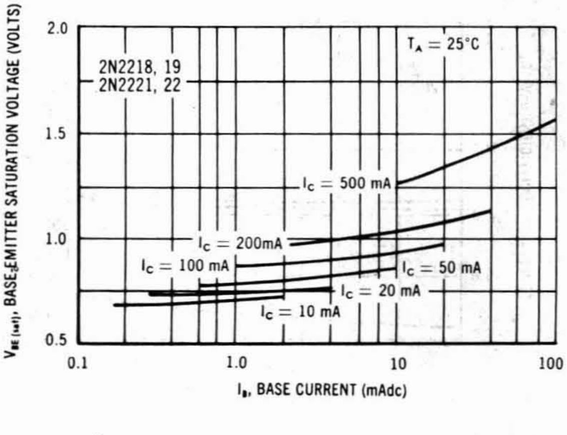
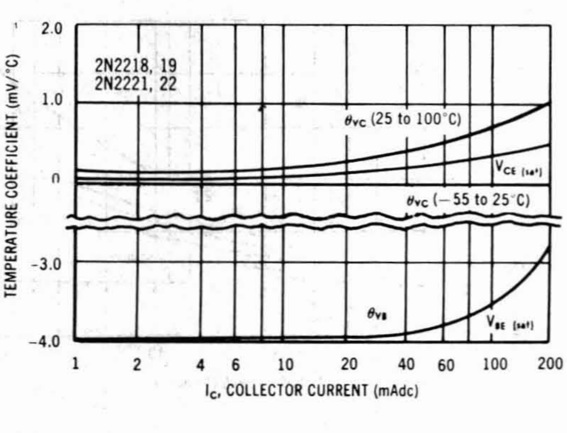


FIGURE 14 — TEMPERATURE COEFFICIENTS



PNP

FIGURE 15 — COLLECTOR SATURATION VOLTAGE versus BASE CURRENT

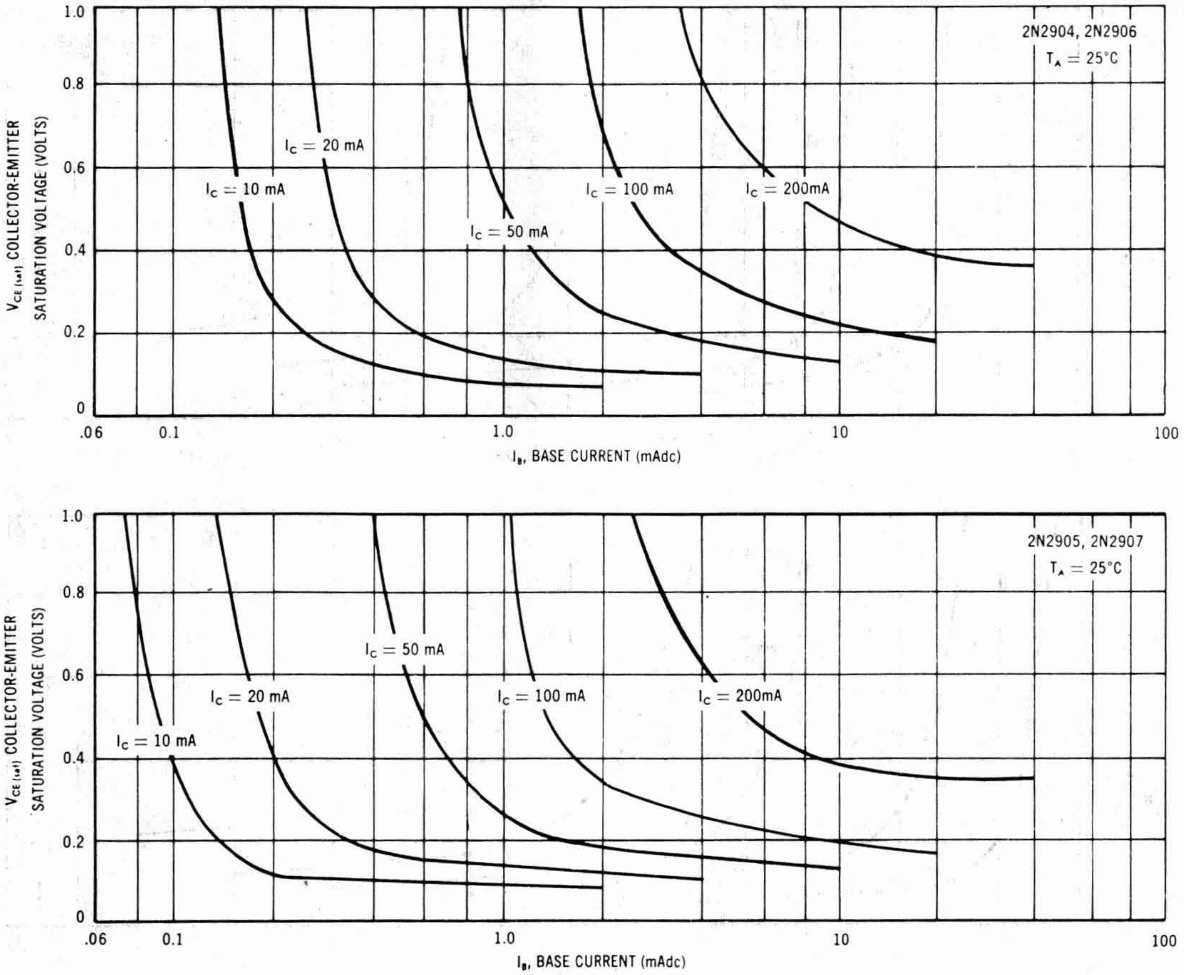


FIGURE 16 — BASE SATURATION versus BASE CURRENT

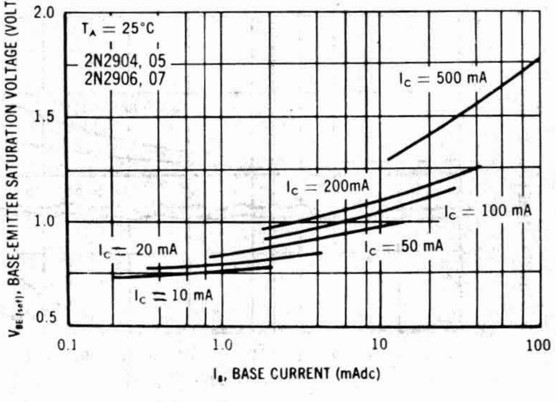
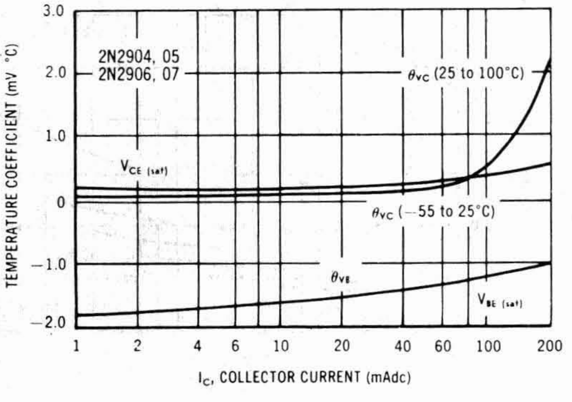


FIGURE 17 — TEMPERATURE COEFFICIENTS



2N2218A (SILICON)
2N2219A
2N2221A
2N2222A

CASE 22
(TO-18)
2N2221A
2N2222A

CASE 31
(TO-5)
2N2218A
2N2219A

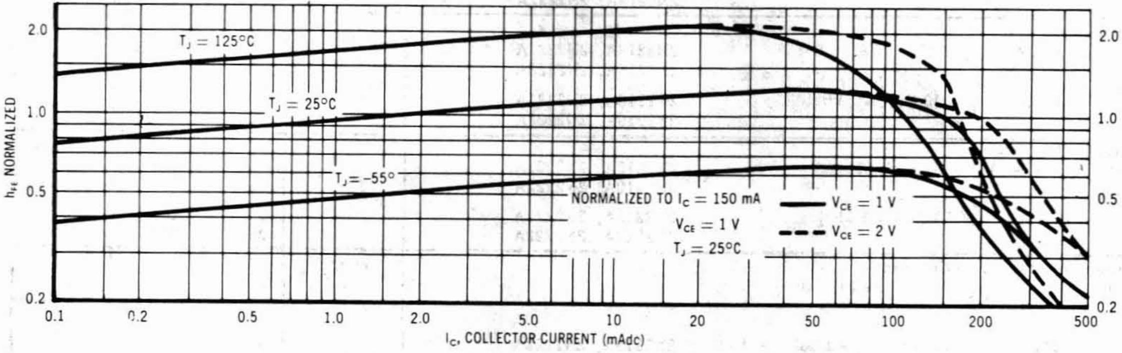
NPN silicon annular Star transistors for high-speed switching and DC to VHF amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N2218A 2N2219A (TO-5)	2N2221A 2N2222A (TO-18)	Unit
Collector-Base Voltage	V_{CB}	75	75	Vdc
Collector-Emitter Voltage	V_{CEO}	40	40	Vdc
Emitter-Base Voltage	V_{EB}	6	6	Vdc
Total Device Dissipation at 25°C Case Temperature Derating Factor Above 25°C	P_D	3 20	1.8 12	Watts mW/°C
Total Device Dissipation at 25°C Ambient Temperature Derating Factor Above 25°C	P_D	0.8 5.33	0.5 3.33	Watts mW/°C
Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to + 200		°C

TYPICAL CURRENT GAIN CHARACTERISTICS



2N2218A, 2N2219A, 2N2221A , 2N2222A (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

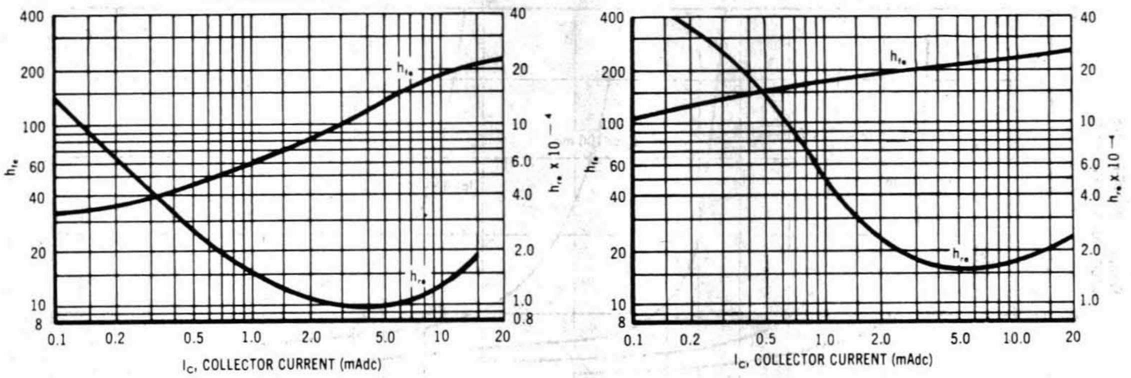
Static Characteristics		Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	75	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	6	—	Vdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)		I_{CBO}	—	0.01	μAdc
(V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)			—	10	
Collector Cutoff Current (V_{CE} = 60 Vdc, $V_{EB(off)}$ = 3.0 Vdc)		I_{CEX}	—	10	nAdc
Base Cutoff Current (V_{CE} = 60 Vdc, $V_{EB(off)}$ = 3.0 Vdc)		I_{BL}	—	20	nAdc
Emitter Cutoff Current (V_{BE} = 3 Vdc, I_C = 0)		I_{EBO}	—	10	nAdc
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE\ (sat)}$*	—	0.3	Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)			—	1.0	
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{BE(sat)}$*	0.6	1.2	Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)			—	2.0	
DC Forward Current Transfer Ratio* (I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N2218A, 2N2221A	h_{FE}*	20	—	—
	2N2219A, 2N2222A		35	—	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	2N2218A, 2N2221A		25	—	
	2N2219A, 2N2222A		50	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N2218A, 2N2221A		35	—	
	2N2219A, 2N2222A		75	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N2218A, 2N2221A		15	—	
	2N2219A, 2N2222A		35	—	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N2218A, 2N2221A		40	120	
	2N2219A, 2N2222A		100	300	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)	2N2218A, 2N2221A		20	—	
	2N2219A, 2N2222A		50	—	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)	2N2218A, 2N2221A		25	—	
	2N2219A, 2N2222A		40	—	

* Pulse Test ≤300 μs, duty cycle ≤2%

SMALL SIGNAL CHARACTERISTICS		Symbol	Min	Max	Unit
Small Signal Current Gain (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N2218A, 2N2221A	h_{fe}	30	150	—
	2N2219A, 2N2222A		50	300	
(I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	2N2218A, 2N2221A		50	300	
	2N2219A, 2N2222A		75	375	
Voltage Feedback Ratio (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N2218A, 2N2221A	h_{re}	-	5	$X10^{-4}$
	2N2219A, 2N2222A		-	8	
(I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	2N2218A, 2N2221A		-	2.5	
	2N2219A, 2N2222A		-	4	
Input Impedance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N2218A, 2N2221A	h_{ie}	1	3.5	k ohms
	2N2219A, 2N2222A		2.0	8	
(I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	2N2218A, 2N2221A		0.2	1.0	
	2N2219A, 2N2222A		0.25	1.25	
Output Admittance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N2218A, 2N2221A	h_{oe}	3	15	μmhos
	2N2219A, 2N2222A		5	35	
(I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	2N2218A, 2N2221A		10	100	
	2N2219A, 2N2222A		25	200	
Collector-Base Time Constant (I_C = 20 mA, V_{CE} = 20 V, f = 31.8 MHz)		r'_bC_c	-	150	ps
Noise Figure (I_C = 100μ A, V_{CE} = 10 V, Rg = 1 kΩ, f = 1 kHz)	2N2219A, 2N2222A	NF	-	4	dB

SMALL SIGNAL FORWARD CURRENT GAIN AND VOLTAGE FEEDBACK RATIO versus COLLECTOR CURRENT

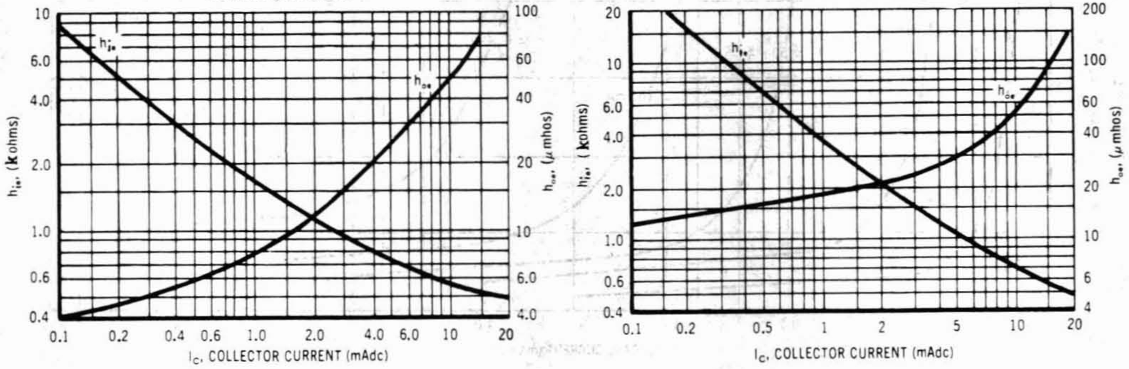
$V_{CE} = 10$ V @ 1 KHz


2N2218A, 2N2221A

2N2219A, 2N2222A

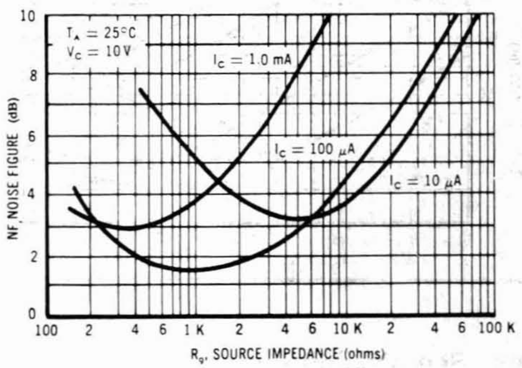
SMALL SIGNAL INPUT IMPEDANCE AND OUTPUT CONDUCTANCE versus COLLECTOR CURRENT

$V_{CE} = 10$ V @ 1 KHz

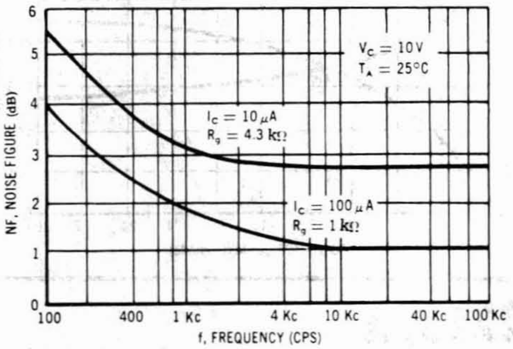

2N2218A, 2N2221A

2N2219A, 2N2222A

1 KC NOISE FIGURE versus SOURCE IMPEDANCE

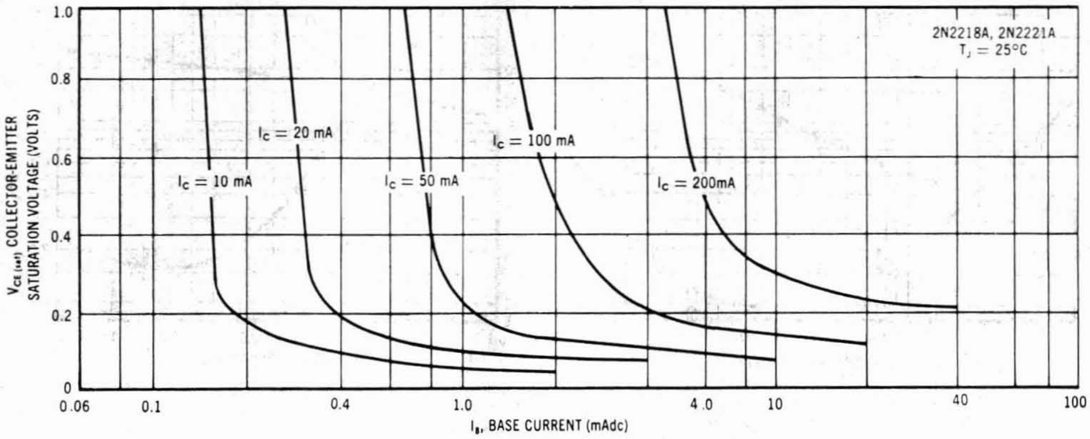


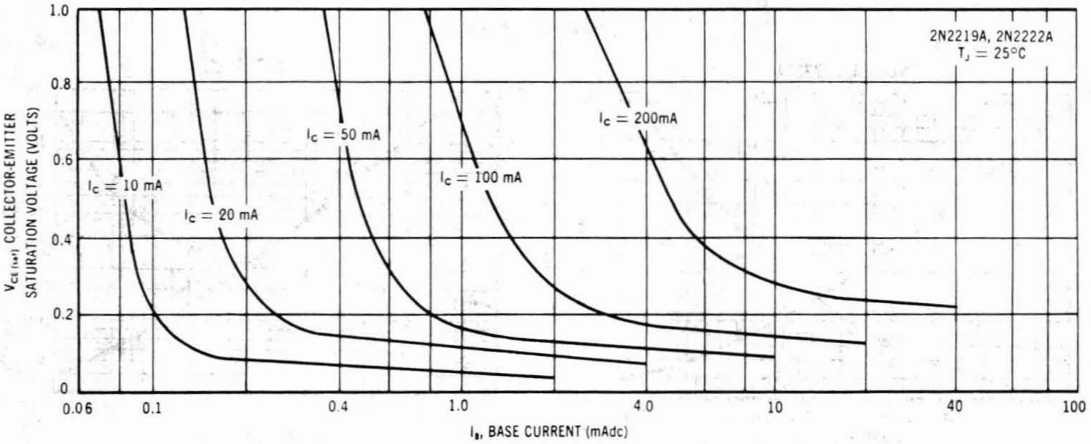
NOISE FIGURE versus FREQUENCY



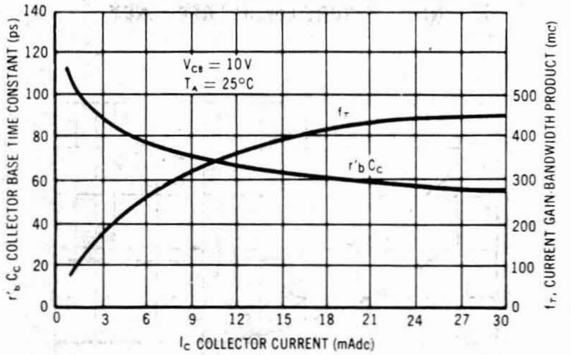
2N2218A, 2N2219A, 2N2221A, 2N2222A (continued)

COLLECTOR SATURATION VOLTAGE versus BASE CURRENT

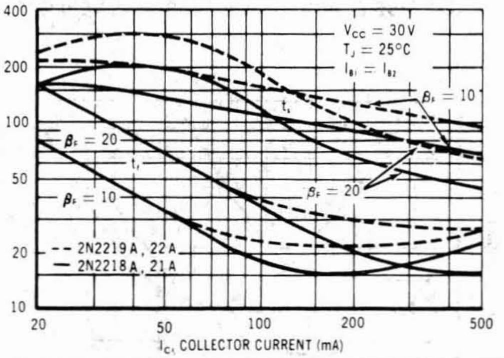




CURRENT GAIN – BANDWIDTH PRODUCT and COLLECTOR BASE TIME CONSTANT versus COLLECTOR CURRENT



STORAGE AND FALL TIME versus COLLECTOR CURRENT



2N2223, A

For Specifications, See 2N2060 Data.

2N2224 (SILICON)

CASE 31
(TO-5)

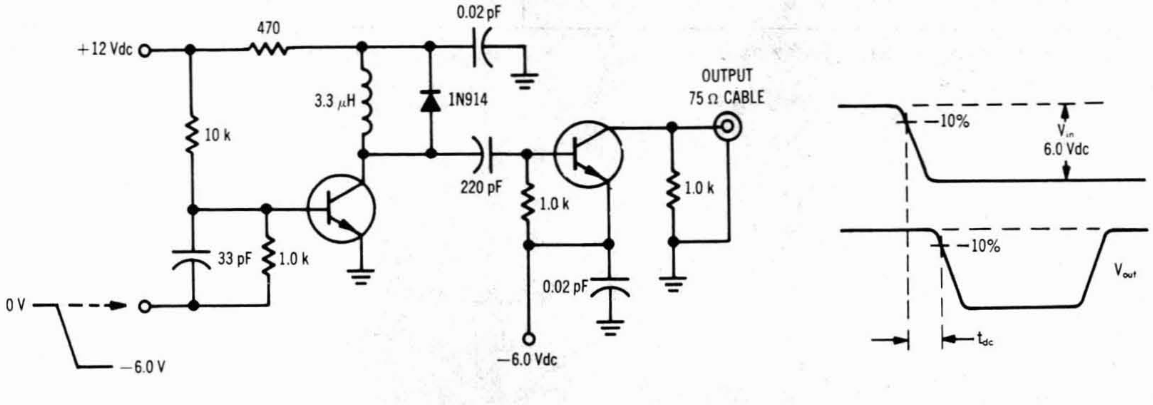
NPN silicon annular transistor designed primarily for high speed switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	65	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current-Continuous	I_C	0.5	Adc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.8 5.33	W mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	3.0 20	Watts mW/°C
Operating Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1


+12 Vdc
470
0.02 pF
3.3 µH
1N914
10 k
220 pF
1.0 k
33 pF
1.0 k
0 V
−6.0 V
0.02 pF
−6.0 Vdc
OUTPUT
75 Ω CABLE
1.0 k
−10%
V_{in}
6.0 Vdc
−10%
V_{out}
t_{dc}

2N2224 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	65	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector-Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = +150°C)	I_{CBO}	- -	0.01 10	μAdc
Emitter Cutoff Current (V_{EB} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	1.0	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) (I_C = 1.0 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	20 25 35 40	- - 115 120	-
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$*	-	0.4	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$*	-	1.3	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain-Bandwidth Product (I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz) (I_C = 80 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250 160	- -	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)	C_{ob}	-	8.0	pF
Circuit Delay (Figure 1) (T_A = 25°C)	t_{dc}	-	15	ns
Circuit Delay - Total Change (Figure 1) (T_A = +10°C to T_A = +25°C)	Δt_{dc}	-	15	ns

*Pulse Test: PW ≦ 300 μs, Duty Cycle ≦ 2.0%

2N2242 (SILICON)

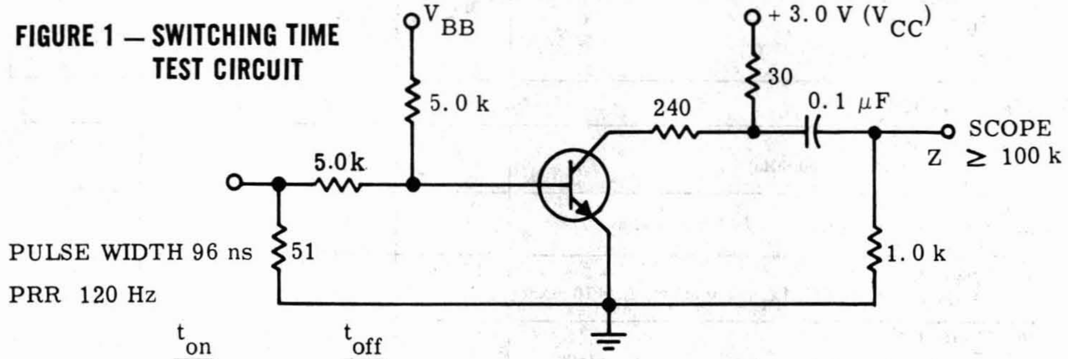
CASE 22
(TO-18)

NPN silicon annular transistors designed for high-speed, low-power saturated switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current — Continuous	I_C	225	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	360 2.0	mWatts mW/°C
Junction Temperature — Operating	T_J	-65 to +200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

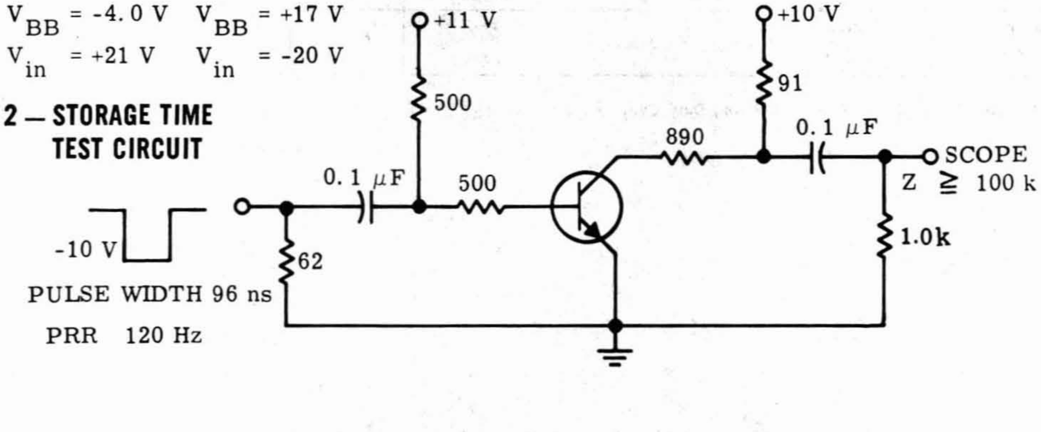
FIGURE 1 — SWITCHING TIME TEST CIRCUIT



V_{BB}
5.0 k
+ 3.0 V (V_{CC})
30
240
0.1 μF
SCOPE
Z ≥ 100 k
5.0k
51
1.0 k
PULSE WIDTH 96 ns
PRR 120 Hz

t_{on}	t_{off}
V_{BB} = -4.0 V	V_{BB} = +17 V
V_{in} = +21 V	V_{in} = -20 V

FIGURE 2 — STORAGE TIME TEST CIRCUIT



+11 V
500
+10 V
91
890
0.1 μF
SCOPE
Z ≧ 100 k
0.1 μF
500
1.0k
-10 V
62
PULSE WIDTH 96 ns
PRR 120 Hz

2N2242 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 30 mAdc, I_E = 0)	BV_{CEO}*	15	-	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 30 mAdc, R_{BE} = ≤ 10 ohms)	BV_{CER}*	20	-	Vdc
Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 0.25 Vdc, T_A = 125°C)	I_{CEX}	-	10	μAdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.1 15	μAdc
Emitter Cutoff Current ($V_{EB(off)}$ = 4.0 Vdc, I_C = 0)	I_{EBO}	-	0.1	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)	h_{FE}*	40 20	120 -	-
Collector-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc) (I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = -55 to +125°C)	$V_{CE(sat)}$	- -	0.7 0.3	Vdc
Base-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc) (I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = 125°C)	$V_{BE(sat)}$	- -	1.5 0.8	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	6.0	pF
Turn-On Time (Figure 1) (V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = +2.0 Vdc, I_{B1} = 3.0 mAdc, I_C = 10 mAdc)	t_{on}	-	30	ns
Turn-Off Time (Figure 1) (V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc)	t_{off}	-	50	ns
Storage Time (Figure 2) (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc)	t_s	-	25	ns

* Pulse Test: Pulse Wdith = 300 μs; Duty Cycle = ≤ 2%

2N2256, 2N2257 (SILICON)
2N2258 (GERMANIUM)
2N2259 (GERMANIUM)

CASE 22
(TO-18)

NPN silicon and PNP germanium mesa complementary transistors for high-speed non-saturated switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N2256 2N2257	2N2258 2N2259	Unit
Collector-Emitter Voltage	V_{CEO}	7	7	Vdc
Collector-Base Voltage	V_{CB}	7	7	Vdc
Emitter-Base Voltage	V_{EB}	1	1	Vdc
Collector Current-Continuous	I_C	100	100	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	300 2	150 2	mW mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	1000 6.67	300 4	mW mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	-65 to +100	^oC

TRANSISTOR SELECTION CHART

TYPE	TYPE		h_{FE} @ $I_C = 25$ mA	
	NPN	PNP	20	40
2N2256	X		X	
2N2257	X			X
2N2258		X	X	
2N2259		X		X

2N2256 thru 2N2259 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	7	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	7	15	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	1	-	-	Vdc
Collector Cutoff Current (V_{CB} = 6 Vdc, I_E = 0)	I_{CBO}	-	3	10	μAdc
(V_{CB} = 6 Vdc, I_E = 0, T_A = 65°C)		-	30	100	
ON CHARACTERISTICS					
DC Current Gain (I_C = 10 mAdc, V_{CE} = 1 Vdc) 2N2256, 2N2258	h_{FE}	17	30	-	-
2N2257, 2N2259		40	50	-	
(I_C = 25 mAdc, V_{CE} = 1 Vdc) 2N2256, 2N2258		20	35	-	
2N2257, 2N2259		40	55	-	
Base-Emitter On Voltage (I_C = 10 mAdc, V_{CE} = 1 Vdc) 2N2256, 2N2257	$V_{BE(on)}$	-	0.70	0.8	Vdc
2N2258, 2N2259		-	0.35	0.5	
(I_C = 25 mAdc, V_{CE} = 1 Vdc) 2N2256, 2N2257		-	0.8	0.9	
2N2258, 2N2259		-	0.45	0.6	
Conduction Threshold Base-Emitter Voltage* (I_C = 200 μAdc, V_{CE} = 1 Vdc) 2N2256, 2N2257	V_T	0.5	-	-	Vdc
2N2258, 2N2259		0.1	-	-	
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 1 Vdc, f = 100 MHz) 2N2258, 2N2259	f_T	250	320	-	MHz
(I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 100 MHz) 2N2256, 2N2257		250	320	-	
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 4 MHz) 2N2256, 2N2257	C_{ob}	-	4	5	pF
2N2258, 2N2259		-	4	8	
Base Resistance (I_E = 5 mAdc, V_{CB} = 2 Vdc, f = 300 MHz) 2N2256, 2N2257	r'_b	-	50	100	Ohms
2N2258, 2N2259		-	75	125	
Turn-On Time 2N2256, 2N2257 See Fig. 1	t_{on}	-	3	7	ns
2N2258, 2N2259 See Fig. 2		-	4	8	
Turn-Off Time 2N2256, 2N2257 See Fig. 1	t_{off}	-	4	7	ns
2N2258, 2N2259 See Fig. 2		-	3	7	

*Base-to-emitter forward bias voltage at which transistor will be at the threshold of conduction; i.e. that base-to-emitter voltage at which the collector current is less than or equal to the specified amount under a given collector-to-emitter voltage condition.

2N2256 thru 2N2259 (continued)

FIGURE 1 — NPN SWITCHING TIME TEST CIRCUIT

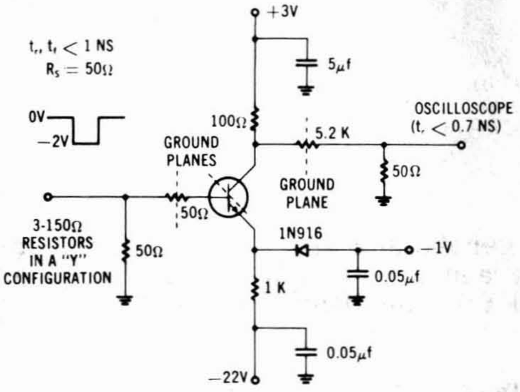

+3V
$t_r, t_f < 1$ NS
$R_S = 50\Omega$
5μf
0V
−2V
100Ω
GROUND PLANES
5.2 K
OSCILLOSCOPE ($t_r < 0.7$ NS)
GROUND PLANE
50Ω
50Ω
3-150Ω RESISTORS IN A "Y" CONFIGURATION
50Ω
1N916
−1V
0.05μf
1 K
0.05μf
−22V

FIGURE 2 — PNP SWITCHING TIME TEST CIRCUIT

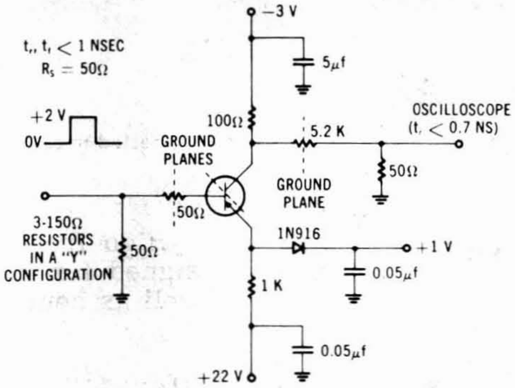

−3 V
$t_r, t_f < 1$ NSEC
$R_S = 50\Omega$
5μf
+2 V
0V
100Ω
GROUND PLANES
5.2 K
OSCILLOSCOPE ($t_r < 0.7$ NS)
GROUND PLANE
50Ω
50Ω
3-150Ω RESISTORS IN A "Y" CONFIGURATION
50Ω
1N916
+1 V
0.05μf
1 K
0.05μf
+22 V

FIGURE 3 — CASCADE COMPLEMENTARY GATE

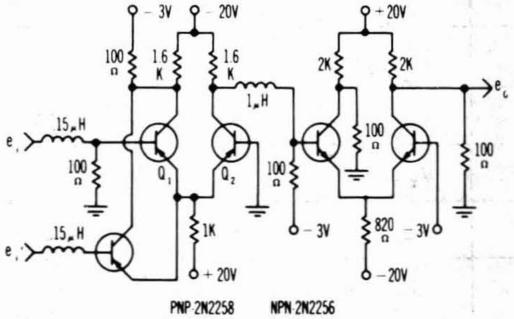

−3V
−20V
+20V
100 Ω
1.6 K
1.6 K
2K
2K
1μH
e_o
15μH
e_i
100 Ω
Q_1
Q_2
100 Ω
100 Ω
100 Ω
15μH
e_i'
1K
+20V
−3V
820 Ω
−3V
−20V
PNP 2N2258
NPN 2N2256

FIGURE 4 — CURRENT MODE INVERTER FOR USE WITH DIODE LOGIC PROPAGATION DELAY TIME 10 ns

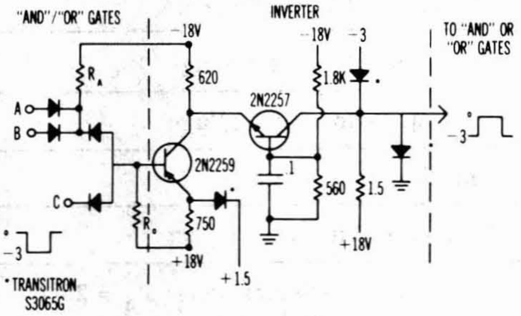

"AND"/"OR" GATES
−18V
R_A
620
A
B
C
2N2259
R_B
750
+18V
+1.5
−3
* TRANSITRON S3065G
INVERTER
−18V
−3
1.8K
*
2N2257
.1
560
1.5
+18V
TO "AND" OR "OR" GATES
−3

FIGURE 5 — CURRENT GAIN CHARACTERISTICS

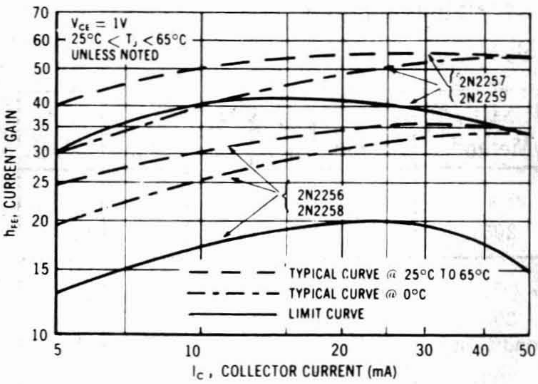
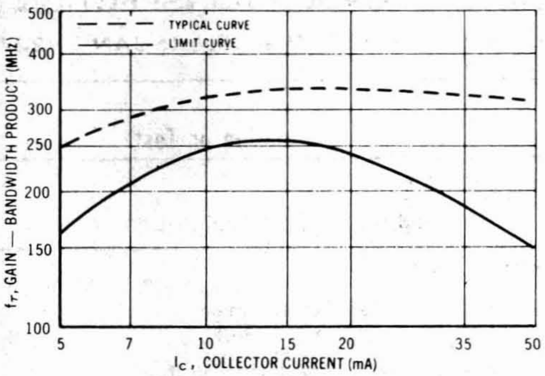
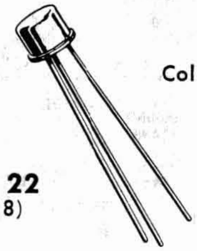


FIGURE 6 — CURRENT GAIN-BANDWITH PRODUCT CHARACTERISTICS



2N2273 (GERMANIUM)
JAN 2N2273



Collector connected to case

CASE 22
(TO-18)

High-frequency germanium PNP transistor, designed for military and high-reliability industrial as well as commercial VHF amplifier applications.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Volts
Collector-Emitter Voltage	V_{CES}	25	Volts
Collector-Emitter Voltage	V_{CEO}	15	Volts
Emitter-Base Voltage	V_{EB}	1.0	Volt
Collector Current	I_C	100	mA
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	150 2	mW mW/°C
Junction Operating & Storage Temperature Range	T_J, T_{stg}	-65 to +100	°C

TABLE I — GROUP A INSPECTION (T$_A$ = 25°C unless otherwise noted)

BOTH TYPES (LTPD applies to JAN 2N2273 only)

Examination or Test	MIL-STD-750 Method	Symbol	Limits Min	Limits Max	Unit	LTPD
SUBGROUP 1						
Visual and Mechanical Examination	2071	—	—	—	—	5
SUBGROUP 2						
Collector-Base Cutoff Current (V_{CB} = 12 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	—	10	μAdc	5
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	3001 Condition D	BV_{CBO}	25	—	Vdc	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	3026 Condition D	BV_{EBO}	1.0	—	Vdc	
Forward Current Transfer Ratio* (I_C = 1 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}*	20	75	—	
Collector-Emitter Breakdown Voltage (I_C = 200 μAdc, V_{BE} = 0)	3011 Condition C	BV_{CES}	25	—	Vdc	
Small-Signal Forward Current Transfer Ratio (I_C = 1 mAdc, V_{CE} = 6 Vdc, f = 10 MHz)	3306	h_{fe}	20	28	dB	

* Applies to MIL unit only

TABLE I — GROUP A INSPECTION (continued)

Examination or Test	MIL-STD-750 Method	Symbol	Limits Min	Limits Max	Unit	LTPD
SUBGROUP 3						
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	3236	C_{ob}	—	3.5	pF	10
Base Spreading Resistance (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 250 MHz)	3266	r_b	—	250	ohms	
Small-Signal Forward Current Transfer Ratio* (I_C = 1 mAdc, V_{CE} = 6 Vdc, f = 100 MHz)	3306	h_{fe}*	2.5	—	—	
Noise Figure* (V_{CB} = 10 Vdc, I_C = 1 mAdc, f = 10 MHz, R_G = 50 ohms)	3246	NF*	—	12	dB	

STANDARD UNIT ONLY

Examination or Test	Symbol	Min	Max	Unit	LTPD
Emitter-Base Leakage Current (V_{EB} = 0.5 Vdc, I_C = 0)	I_{EBO}	—	100	μAdc	
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CEO}	15	—	Vdc	
Forward Current Transfer Ratio (I_C = 1 mAdc, V_{CE} = 10 Vdc)	h_{FE}	20	150	—	—
Real Part of Small-Signal Short-Circuit Input Impedance (V_{CE} = 10 Vdc, I_C = 1 mAdc, f = 250 MHz) Power Gain (See Figure 1) (V_{CE} = 9 Vdc, I_C = 1 mAdc, f = 30 MHz)	$Re(h_{ie})$ G_{PE}	50 10	250 30	ohms dB	

* Applies to MIL unit only

TABLE II — GROUP B INSPECTION — JAN 2N2273 only

(T_A = 25°C unless otherwise noted)

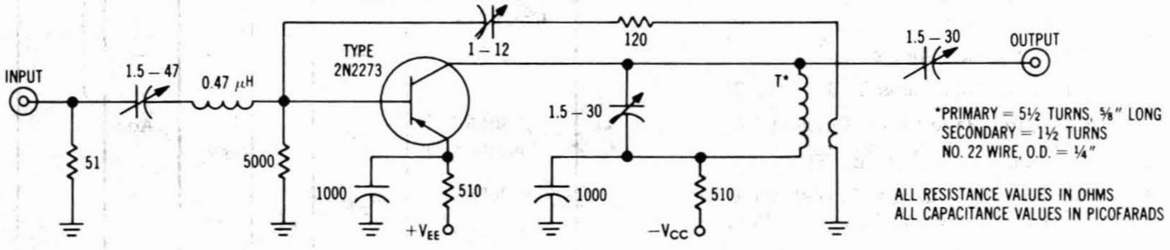
Examination or Test	MIL-STD-750 Method	Symbol	Limits Min	Limits Max	Unit	LTPD
SUBGROUP 1						
Physical Dimensions	2066	—	—	—	—	10
SUBGROUP 2						
Solderability	2026	—	—	—	—	10
Temperature Cycling (T_{high} = 100^{+3}_{-0} °C; 10 cycles)	1051 Condition B	—	—	—	—	
Thermal Shock (Glass Strain)	1056 Condition A	—	—	—	—	
Moisture Resistance	1021	—	—	—	—	
End Points: (Subgroups 2, 3, 5, 6, 7)						
Collector-Base Cutoff Current (V_{CB} = 12 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	—	20	μAdc	
DC Forward Current Transfer Ratio (I_C = 1 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}	15	—	—	

TABLE II — GROUP B INSPECTION (continued)

Examination or Test	MIL-STD-750 Method	Symbol	Limits		Unit	LTPD
			Min	Max		
SUBGROUP 3						
Shock (500 G, 1 msec, 5 blows each orientation: Y_1, Y_2, X_1 and Z_1)	2016 Nonoperating	—	—	—	—	10
Vibration, Variable Frequency (10 G)	2056	—	—	—	—	
Constant Accelerating (10, 000 G)	2006	—	—	—	—	
End Points: Same as Subgroup 2						
SUBGROUP 4						
Lead Fatigue (Note 1)	2036 Condition E	—	—	—	—	10
SUBGROUP 5						
High Temperature Operation (Note 2) ($T_A = 70^{+3}_{-0}$°C)		—	—	—	—	10
Collector-Base Cutoff Current (V_{CB} = 12 Vdc, I_E = 0)	3036	I_{CBO}	—	100	μAdc	
Low Temperature Operation (Note 2) (T_A = -55±3°C)		—	—	—	—	
Forward Current Transfer Ratio (V_{CE} = 10 Vdc, I_C = 1 mAdc)	3076	h_{FE}	8	—	—	
Salt Atmosphere (Corrosion)	1041	—	—	—	—	
End Points: Same as Subgroup 2						
SUBGROUP 6						
High Temperature Life ($T_A = 100^{+5}_{-0}$°C)	1031 (Nonoperating)	—	—	—	—	λ = 10
End Points: Same as Subgroup 2						
SUBGROUP 7						
Steady State Operation Life (V_{CB} = 10 Vdc, P_C = 60 mW, $T_A = 55^{+3}_{-0}$°C)	1026	—	—	—	—	λ = 10
End Points: Same as Subgroup 2						

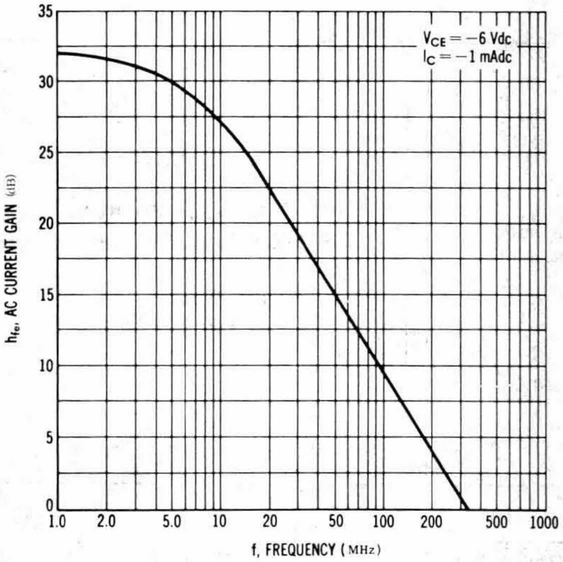
Note 1. Rejects from prior electrical tests from the same lot may be used for this test.
Note 2. Test measurement shall be made after thermal equilibrium has been reached at the temperature specified.

FIGURE 1 — 30 MHz POWER GAIN TEST CIRCUIT

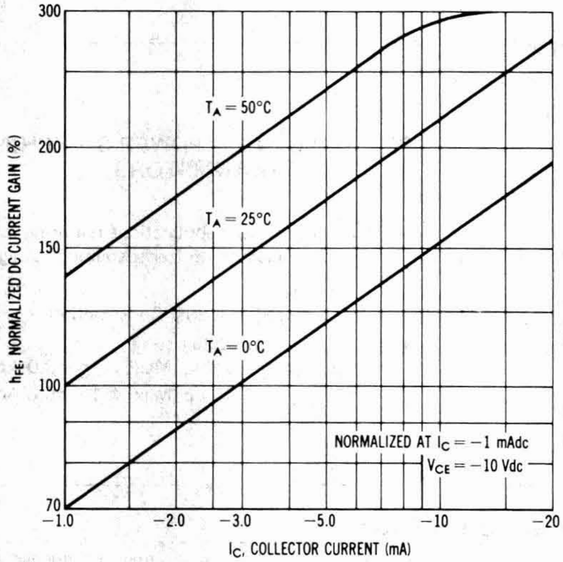


*PRIMARY = 5½ TURNS, ⅝" LONG
SECONDARY = 1½ TURNS
NO. 22 WIRE, O.D. = ¼"

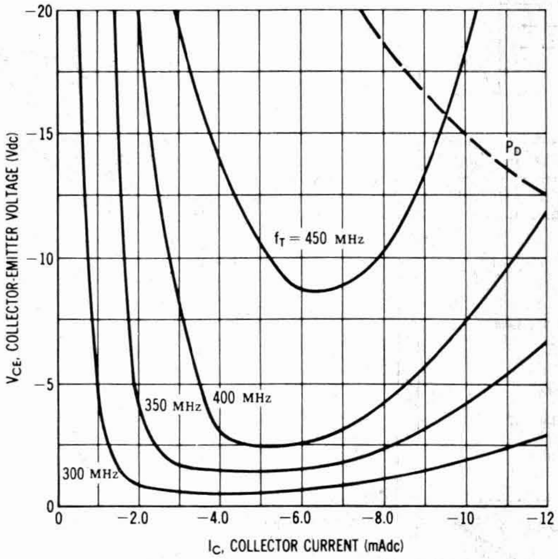
ALL RESISTANCE VALUES IN OHMS
ALL CAPACITANCE VALUES IN PICOFARADS



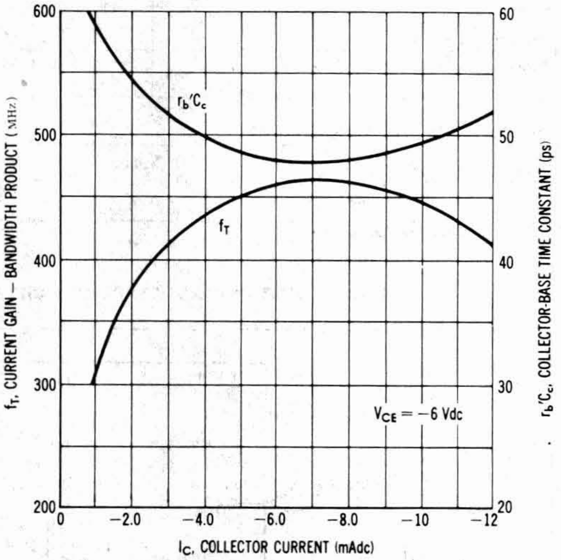
AC CURRENT GAIN versus FREQUENCY



VARIATION IN DC GAIN versus COLLECTOR CURRENT



CONTOURS OF CURRENT GAIN — BANDWIDTH PRODUCT



f_T AND $r_b'C_c$ versus COLLECTOR CURRENT

2N2285 thru 2N2287

For Specifications, See 2N1651 Data.

2N2288 2N2289
2N2290

PNP GERMANIUM POWER SWITCHING TRANSISTORS

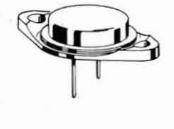
. . . designed for fast-switching applications requiring low saturation voltage and excellent collector-emitter sustaining voltage capability.

- Alloy-Diffused Epitaxial Construction
- Low Saturation Voltages –
  $V_{CE(sat)}$ = 0.5 Vdc (Max) @ I_C = 5.0 Adc
  $V_{BE(sat)}$ = 1.0 Vdc (Max) @ I_C = 5.0 Adc

10 AMPERE

PNP ADE GERMANIUM POWER TRANSISTORS

40-120 VOLTS
70 WATTS



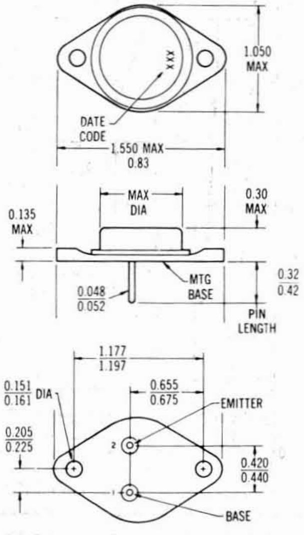
MAXIMUM RATINGS

Rating	Symbol	2N2288	2N2289	2N2290	Unit
*Collector-Emitter Voltage (R_{BE} = 100 Ohms)	V_{CER}	40	80	120	Vdc
*Collector-Base Voltage	V_{CB}	40	80	120	Vdc
*Emitter-Base Voltage	V_{EB}	← 0.75 →			Vdc
*Collector Current - Continuous	I_C	← 10 →			Adc
Base Current - Continuous	I_B	← 3.0 →			Adc
Total Device Dissipation @ T_C = 25°C *Derate above 25°C	P_D	← 70 → 0.833			Watts W/°C
*Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +110 →			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.2	°C/W

*Indicates JEDEC Registered Data.

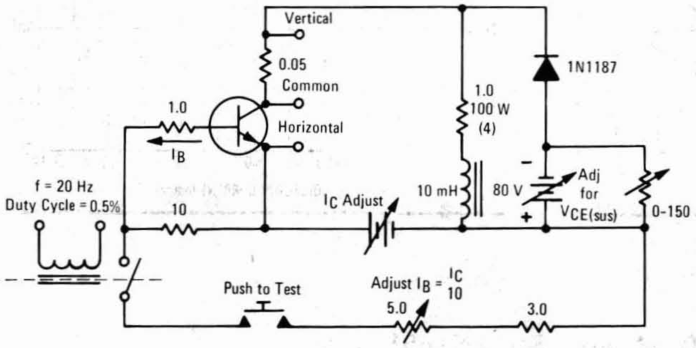

1.050
MAX
XXX
DATE
CODE
1.550 MAX
0.83
MAX
DIA
0.30
MAX
0.135
MAX
MTG
BASE
0.048
0.052
0.32
0.42
PIN
LENGTH
1.177
1.197
0.151
0.161
DIA
0.655
0.675
EMITTER
0.205
0.225
2
1
0.420
0.440
BASE

Collector Connected to Case

CASE 11A
(TO-3)

Except Pin Diameter

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT


Vertical
0.05
Common
1.0
Horizontal
I_B
f = 20 Hz
Duty Cycle = 0.5%
10
I_C Adjust
1.0
100 W
(4)
10 mH
1N1187
80 V
Adj
for
$V_{CE(sus)}$
0-150
Push to Test
Adjust $I_B = \frac{I_C}{10}$
5.0
3.0

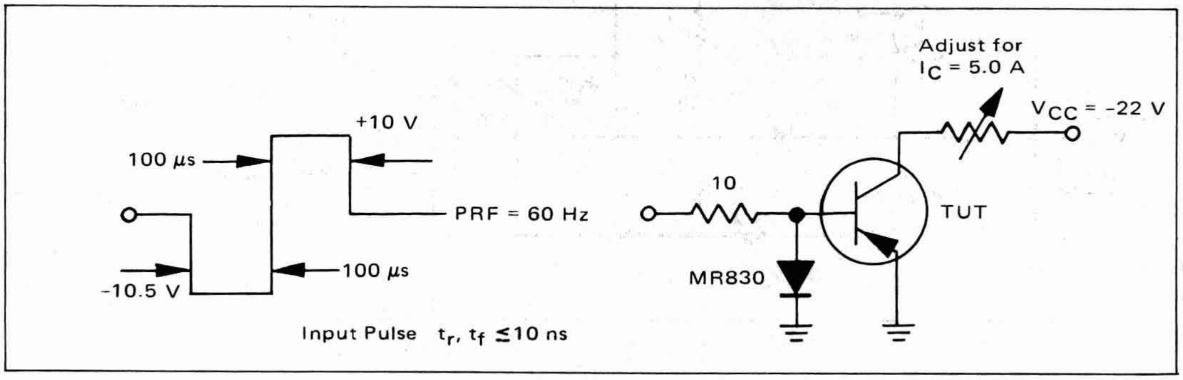
2N2288, 2N2289, 2N2290 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	2N2288	BV_{CEO}	30	-	Vdc
	2N2289		50	-	
	2N2290		70	-	
Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 5.0 Adc)	2N2288	$V_{CE(sus)}$	30	-	Vdc
	2N2289		50	-	
	2N2290		70	-	
*Collector-Emitter Breakdown Voltage (I_C = 50 mAdc, R_{BE} = 100 Ohms)	2N2288	BV_{CER}	40	-	Vdc
	2N2289		80	-	
	2N2290		120	-	
*Collector Cutoff Current (V_{CE} = 15 Vdc, I_B = 0)	2N2288	I_{CEO}	-	50	mAdc
(V_{CE} = 25 Vdc, I_B = 0)	2N2289		-	50	
(V_{CE} = 35 Vdc, I_B = 0)	2N2290		-	50	
*Collector Cutoff Current (V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C, +0, -3.0°C)	2N2288	I_{CEX}	-	35	mAdc
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C, +0, -3.0°C)	2N2289		-	35	
(V_{CE} = 120 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C, +0, -3.0°C)	2N2290		-	35	
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)	All Types	I_{CBO}	-	200	μAdc
*(V_{CB} = 40 Vdc, I_E = 0)	2N2288		-	5.0	mAdc
*(V_{CB} = 80 Vdc, I_E = 0)	2N2289		-	5.0	
*(V_{CB} = 120 Vdc, I_E = 0)	2N2290		-	5.0	
Emitter Cutoff Current (V_{EB} = 0.75 Vdc, I_C = 0)		I_{EBO}	-	25	mAdc
ON CHARACTERISTICS					
*DC Current Gain (I_C = 2.0 Adc, V_{CE} = 5.0 Vdc)		h_{FE}	20	-	-
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)			20	60	
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)		$V_{CE(sat)}$	-	0.5	Vdc
*Base-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)		$V_{BE(sat)}$	-	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS					
*Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 14 Vdc, f = 1.0 kHz)		h_{fe}	25	100	-
(I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)			15	-	
SWITCHING CHARACTERISTICS					
Rise Time	I_C = 5.0 Adc, I_{B1} = I_{B2} = 1.0 Adc) (See Figure 2)	t_r	-	5.0	μs
Storage Time		t_s	-	7.0	μs
Fall Time		t_f	-	8.0	μs

*Indicates JEDEC Registered Data.

FIGURE 2 – SWITCHING TIME TEST CIRCUIT



2N2291 2N2292
2N2293

PNP GERMANIUM POWER SWITCHING TRANSISTORS

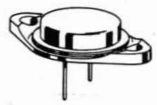
. . . designed for fast switching applications requiring low saturation voltage and excellent collector-emitter sustaining voltage capability.

- Alloy-Diffused Epitaxial Construction
- Low Saturation Voltages –
  $V_{CE(sat)}$ = 0.5 Vdc @ I_C = 5.0 Adc
  $V_{BE(sat)}$ = 1.0 Vdc @ I_C = 5.0 Adc

10 AMPERE

PNP ADE GERMANIUM POWER TRANSISTORS

40-120 VOLTS
70 WATTS



MAXIMUM RATINGS

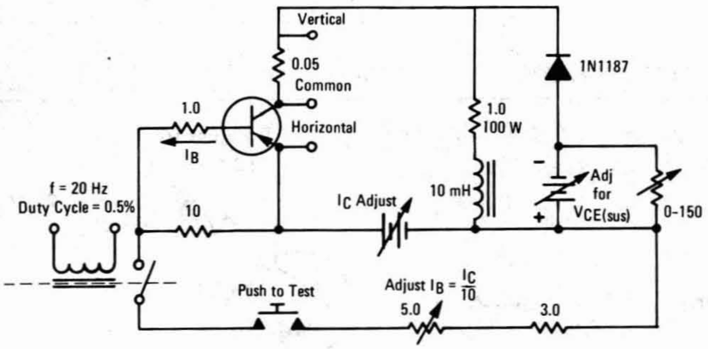
Rating	Symbol	2N2291	2N2292	2N2293	Unit
*Collector-Emitter Voltage	V_{CEO}	30	50	70	Vdc
*Collector-Base Voltage	V_{CB}	40	80	120	Vdc
*Emitter-Base Voltage	V_{EB}	←	1.5	→	Vdc
*Collector Current - Continuous	I_C	←	10	→	Adc
*Base Current - Continuous	I_B	←	3.0	→	Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	←	70 0.83	→	Watts W/°C
*Operating and Storage Junction Temperature Range	T_J, T_{stg}	←	-65 to +110	→	°C

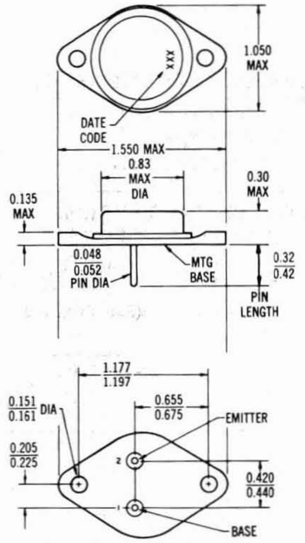
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.2	°C/W

*Indicates JEDEC Registered Data.

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT


Vertical
0.05
Common
1.0
Horizontal
I_B
1N1187
1.0
100 W
10 mH
Adj
for
$V_{CE(sus)}$
0-150
f = 20 Hz
Duty Cycle = 0.5%
10
I_C Adjust
Push to Test
Adjust $I_B = \frac{I_C}{10}$
5.0
3.0


XXX
DATE CODE
1.050 MAX
1.550 MAX
0.83 MAX DIA
0.30 MAX
0.135 MAX
0.048/0.052 PIN DIA
MTG BASE
0.32/0.42
PIN LENGTH
1.177/1.197
0.151/0.161 DIA
0.655/0.675
EMITTER
0.205/0.225
2
1
0.420/0.440
BASE

Collector Connected to Case

CASE 11A
(TO-3)

Except Pin Diameter

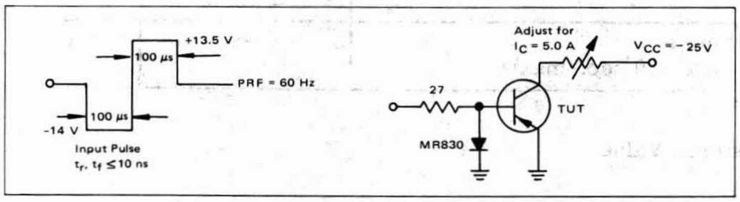
2N2291 thru 2N2293 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	2N2291	BV_{CEO}	30	-	Vdc
	2N2292		50	-	
	2N2293		70	-	
*Collector-Emitter Sustaining Voltage (See Figure 1) *(I_C = 500 mAdc)	2N2291	$V_{CE(sus)}$	30	-	Vdc
	2N2292		50	-	
	2N2293		70	-	
**(I_C = 5.0 Adc)	2N2291		25	-	
	2N2292		50	-	
	2N2293		70	-	
*Collector-Emitter Breakdown Voltage (I_C = 50 mAdc, R_{BE} = 100 ohms)	2N2291	BV_{CER}	40	-	Vdc
	2N2292		80	-	
	2N2293		120	-	
*Collector Cutoff Current (V_{CE} = 15 Vdc, I_B = 0)	2N2291	I_{CEO}	-	50	mAdc
(V_{CE} = 25 Vdc, I_B = 0)	2N2292		-	50	
(V_{CE} = 35 Vdc, I_B = 0)	2N2293		-	50	
*Collector Cutoff Current (V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C)	2N2291	I_{CEX}	-	35	mAdc
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C)	2N2292		-	35	
(V_{CE} = 120 Vdc, $V_{BE(off)}$ = 0.1 Vdc, T_C = 100°C)	2N2293		-	35	
Collector Cutoff Current *(V_{CB} = -2.0 Vdc, I_E = 0)	All Types	I_{CBO}	-	200	µAdc
*(V_{CB} = 40 Vdc, I_E = 0)	2N2291		-	5.0	mAdc
*(V_{CB} = 80 Vdc, I_E = 0)	2N2292		-	5.0	
*(V_{CB} = 120 Vdc, I_E = 0)	2N2293		-	5.0	
Emitter Cutoff Current (V_{EB} = 1.5 Vdc, I_C = 0)		I_{EBO}	-	50	mAdc
ON CHARACTERISTICS					
*DC Current Gain (I_C = 2.0 Adc, V_{CE} = 5.0 Vdc)		h_{FE}	40	-	-
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)			50	120	
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)		$V_{CE(sat)}$	-	0.5	Vdc
*Base-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc)		$V_{BE(sat)}$	-	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS					
*Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 14 Vdc, f = 1.0 kHz)		h_{fe}	50	200	-
(I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)			15	-	
SWITCHING CHARACTERISTICS					
Rise Time	(I_C = 5.0 Adc, I_{B1} = I_{B2} = 0.5 Adc) (See Figure 2)	t_r	-	7.0	µs
Storage Time		t_s	-	10	µs
Fall Time		t_f	-	8.0	µs

*Indicates JEDEC Registered Data.
**Motorola guarantees this data in addition to the JEDEC Registered Data Shown.

FIGURE 2 – SWITCHING TIME TEST CIRCUIT



2N2303 (SILICON)

For Specifications, See 2N722 Data.

2N2322 thru 2N2326 (SILICON)

All-diffused PNPN thyristors designed for gating operation in mA/µA signal or detection circuits.

CASE 31(2)
(TO-5)

MAXIMUM RATINGS* (T_J = 125°C unless otherwise noted, R_{GK} = 1000 ohms)

Rating		Symbol	Value	Unit
Peak Reverse Blocking Voltage		$V_{RXM(rep)}$		Volts
(Note 1)	2N2322		25	
	2N2323		50	
	2N2324		100	
	2N2325		150	
	2N2326		200	
Non-Repetitive Peak Reverse Blocking Voltage		$V_{RXM(non-rep)}$		Volts
(t < 5.0 ms)	2N2322		40	
	2N2323		75	
	2N2324		150	
	2N2325		225	
	2N2326		300	
Forward Current RMS (All Conduction Angles)		I_f	1.6	Amp
Peak Surge Current (One-Half Cycle, 60 Hz) No Repetition Until Thermal Equilibrium is Restored		$I_{FM(surge)}$	15	Amp
Peak Gate Power — Forward		P_{GFM}	0.1	Watt
Average Gate Power — Forward		$P_{GF(AV)}$	0.01	Watt
Peak Gate Current — Forward		I_{GFM}	0.1	Amp
Peak Gate Voltage — Forward		V_{GFM}	6.0	Volts
Reverse		V_{GRM}	6.0	
Operating Junction Temperature Range		T_J	-65 to +125	°C
Storage Temperature Range		T_{stg}	-65 to +150	°C
Lead Solder Temperature (> 1/16" from case, 10 sec. max)		-	+230	°C

* JEDEC Registered Values

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted, R_{GK} = 1000 ohms)

Characteristic	Symbol	Min	Max	Unit
Peak Forward Blocking Voltage (Note 1)	V_{FXM}			Volts
2N2322		25*	-	
2N2323		50*	-	
2N2324		100*	-	
2N2325		150*	-	
2N2326		200*	-	
Peak Reverse Blocking Current (Rated V_{RXM}, T_J = 125°C)	I_{RXM}	-	100*	µA
Peak Forward Blocking Current (Rated V_{FXM}, T_J = 125°C)	I_{FXM}	-	100*	µA
Forward "On" Voltage	V_F			Volts
(I_F = 1.0 A Peak)		-	1.5	
(I_F = 3.14 A Peak, T_C = 85°C)		-	2.0*	
Gate Trigger Current (Note 2)	I_{GT}			µA
(Anode Voltage = 6.0 Vdc, R_L = 100 ohms)		-	200	
(Anode Voltage = 6.0 Vdc, R_L = 100 ohms, T_C = -65°C)		-	350*	
Gate Trigger Voltage	V_{GT}			Volts
(Anode Voltage = 6.0 V, R_L = 100 ohms)		-	0.8	
(Anode Voltage = 6.0 V, R_L = 100 ohms, T_C = -65°C)		-	1.0*	
(Anode Voltage = Rated V_{FXM}, R_L = 100 ohms, T_J = 125°C)		0.1*	-	
Holding Current	I_{HX}			mA
(Anode Voltage = 6.0 V)		-	2.0	
(Anode Voltage = 6.0 V, T_C = -65°C)		-	3.0*	
(Anode Voltage = 6.0 V, T_C = 125°C)		0.15*	-	
Turn-On Time	t_{on}	Circuit dependent, consult manufacturer		
Turn-Off Time	t_{off}			

* JEDEC Registered Values

Notes: 1. V_{RXM} and V_{FXM} can be applied for all types on a continuous dc basis without incurring damage.

2. R_{GK} current is not included in measurement.

Thyristor devices shall not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

Thyristor devices shall not have a positive bias applied to the gate concurrently with a negative potential applied to the anode.

FIGURE 1 — CASE TEMPERATURE vs CURRENT

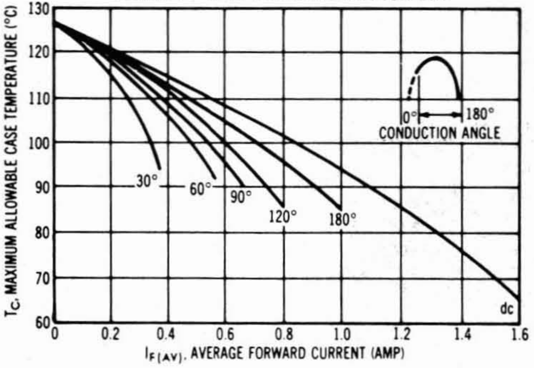
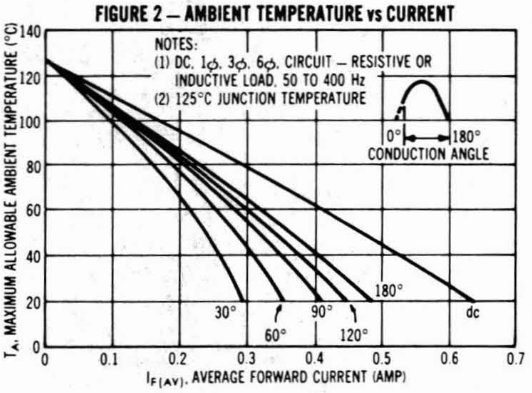


FIGURE 2 — AMBIENT TEMPERATURE vs CURRENT



2N2330 (SILICON)
2N2331

CASE 22
(TO-18)
2N2331

CASE 31
(TO-5)
2N2330

NPN silicon annular Star transistors for low-level DC/AC chopper applications.

Collector connected to case

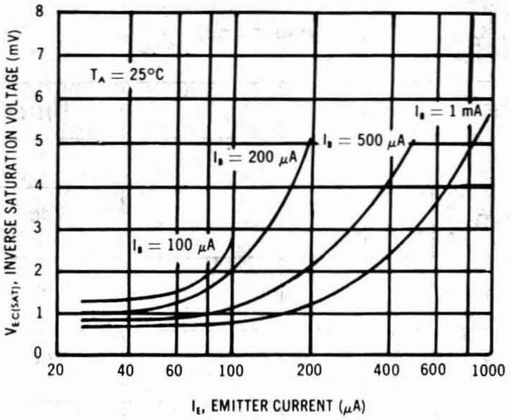
MAXIMUM RATINGS

Rating	Symbol	2N2330 (TO-5)	2N2331 (TO-18)	Unit
Collector-Emitter Voltage	V_{CEO}	20	20	Vdc
Collector-Base Voltage	V_{CB}	30	30	Vdc
Emitter-Base Voltage	V_{EB}	5	5	Vdc
Collector Current	I_C	500		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.8 5.33	0.5 3.33	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	3 20	1.8 12	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

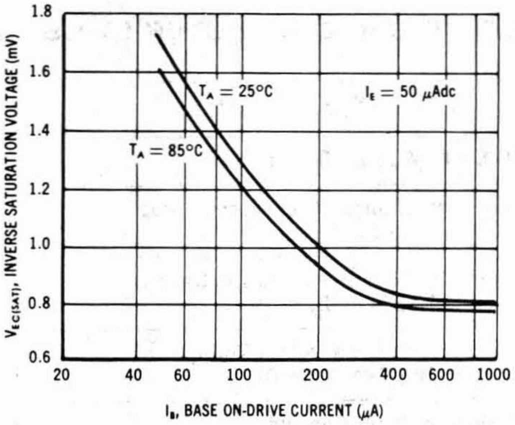
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 1$ mAdc, $I_B = 0$)	BV_{CEO}	20	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 10$ μAdc, $I_E = 0$)	BV_{CBO}	30	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10$ μAdc, $I_C = 0$)	BV_{EBO}	5	-	Vdc
Collector Cutoff Current ($V_{CB} = 4.5$ Vdc, $I_E = 0$)	I_{CBO}	-	1.0	nAdc
Emitter Cutoff Current ($V_{BE} = 4.5$ Vdc)	I_{EBO}	-	5.0	nAdc
Offset Current ($V_{BC} = 2$ Vdc, $V_{CE} = 0$, $T_A = 25^oC$)	$I_{(off)}$	-	1	nAdc
($V_{BC} = 2$ Vdc, $V_{CE} = 0$, $T_A = 85^oC$)		-	10	
ON CHARACTERISTICS				
DC Current Gain ($I_C = 10$ mAdc, $V_{CE} = 1$ Vdc)	h_{FE}	50	-	-
Offset Voltage ($I_B = 200$ μAdc, $I_E = 0$)	$V_{(off)}$	-	0.75	mVdc
Inverse Saturation Voltage ($I_B = 200$ μAdc, $I_E = 50$ μAdc)	$V_{EC(sat)}$	-	3.0	mVdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product ($I_C = 1$ mAdc, $V_{CE} = 1$ Vdc, f = 100 MHz)	f_T	100	-	MHz
Output Capacitance ($V_{CB} = 2$ Vdc, $I_E = 0$)	C_{ob}	-	10	pF
Input Capacitance ($V_{BE} = 2$ Vdc, $I_C = 0$)	C_{ib}	-	20	pF

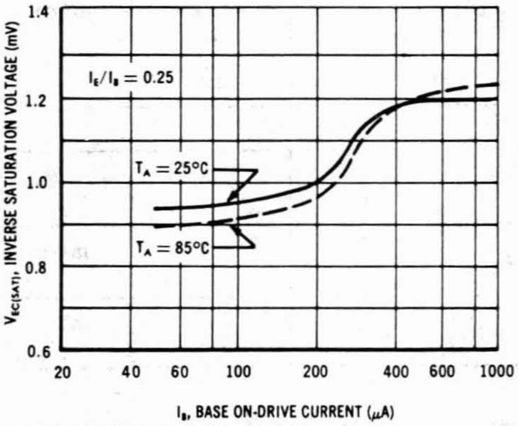
INVERSE SATURATION VOLTAGE versus EMITTER CURRENT



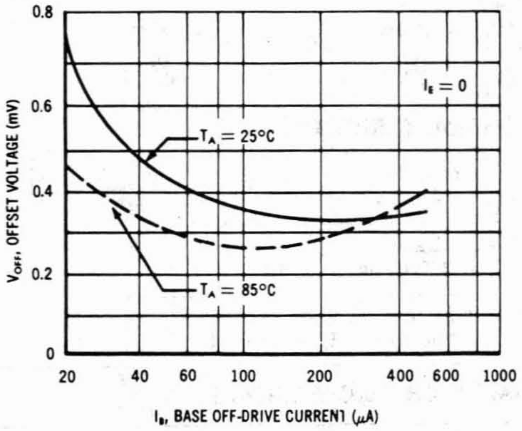
INVERSE SATURATION VOLTAGE versus BASE CURRENT



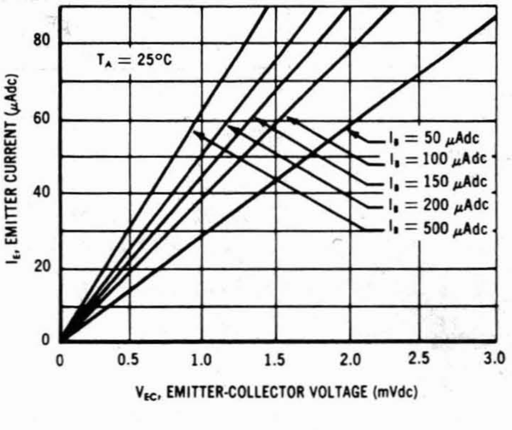
INVERSE SATURATION VOLTAGE versus BASE CURRENT



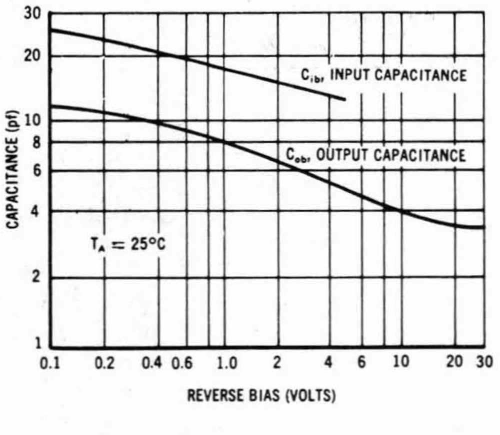
OFFSET VOLTAGE versus BASE CURRENT



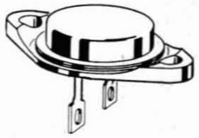
INVERSE SATURATION CHARACTERISTICS



OUTPUT CAPACITANCE versus COLLECTOR-BASE VOLTAGE and INPUT CAPACITANCE versus EMITTER-BASE VOLTAGE



2N2357 thru 2N2359 (Germanium)



CASE 161
(TO-41)
Collector Connected to Case

PNP Germanium power transistors designed for very high-current switching applications requiring low saturation voltages, fast switching times and good safe operating area.

MAXIMUM RATINGS

<table>
<tr><th>Rating</th><th>Symbol</th><th>2N2357</th><th>2N2358</th><th>2N2359</th><th>Unit</th></tr>
<tr><td>Collector-Emitter Voltage</td><td>V_{CEO}</td><td>30</td><td>60</td><td>80</td><td>Vdc</td></tr>
<tr><td>Collector-Base Voltage</td><td>V_{CB}</td><td>60</td><td>100</td><td>120</td><td>Vdc</td></tr>
<tr><td>Emitter-Base Voltage</td><td>V_{EB}</td><td colspan="3">← 2.5 →</td><td>Vdc</td></tr>
<tr><td>Collector Current - Continuous</td><td>I_C</td><td colspan="3">← 50 →</td><td>Adc</td></tr>
<tr><td>Base Current - Continuous</td><td>I_B</td><td colspan="3">← 10 →</td><td>Adc</td></tr>
<tr><td>Total Device Dissipation @ $T_C = 25°C$
Derate above 25°C</td><td>P_D</td><td colspan="3">← 170 →
2.0</td><td>Watts
W/°C</td></tr>
<tr><td>Operating and Storage Junction Temperature Range</td><td>T_J, T_{stg}</td><td colspan="3">← -65 to +110 →</td><td>°C</td></tr>
</table>

THERMAL CHARACTERISTICS

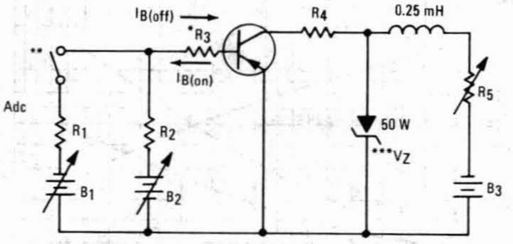
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.5	°C/W

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT

R_1 = 1.0 Ohm, 20 Watts
R_2 = 10 Ohms, 2.0 Watts
R_3 = 0.1 Ohm, 1.0%
$R_4 \leq$ 0.04 Ohm

R_5: I_C Adjust @ $V_{CE} = V_Z$
B_1: Adjust for $I_{B(on)} = \frac{I_C}{10}$
B_2 = 2.0 Vdc, Adjust for $I_{B(off)}$ = 0.2 Adc
B_3 = 12 Vdc

*Not required if current probe is used to read I_{B1}
**PRF ≈ 60 Hz
***Zener selected to establish Sustaining Voltage.
NOTE: Series impedance and inductance must be kept to a minimum.



2N2357 thru 2N2359 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	2N2357	BV_{CEO}	30	-	-	Vdc
	2N2358		60	-	-	
	2N2359		80	-	-	
Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 50 Adc)	2N2357	$V_{CE(sus)}$	35	-	-	Vdc
	2N2358		40	-	-	
	2N2359		45	-	-	
Collector -Emitter Cutoff Current (V_{CE} = 60 Vdc, V_{BE} = 0	2N2357	I_{CES}	-	-	50	mAdc
(V_{CE} = 100 Vdc, V_{BE} = 0)	2N2358		-	-	50	
(V_{CE} = 120 Vdc, V_{BE} = 0)	2N2359		-	-	50	
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)		I_{CBO}	-	-	200	μAdc
Collector-Emitter Cutoff Current (V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N2357	I_{CEX}	-	-	5.0	mAdc
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N2358		-	-	5.0	
(V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	2N2359		-	-	5.0	
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100°C) (+0, -3.0°C)	2N2357		-	-	35	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100°C) (+0, -3.0°C)	2N2358		-	-	35	
(V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100°C) (+0, -3.0°C)	2N2359		-	-	35	
Emitter Cutoff Current (V_{EB} = 2.5 Vdc, I_C = 0)		I_{EBO}	-	-	50	mAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 20 Adc, V_{CE} = 1.5 Vdc)		h_{FE}	30	-	90	-
(I_C = 50 Adc, V_{CE} = 1.5 Vdc)			15	-	-	
Collector-Emitter Saturation Voltage (I_C = 50 Adc, I_B = 5.0 Adc)		$V_{CE(sat)}$	-	-	0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 50 Adc, I_B = 5.0 Adc)		$V_{BE(sat)}$	-	-	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 6.0 Vdc, f = 30 kHz)		h_{fe}	20	-	-	-
SWITCHING CHARACTERISTICS						
Rise Time	(V_{CC} = -28 Vdc, I_C = 50 Adc, I_{B1} = 5.0 Adc, I_{B2} = 3.0 Adc) (See Figure 3)	t_r	-	12	-	μs
Storage Time		t_s	-	5.0	-	μs
Fall Time		t_f	-	6.0	-	μs

FIGURE 2 – SWITCHING TIMES

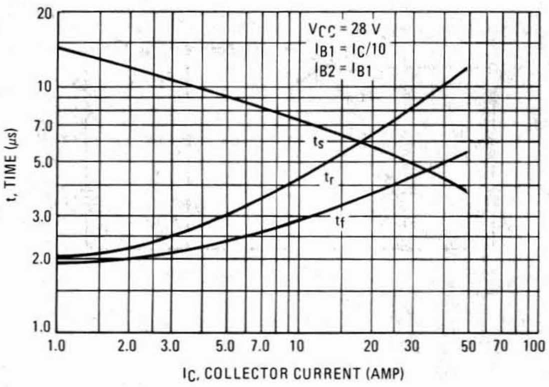
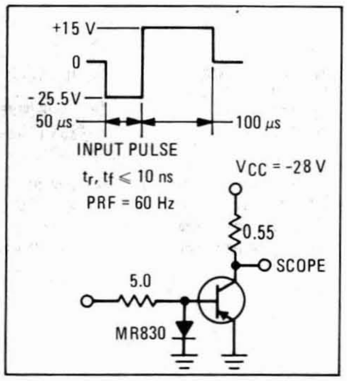


FIGURE 3 – SWITCHING TIME TEST CIRCUIT



2N2368 (SILICON)

CASE 22
(TO-18)

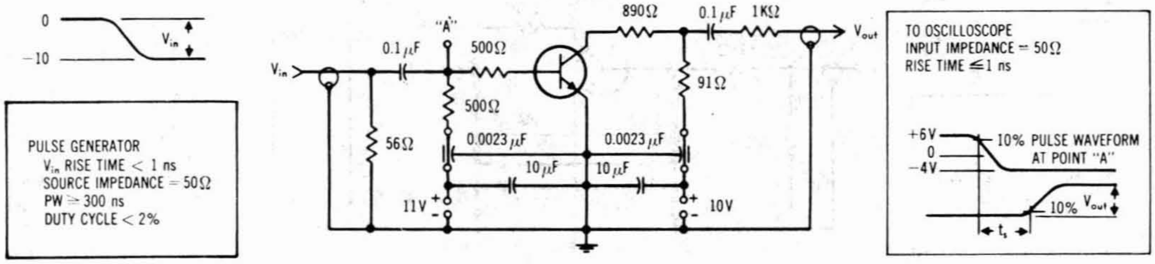
NPN silicon annular transistor designed for high-speed, low-level, saturated-switching application.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25°C	P_D	1.2 6.85	Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to + 200	°C

FIGURE 1 — STORAGE TIME TEST CIRCUIT

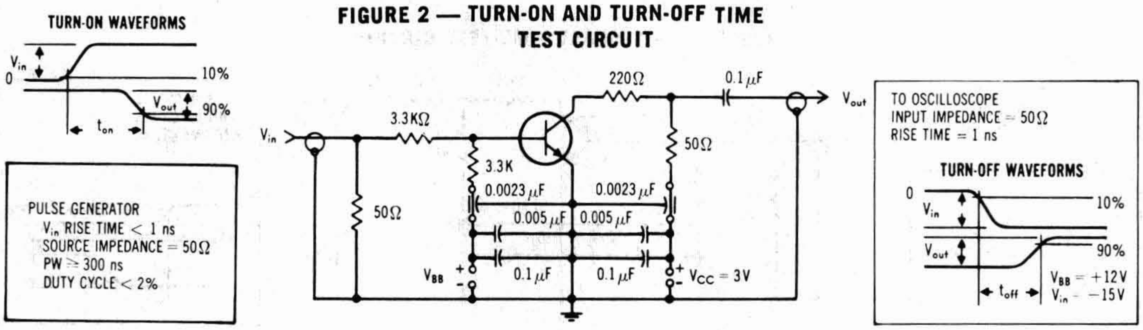

0
−10
Vin
PULSE GENERATOR
Vin RISE TIME < 1 ns
SOURCE IMPEDANCE = 50Ω
PW ≥ 300 ns
DUTY CYCLE < 2%
Vin
0.1 μF
"A"
500Ω
500Ω
56Ω
0.0023 μF
10 μF
10 μF
0.0023 μF
11V
890Ω
91Ω
0.1 μF
1KΩ
10V
Vout
TO OSCILLOSCOPE
INPUT IMPEDANCE = 50Ω
RISE TIME ≤1 ns
+6V
0
−4V
10% PULSE WAVEFORM AT POINT "A"
10%
Vout
ts

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	15	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 μAdc, V_{BE} = 0)	BV_{CES}	40	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4.5	—	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 — —	 0.4 30	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C) (I_C = 100 mAdc, V_{CE} = 2.0 Vdc)	h_{FE}*	 20 10 10	 60 — —	—
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	—	0.25	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	0.7	0.85	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	400	—	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	4	pF
Storage Time (Figure 1) (I_C = I_{B1} = 10 mAdc, I_{B2} = -10 mAdc)	t_s	—	10	ns
Turn-On Time (Figure 2) (I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = -1.5 mAdc)	t_{on}	—	12	ns
Turn-Off Time (Figure 2) (I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = -1.5 mAdc)	t_{off}	—	15	ns

*Pulse Test: Pulse Width = 300 μs; Duty Cycle ≤ 2%

FIGURE 2 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT


TURN-ON WAVEFORMS
V_{in}
0
10%
V_{out}
90%
t_{on}
V_{in}
3.3KΩ
50Ω
3.3K
0.0023 μF
0.005 μF
0.1 μF
V_{BB}
220Ω
0.1 μF
50Ω
0.0023 μF
0.005 μF
0.1 μF
V_{CC} = 3V
V_{out}
TURN-OFF WAVEFORMS
0
V_{in}
10%
V_{out}
90%
t_{off}
V_{BB} = +12V
V_{in} = −15V

PULSE GENERATOR
V_{in} RISE TIME < 1 ns
SOURCE IMPEDANCE = 50Ω
PW ≥ 300 ns
DUTY CYCLE < 2%

TO OSCILLOSCOPE
INPUT IMPEDANCE = 50Ω
RISE TIME = 1 ns

2N2369 (SILICON)
2N3227

CASE 22
(TO-18)

NPN silicon annular transistors for low-current, high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Emitter Voltage 2N2369 2N3227	V_{CEO}	15 20	Vdc
Emitter-Base Voltage 2N2369 2N3227	V_{EB}	4.5 6.0	Vdc
Collector Current (10 μsec pulse)	$I_{C(Peak)}$	500	mA
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	1.2 6.85	Watts mW/°C
Junction Temperature, Operating	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 — t_{on} CIRCUIT — 10 mA

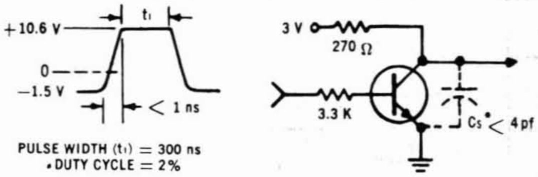

+10.6 V
0
−1.5 V
t₁
< 1 ns
3 V
270 Ω
3.3 K
Cs* < 4 pf
PULSE WIDTH (t₁) = 300 ns
• DUTY CYCLE = 2%

FIGURE 2 — t_{on} CIRCUIT — 100 mA

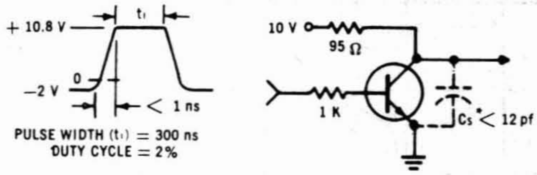

+ 10.8 V
0
−2 V
t₁
< 1 ns
10 V
95 Ω
1 K
Cs* < 12 pf
PULSE WIDTH (t₁) = 300 ns
DUTY CYCLE = 2%

FIGURE 3 — t_{off} CIRCUIT — 10 mA

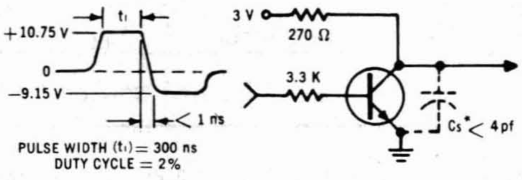
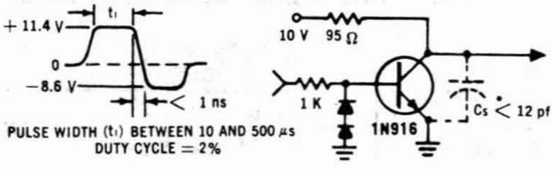

+10.75 V
0
−9.15 V
t₁
< 1 ns
3 V
270 Ω
3.3 K
Cs* < 4 pf
PULSE WIDTH (t₁) = 300 ns
DUTY CYCLE = 2%

FIGURE 4 — t_{off} CIRCUIT — 100 mA


+ 11.4 V
0
−8.6 V
t₁
< 1 ns
10 V
95 Ω
1 K
1N916
Cs* < 12 pf
PULSE WIDTH (t₁) BETWEEN 10 AND 500 μs
DUTY CYCLE = 2%

*Total shunt capacitance of test jig and connectors.

2N2369, 2N3227 (continued)

ELECTRICAL CHARACTERISTICS

Characteristic		Fig. No.	Symbol	Min	Max	Unit
Collector Cutoff Current			I_{CBO}			μ Adc
(V_{CB} = 20 Vdc)	2N2369			—	0.4	
	2N3227			—	0.2	
(V_{CB} = 20 Vdc, T_A = 150°C)	2N2369			—	30	
	2N3227			—	50	
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3 Vdc)	2N3227		I_{CEX}	—	0.2	μ Adc
Base Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3 Vdc)	2N3227		I_{BL}	—	0.5	μ Adc
Collector-Base Breakdown Voltage (I_C = 10μ Adc, I_B = 0)			BV_{CBO}	40	—	Vdc
Emitter-Base Breakdown Voltage			BV_{EBO}			Vdc
(I_E = 10μ Adc, I_C = 0)	2N2369			4.5	—	
	2N3227			6.0	—	
Collector-Emitter Breakdown Voltage *			BV_{CEO}*			Vdc
(I_C = 10 mAdc)	2N2369			15	—	
	2N3227			20	—	
Collector-Emitter Voltage (I_C = 10μ Adc, I_B = 0)			BV_{CES}	40	—	Vdc
Collector-Emitter Saturation Voltage *			$V_{CE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)	Both Types	11,13		—	0.25	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N3227			—	0.45	
Base-Emitter Saturation Voltage *			$V_{BE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)	Both Types	13		0.70	0.85	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N3227			0.8	1.4	
DC Current Gain*			h_{FE}*			—
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N2369			40	120	
	2N3227	12		100	300	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)	2N2369			20	—	
	2N3227	12		40	—	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	2N3227	12		30	—	
(I_C = 100 mAdc, V_{CE} = 2 Vdc)	2N2369			20	—	
Small Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)			h_{fe}	5	—	—
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 140 kHz)		5	C_{ob}	—	4	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 140 kHz)	2N3227		C_{ib}		4	pF
Storage Time (I_C = I_{B1} = I_{B2} = 10 mA)		10	t_s	—	13	ns
Turn-On Time (I_C = 10 mA, I_{B1} = 3 mA, V_{CC} = 3 V, $V_{EB(off)}$ = 1.5 Vdc)		1,6	t_{on}	—	12	ns
Turn-Off Time (I_C = 10 mA, I_{B1} = 3 mA, I_{B2} = 1.5 mA, V_{CC} = 3 V)		3,6	t_{off}	—	18	ns
Total Control Charge (I_C = 10 mA, I_B = 1 mA, V_{CC} = 3 V)	2N3227	7,8	Q_T	—	50	pC
Delay Time — V_{CC}=10 V, $V_{EB(off)}$ = 2 Vdc, I_C = 100 mA, I_{B1}=10 mA	2N3227	2,6	t_d	—	5	ns
Rise Time			t_r	—	18	ns
Storage Time — V_{CC}= 10 V, I_C = 100 mA, I_{B1}=I_{B2} = 10 mA	2N3227	4,6	t_s	—	13	ns
Fall Time			t_f	—	15	ns

***Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2%**

FIGURE 5 — JUNCTION CAPACITANCE VARIATIONS

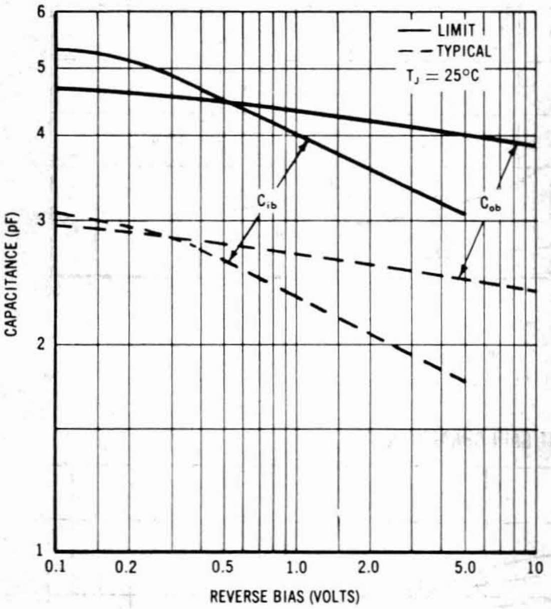


FIGURE 6 — TYPICAL SWITCHING TIMES

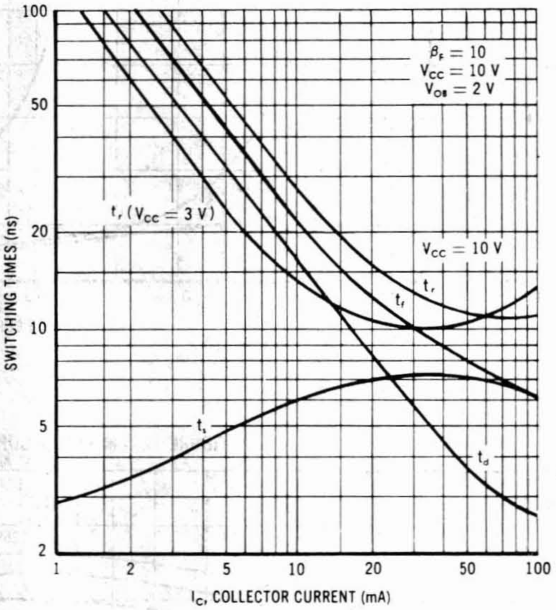


FIGURE 7 — MAXIMUM CHARGE DATA

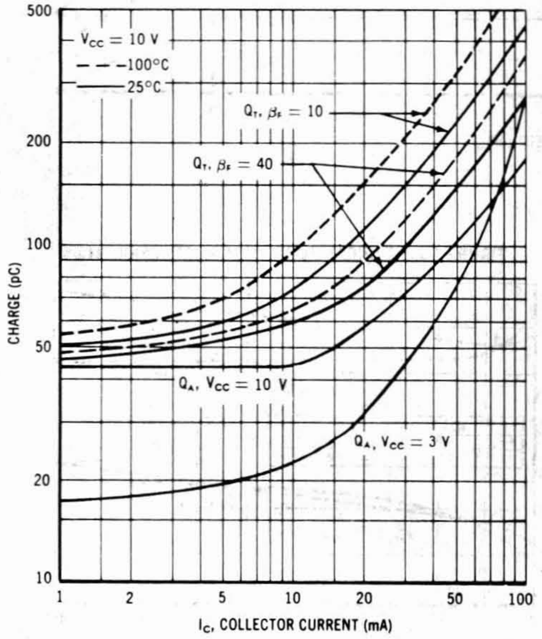


FIGURE 8 — Q_T TEST CIRCUIT

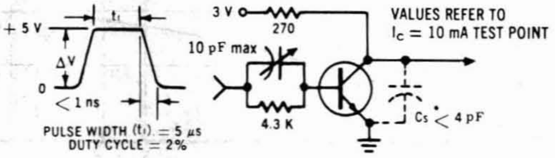

+ 5 V
t_1
ΔV
0
< 1 ns
PULSE WIDTH (t_1) = 5 μs
DUTY CYCLE = 2%
3 V
270
10 pF max
4.3 K
VALUES REFER TO
$I_C = 10$ mA TEST POINT
C_S * < 4 pF

FIGURE 9 — TURN-OFF WAVE FORM

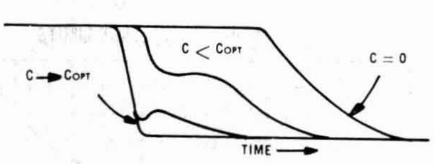
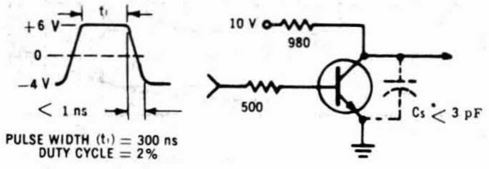

C < C_{OPT}
C = 0
C → C_{OPT}
TIME →

FIGURE 10 — STORAGE TIME EQUIVALENT TEST CIRCUIT


+6 V
t_1
0
−4 V
< 1 ns
PULSE WIDTH (t_1) = 300 ns
DUTY CYCLE = 2%
10 V
980
500
C_S * < 3 pF

* Total shunt capacitance of test jig and connectors.

FIGURE 11 — MAXIMUM COLLECTOR SATURATION VOLTAGE CHARACTERISTICS

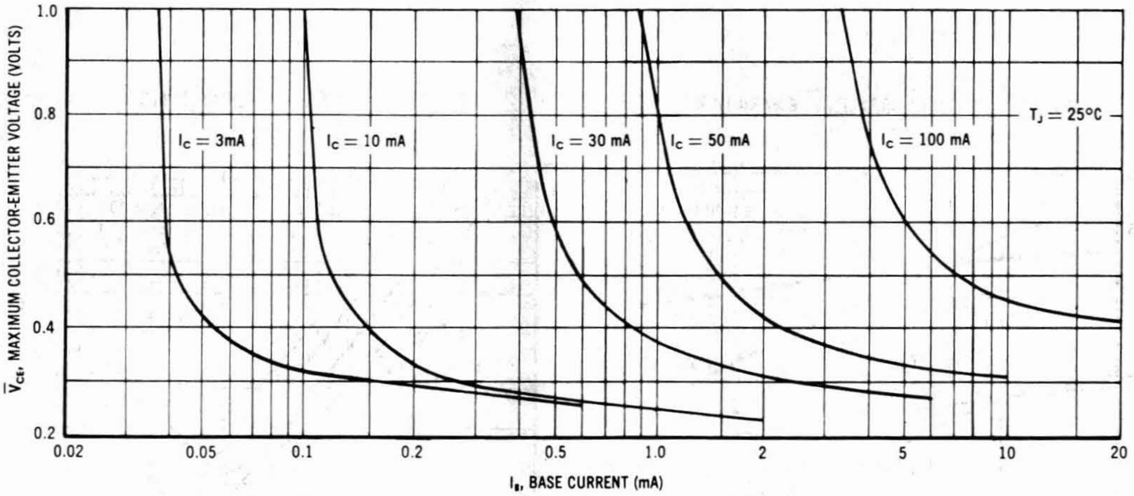


FIGURE 12 — MINIMUM CURRENT GAIN CHARACTERISTICS

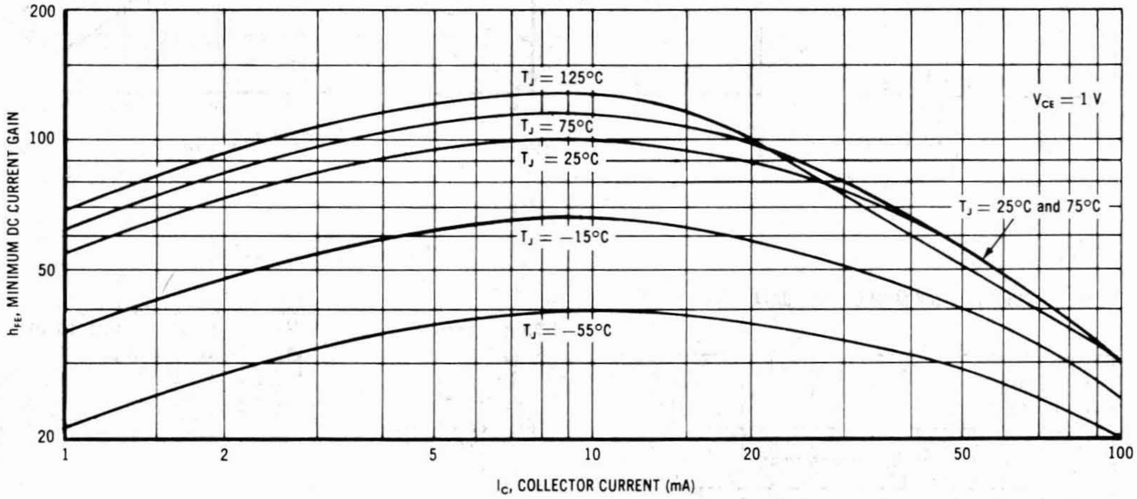


FIGURE 13 — SATURATION VOLTAGE LIMITS

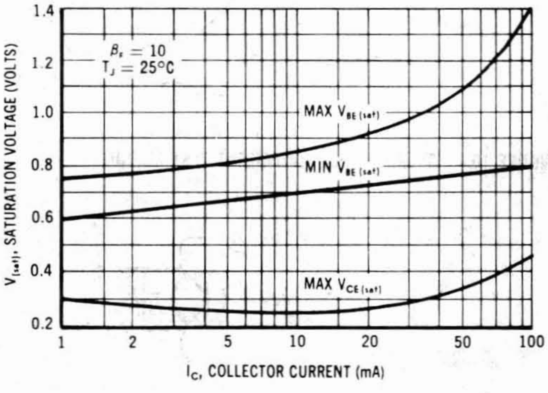
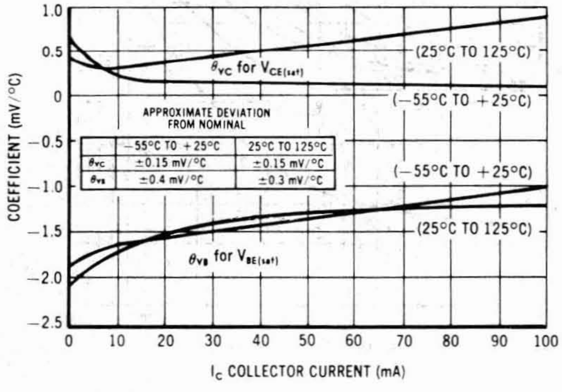


FIGURE 14 — TYPICAL TEMPERATURE COEFFICIENTS



2N2369A (SILICON)

CASE 22
(TO-18)

Collector connected to case

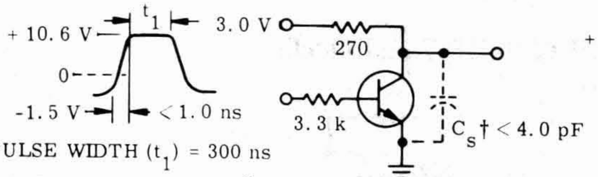
NPN silicon epitaxial transistor for high-speed range of 10 – 100 mAdc switching applications. Specifications provided at -55°C to +125°C for critical dc characteristics.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Collector Current — Continuous	I_C	200	mAdc
Peak (10 μs Pulse)		500	
Total Device Dissipation @ $T_A = 25°C$	P_D	0.36	Watt
Derate above 25°C		2.06	mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D	1.2	Watts
Derate above 25°C		6.85	mW/°C
Operating Junction Temperature Range	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

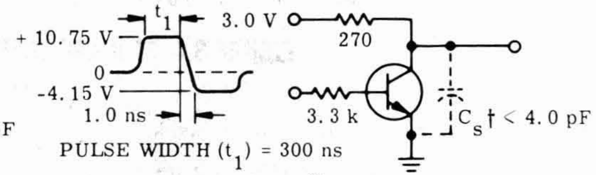
SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 — t_{on} CIRCUIT — 10 mA



PULSE WIDTH (t_1) = 300 ns
DUTY CYCLE = 2.0%

FIGURE 2 — t_{off} CIRCUIT — 10 mA



PULSE WIDTH (t_1) = 300 ns
DUTY CYCLE = 2.0%

† Total shunt capacitance of test jig and connectors.

2N2369A (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic	Fig. No.	Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	-	BV_{CEO}*	15	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 µAdc, I_B = 0)	-	BV_{CES}	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	-	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)	-	BV_{EBO}	4.5	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0)	-	I_{CES}	-	0.4	µAdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	-	I_{CBO}	-	30	µAdc
Base Current (V_{CE} = 20 Vdc, V_{BE} = 0)	-	I_B	-	0.4	µAdc

ON CHARACTERISTICS

Characteristic	Fig. No.	Symbol	Min	Max	Unit
DC Current Gain*	-	h_{FE}*			-
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)			-	120	
(I_C = 10 mAdc, V_{CE} = 0.35 Vdc)			40	-	
(I_C = 10 mAdc, V_{CE} = 0.35 Vdc, T_A = -55°C)			20	-	
(I_C = 30 mAdc, V_{CE} = 0.4 Vdc)			30	-	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)			20	-	
Collector-Emitter Saturation Voltage*	-	$V_{CE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)			-	0.20	
(I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = +125°C)			-	0.30	
(I_C = 30 mAdc, I_B = 3.0 mAdc)			-	0.25	
(I_C = 100 mAdc, I_B = 10 mAdc)			-	0.50	
Base-Emitter Saturation Voltage*	-	$V_{BE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)			0.70	0.85	
(I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = +125°C)			0.59	-	
(I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = -55°C)			-	1.02	
(I_C = 30 mAdc, I_B = 3.0 mAdc)			-	1.15	
(I_C = 100 mAdc, I_B = 10 mAdc)			-	1.60	

DYNAMIC CHARACTERISTICS

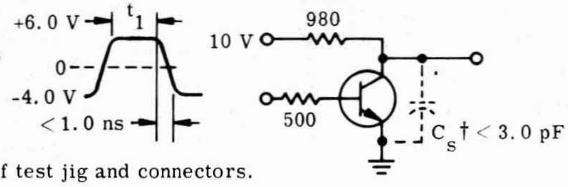
Characteristic	Fig. No.	Symbol	Min	Max	Unit
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	-	f_T	500	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	-	C_{ob}	-	4.0	pF
Turn-On Time (V_{CC} = 3.0 V, $V_{BE(off)}$ = 1.5 V, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.5 mAdc)	1	t_{on}	-	12	ns
Turn-Off Time (V_{CC} = 3.0 V, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.5 mAdc)	2	t_{off}	-	18	ns
Storage Time (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc)	3	t_s	-	13	ns

* Pulse Test: PW = 300 µs, Duty Cycle = 2.0%

FIGURE 3 — STORAGE TIME EQUIVALENT TEST CIRCUIT

PULSE WIDTH (t_1) = 300 ns

DUTY CYCLE = 2.0%



† Total shunt capacitance of test jig and connectors.

2N2381 (GERMANIUM)
2N2382

PNP germanium epitaxial mesa transistors for high-speed, high-current switching applications.

Collector connected to case

CASE 31
(TO-5)

MAXIMUM RATINGS

Rating	Symbol	2N2381	2N2382	Unit
Collector-Emitter Voltage	V_{CEO}	15	20	Vdc
Collector-Base Voltage	V_{CB}	30	45	Vdc
Emitter-Base Voltage	V_{EB}	4	4	Vdc
Collector Current-Continuous	I_C	500		mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	300 4		mW $mW/^oC$
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	750 10		mW $mW/^oC$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100		^oC

FIGURE 1 — ACTIVE REGION TIME CONSTANT

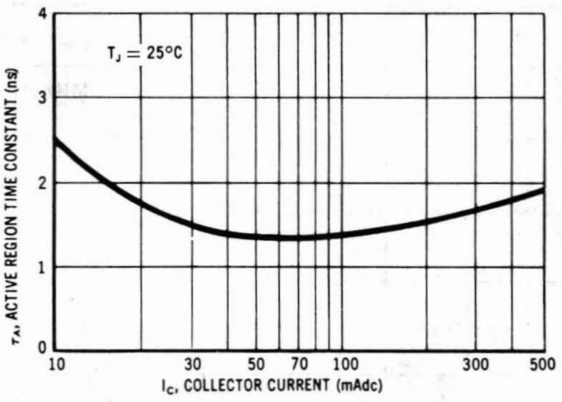
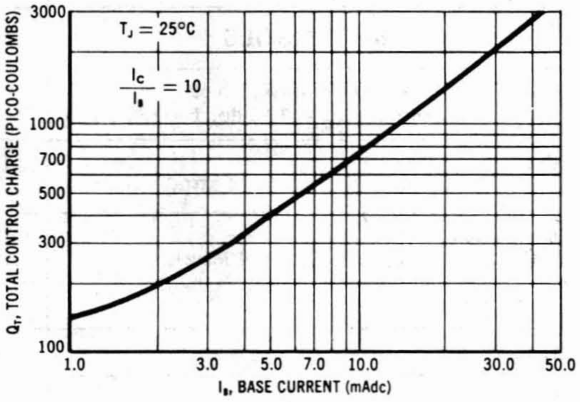


FIGURE 2 — TOTAL CONTROL CHARGE



ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_E = 0) 2N2381 2N2382		BV_{CEO}	15 20	- -	- -	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0) 2N2381 2N2382		BV_{CBO}	30 45	- -	- -	Vdc
Latch-Up Voltage 2N2381 2N2382	7	LV_{CEX}	20 25	- -	- -	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0) 2N2381 (V_{CE} = 45 Vdc, V_{BE} = 0) 2N2382		I_{CES}	- -	- -	100 100	μAdc
Collector Cutoff Current (V_{CB} = 5 Vdc, I_E = 0) (V_{CB} = 5 Vdc, I_E = 0, T_A = 85°C) (V_{CB} = 20 Vdc, I_E = 0) 2N2381 2N2382		I_{CBO}	- - - -	1.0 - - -	7 100 25 15	μAdc
Emitter Cutoff Current (V_{BE} = 0.5 Vdc, I_C = 0) (V_{BE} = 4 Vdc, I_C = 0)		I_{EBO}	- -	- -	0.005 1	mAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 200 mAdc, V_{CE} = 0.5 Vdc) (I_C = 400 mAdc, V_{CE} = 1.0 Vdc)	11	h_{FE}	40 25	- -	- -	-
Collector-Emitter Saturation Voltage (I_C = 200 mAdc, I_B = 20 mAdc) (I_C = 400 mAdc, I_B = 40 mAdc)	8, 10	$V_{CE(sat)}$	- -	0.25 0.4	0.4 0.7	Vdc
Base-Emitter Saturation Voltage (I_C = 200 mAdc, I_B = 20 mAdc) (I_C = 400 mAdc, I_B = 40 mAdc)	9, 10	$V_{BE(sat)}$	0.45 -	0.54 0.71	0.7 0.9	Vdc
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	300	-	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 4 MHz)	13	C_{ob}	-	3.5	6	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 4 MHz)	13	C_{ib}	-	8	15	pF
Delay Time	4	t_d	-	4.5	7	ns
Rise Time	4	t_r	-	8	15	ns
Storage Time	3, 4	t_s	-	20	30	ns
Fall Time	4	t_f	-	8	15	ns
Active Region Time Constant	1, 4	τ_A	-	1.6	3.0	ns

FIGURE 3 — STORAGE TIME VARIATIONS

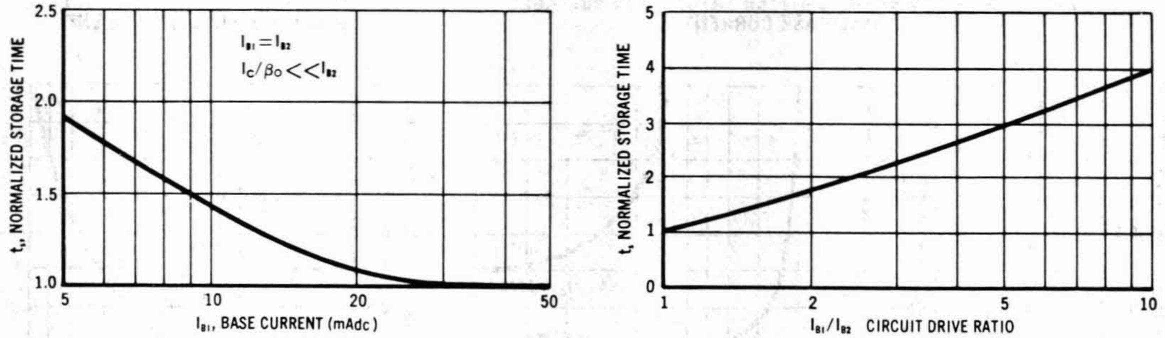


FIGURE 4 — SWITCHING TIME EQUATIONS & TEST CIRCUIT

Rise Time = $t_r = T_A\beta_F R$ = 10 to 90% Rise Time (fig. 5)
Fall Time = $t_f = T_A\beta_C F$ = 10 to 90% Fall Time (fig. 6)
$\beta_O = h_{FE}$ at Edge of Saturation
$\beta_C = I_C$ in Saturation / I_{B2} (Base "OFF" Current)
$\beta_F = I_C$ in Saturation / I_{B1} (Base "ON" Current)

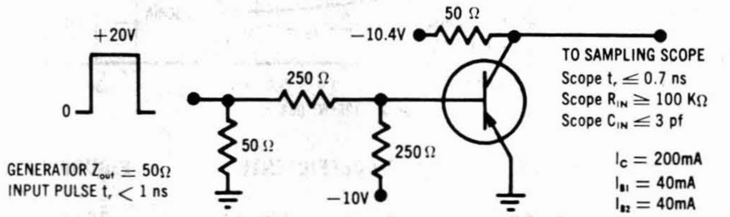

+20V
0
GENERATOR $Z_{out} = 50\Omega$
INPUT PULSE $t_r < 1$ ns
50 Ω
250 Ω
250 Ω
−10V
−10.4V
50 Ω
TO SAMPLING SCOPE
Scope $t_r \leq 0.7$ ns
Scope $R_{IN} \geq 100$ KΩ
Scope $C_{IN} \leq 3$ pf
$I_C = 200$mA
$I_{B1} = 40$mA
$I_{B2} = 40$mA

FIGURE 5 — RISE TIME FACTOR

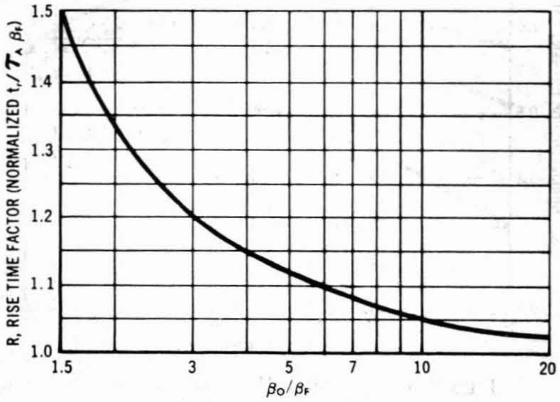


FIGURE 6 — FALL TIME FACTOR

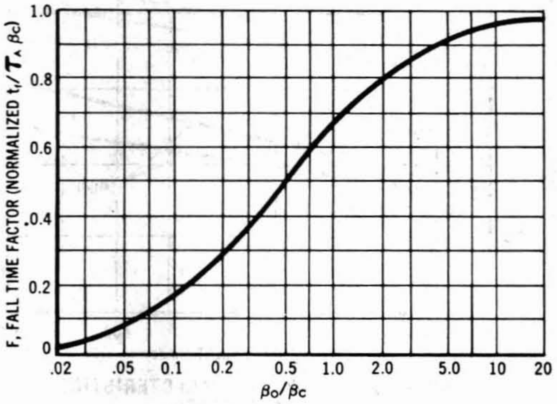
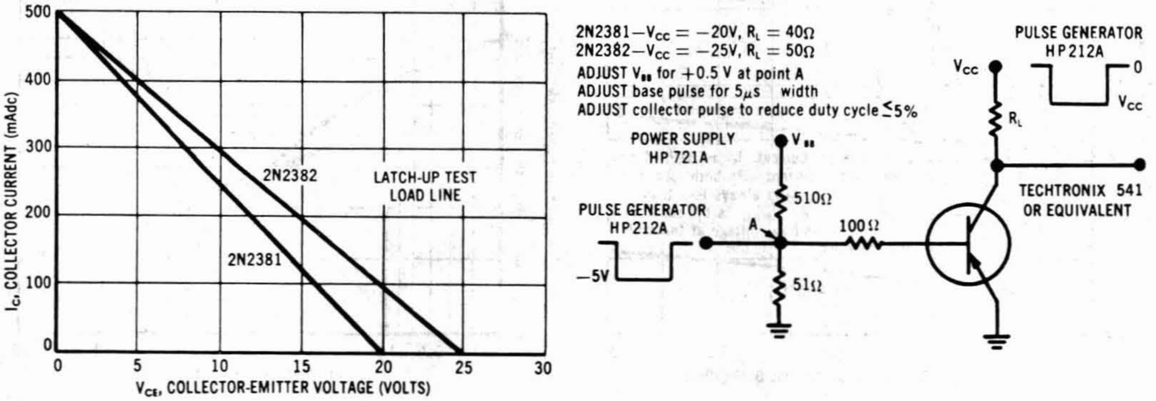


FIGURE 7 — COLLECTOR LATCH-UP VOLTAGE AND TEST CIRCUIT



2N2381—$V_{CC} = -20$V, $R_L = 40\Omega$
2N2382—$V_{CC} = -25$V, $R_L = 50\Omega$
ADJUST V_{BB} for +0.5 V at point A
ADJUST base pulse for 5μs width
ADJUST collector pulse to reduce duty cycle ≤5%

FIGURE 8 — COLLECTOR-EMITTER SATURATION VOLTAGES versus BASE CURRENT

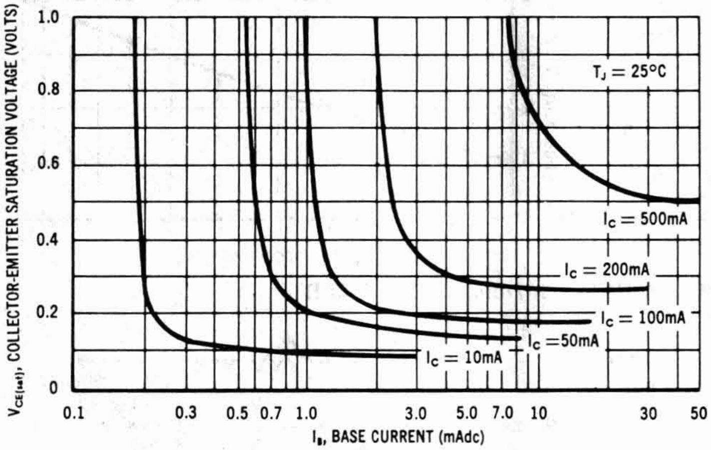


FIGURE 9 — BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT

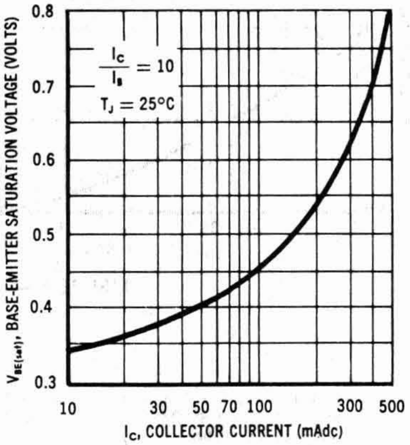


FIGURE 10 — TEMPERATURE COEFFICIENTS

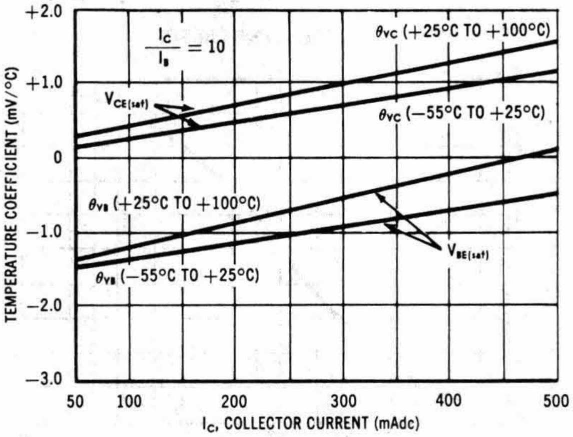


FIGURE 11 — NORMALIZED GAIN CHARACTERISTICS

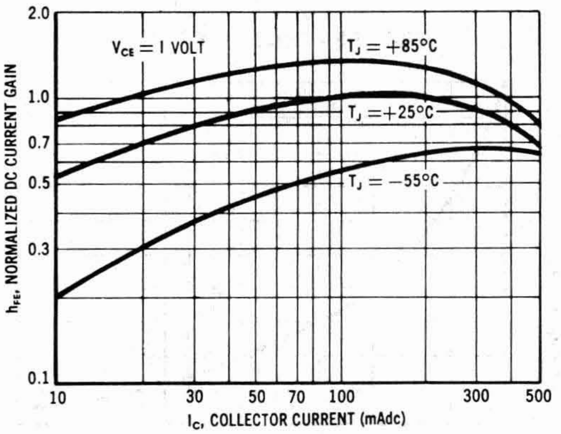
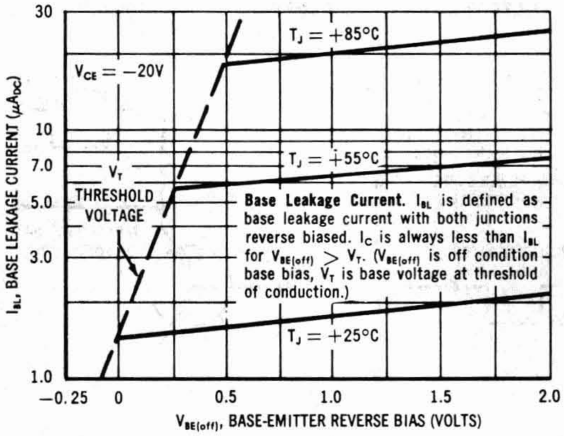
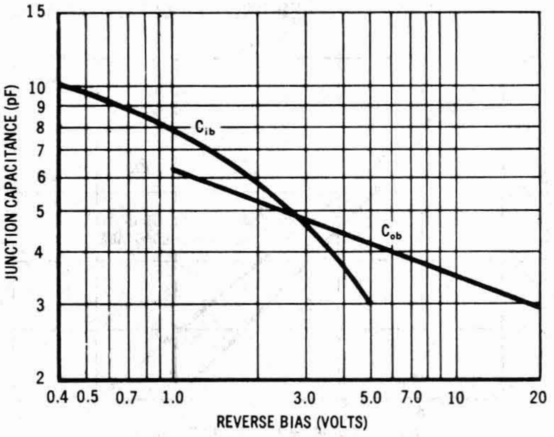


FIGURE 12 — LEAKAGE CHARACTERISTICS COMMON EMITTER



Base Leakage Current. I_{BL} is defined as base leakage current with both junctions reverse biased. I_C is always less than I_{BL} for $V_{BE(off)} > V_T$. ($V_{BE(off)}$ is off condition base bias, V_T is base voltage at threshold of conduction.)

FIGURE 13 — JUNCTION CAPACITANCE versus REVERSE VOLTAGE



2N2405

For Specifications, See 2N1893 Data.

2N2410 (SILICON)

CASE 31
(TO-5)

Collector connected to case

NPN silicon annular transistor designed for high-speed, medium-power saturated switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Emitter Voltage R_{BE} = 10 ohms	V_{CER}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current	I_C	800	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	800 4.57	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	2.5 14.3	Watts mW/°C
Operating Junction Temperature Range	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

2N2410 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise specified)

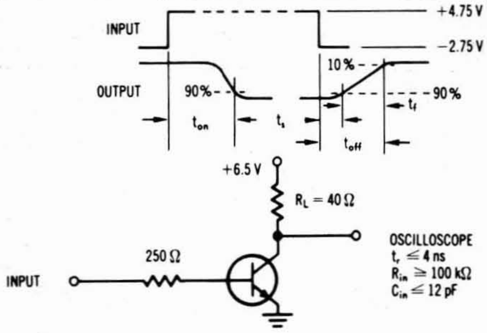
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 30 mAdc, I_B = 0)	BV_{CEO} (sus)*	30	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 30 mAdc, R_{BE} = 10 ohms)	BV_{CER}*	40	—	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	5.0	—	Vdc
Collector-Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0) (V_{CE} = 30 Vdc, V_{BE} = 0, T_A = 150°C)	I_{CES}	— —	0.3 350	μAdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)	I_{CBO}	—	0.3	μAdc
Emitter Cutoff Current (V_{BE} = 4 Vdc, I_C = 0)	I_{EBO}	—	0.3	μVdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 150 mAdc, V_{CE} = 1 Vdc) (I_C = 150 mAdc, V_{CE} = 10 Vdc) (I_C = 500 mAdc, V_{CE} = 10 Vdc)	h_{FE}*	30 15 30 25	120 — 120 100	—
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{CE(sat)}$*	— —	0.45 1.3	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{BE\,(sat)}$*	— —	1.2 1.6	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	200	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	11	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1 MHz)	C_{ib}	—	50	pF
Turn-On Time (t_d + t_r) (I_C = 150 mAdc, Figure 1) (I_C = 500 mAdc, Figure 2)	t_{on}	— —	65 65	ns
Turn-Off Time (t_s + t_f) (I_C = 150 mAdc, Figure 1) (I_C = 500 mAdc, Figure 2)	t_{off}	— —	55 65	ns
Storage Time (I_C = 150 mAdc, Figure 1)	t_s	—	40	ns
Fall Time (I_C = 150 mAdc, Figure 1)	t_f	—	30	ns

*Pulse Test: Pulse Width = 300 μs; Duty Cycle = 2%

SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 — I_c = 150 mA

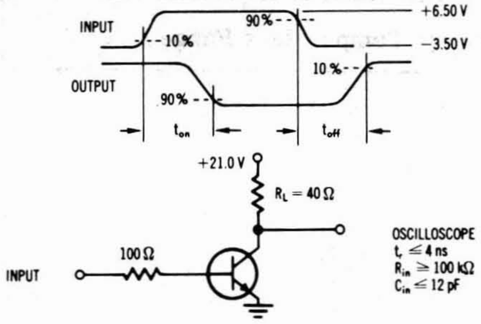
$t_r \leq$ 1 ns, PULSE WIDTH $\geq$ 300 ns



INPUT
+4.75 V
−2.75 V
OUTPUT
90%
10%
90%
t_{on}
t_s
t_f
t_{off}
+6.5 V
R_L = 40 Ω
250 Ω
INPUT
OSCILLOSCOPE
$t_r \leq$ 4 ns
$R_{in} \geq$ 100 kΩ
$C_{in} \leq$ 12 pF

FIGURE 2 — I_c = 500mA

$t_r \leq$ 12 ns, $t_f \leq$ 12 ns, PULSE WIDTH = 1.5 μs ± 0.5 μs, PRR ≤ 500 Hz



INPUT
90%
10%
+6.50 V
−3.50 V
OUTPUT
10%
90%
t_{on}
t_{off}
+21.0 V
R_L = 40 Ω
100 Ω
INPUT
OSCILLOSCOPE
$t_r \leq$ 4 ns
$R_{in} \geq$ 100 kΩ
$C_{in} \leq$ 12 pF

2N2415 (GERMANIUM)
2N2416

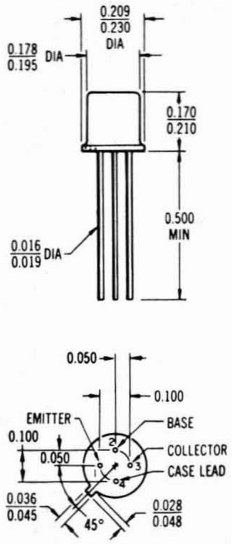
GERMANIUM ULTRA-HIGH-FREQUENCY TRANSISTORS

. . . for very low-noise, high-gain amplifiers, oscillators, mixers, and frequency multipliers.

- High Maximum Frequency of Oscillation
  $f_{max} = 2000$ MHz typ
- Low Noise Figure
  NF = 3.0 dB max at 200 MHz (2N2415)
- High Maximum Available Gain
  MAG = 14 dB typ at 500 MHz for 2N2415
  MAG = 12.5 dB typ at 500 MHz for 2N2416
- High Breakdown Voltages
  $BV_{CBO} = 25$ Volts typ
  $BV_{CEO} = 15$ Volts typ
- Low Output Capacitance
  $C_{ob} = 0.9$ pF typ

AMPLIFIER TRANSISTORS

GERMANIUM PNP
EPITAXIAL MESA
DIFFUSED BASE


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
EMITTER
BASE
0.100
COLLECTOR
0.050
CASE LEAD
1
2
3
4
0.036
0.045
45°
0.028
0.048

TO-72 PACKAGE
CASE 20

MAXIMUM RATINGS*

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	10	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	0.3	Vdc
Collector Current	I_C	20	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	75 1.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	°C

* The maximum rating is that value above which device operation may be impaired from the viewpoint of life or performance.

2N2415, 2N2416 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

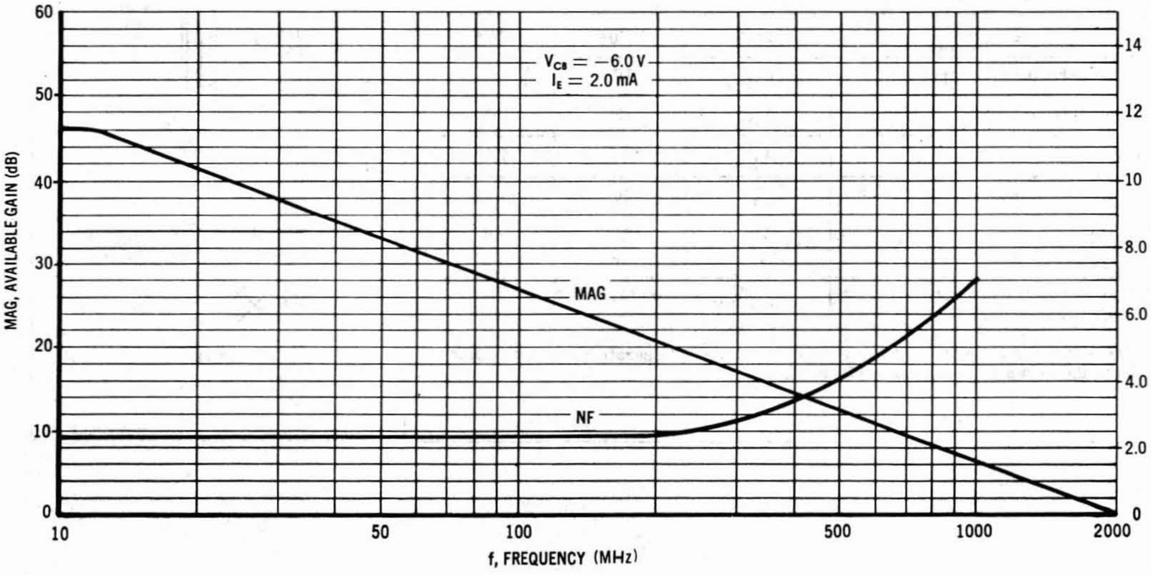
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 2.0 mAdc, I_B = 0)	BV_{CEO}*	10	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	15	25	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	1.0	5.0	μAdc
Emitter Cutoff Current (V_{BE} = 0.3 Vdc, I_C = 0)	I_{EBO}	-	-	100	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 2.0 mAdc, V_{CE} = 6.0 Vdc) 2N2415 2N2416	h_{FE}	10 8.0	- -	200 200	-
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 2.0 mAdc, V_{CE} = 6.0 Vdc, f = 200 MHz) 2N2415 2N2416	f_T	500 400	- -	- -	MHz
Output Capacitance (V_{CB} = 6.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	0.9	2.0	pF
Small-Signal Current Gain (I_C = 2.0 mAdc, V_{CE} = 6.0 Vdc, f = 1.0 kHz) 2N2415 2N2416	h_{fe}	15 10	- -	300 300	-
Collector-Base Time Constant** (I_E = 2.0 mAdc, V_{CB} = 6.0 Vdc, f = 79.8 MHz) 2N2415 2N2416	$r_b'C_c$**	- -	- -	8.0 10	ps
Noise Figure (V_{CB} = 6.0 Vdc, I_E = 1.5 mAdc, R_S = 75 ohms, f = 200 MHz) 2N2415 2N2416	NF	- -	2.4 3.4	3.0 4.0	dB
FUNCTIONAL TESTS					
Maximum Available Gain# (V_{CB} = 6.0 Vdc, I_E = 2.0 mAdc, f = 500 MHz) 2N2415 2N2416	MAG#	- -	14 12.5	- -	dB

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

** Direct Collector-Emitter header capacitance balanced out to give true device capability.

# MAG calculated from f_{max} as determined from actual amplifier circuits.

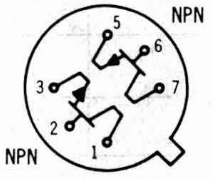
TYPICAL MAG and NOISE FIGURE versus FREQUENCY



2N2453 (SILICON)
2N2453A

CASE 32C

Dual NPN silicon transistors designed for differential amplifier applications.



PINS 4 AND 8 OMITTED

Pin Connections, Bottom View

All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	2N2453	2N2453A	Unit
Collector-Emitter Voltage	V_{CEO}	30	50	Vdc
Collector-Base Voltage	V_{CB}	60	80	Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Collector Current	I_C	50		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		C
		One Side	Both Sides	
Power Dissipation @ T_A = 25°C Derate above 25°C	P_D	200 1.14	300 1.71	mW mW/°C
Power Dissipation @ T_C = 25°C T_C = 100°C Derate above 25°C	P_D	600 350 3.43	1200 700 6.86	mW mW mW/°C

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	 2N2453 2N2453A	$BV_{CEO(sus)}$*	 30 50	 - -	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	 2N2453 2N2453A	BV_{CBO}	 60 80	 - -	Vdc
Emitter Base Breakdown Voltage (I_E = 0.1 μAdc, I_C = 0)		BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)		I_{CBO}	 - -	 0.005 10	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	0.002	μAdc

* Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

2N2453, 2N2453A (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			-
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc)		80	-	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)		40	-	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		150	600	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)		75	-	
Collector-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 0.5 mAdc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 0.5 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 30 MHz)	f_T	60	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	8.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	10	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{ie}	5.0	-	k ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{re}	-	6.0	$X\ 10^{-4}$
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	150	600	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{oe}	5.0	30	μmhos
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20	30	Ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	5.0	$X\ 10^{-4}$
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	0.2	μmho
Noise Figure (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 1.0 kHz)	NF	-	7.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio**	h_{FE1}/h_{FE2}**			-
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N2453A		0.90	1.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		0.90	1.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, T_A = -55°C to +125°C)		0.85	1.0	
Base Voltage Differential	$\lvert V_{BE1} - V_{BE2} \rvert$			mVdc
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc)		-	3.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		-	5.0	
Base Voltage Differential Gradient (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C to +125°C)	$\frac{\Delta(V_{BE1} - V_{BE2})}{\Delta T_A}$			μV/°C
2N2453		-	10	
2N2453A		-	5.0	

** Lowest h_{FE} reading is taken as h_{FE1} for this ratio.

2N2476 (SILICON)
2N2477

CASE 31
(TO-5)

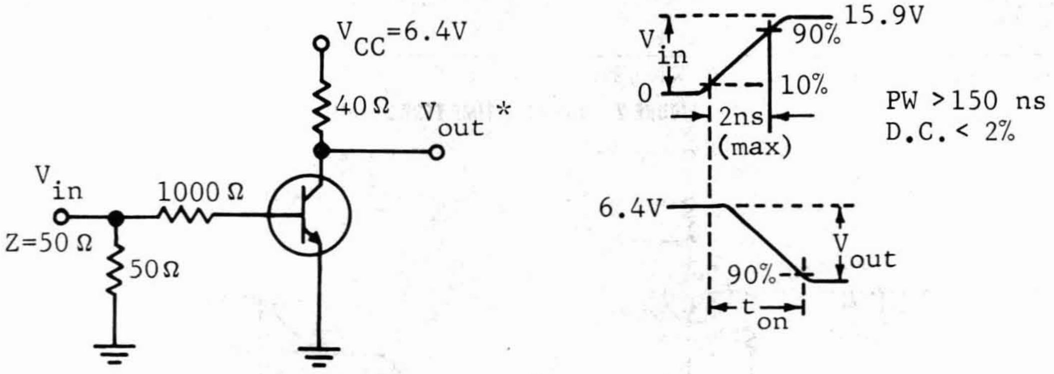
NPN silicon annular transistors designed for high-speed, low-power saturated switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.6 3.4	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	2.0 11.4	Watts mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

FIGURE 1 — TURN-ON TIME TEST CIRCUIT


V_{CC}=6.4V
40 Ω
V_{out} *
V_{in}
1000 Ω
Z=50 Ω
50Ω
V_{in}
15.9V
90%
0
10%
2ns
(max)
PW >150 ns
D.C. < 2%
6.4V
V_{out}
90%
t_{on}

*Input and output waveforms monitored by means of an oscilloscope or other indicating device having a rise time<0.5 ns; input capacitance of probe < 2.5 pF with shunt resistance ≥ 1 megohm.

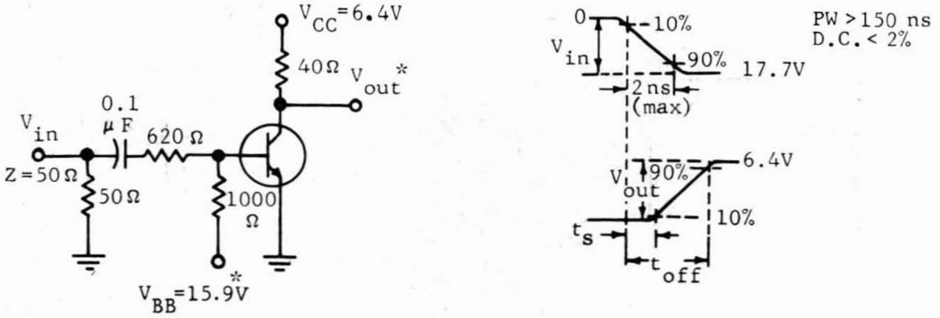
2N2476, 2N2477 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 50 mAdc, I_B = 0)		BV_{CEO}*	20	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)		I_{CBO}	- -	0.2 200	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	100	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 150 mAdc, V_{CE} = 0.4 Vdc)	2N2476 2N2477	h_{FE}	20 40	- -	-
Collector-Emitter Saturation Voltage (I_C = 150 mAdc. I_B = 7.5 mAdc) (I_C = 150 mAdc. I_B = 3.75 mAdc) (I_C = 500 mAdc. I_B = 50 mAdc)	2N2476 2N2477 2N2476 2N2477	$V_{CE(sat)}$	- - - -	0.4 0.4 0.75 0.65	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc. I_B = 7.5 mAdc) (I_C = 150 mAdc. I_B = 3.75 mAdc)	2N2476 2N2477	$V_{BE(sat)}$	- -	1.0 0.95	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	250	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)		C_{ob}	-	10	pF
Turn-On Time (Figure 1) (V_{CC} = 6.4 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc)		t_{on}	-	25	ns
Turn-Off Time (Figure 2) (V_{CC} = 6.4 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc)		t_{off}	-	45	ns
Storage Time (Figure 2) (I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc)		t_s	-	25	ns

* Pulse Test: pulse width ≦ 400 μs, duty cycle ≦ 3%.

FIGURE 2 — TURN-OFF TIME TEST CIRCUIT

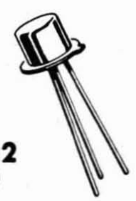


*Input and output waveforms monitored by means of an oscilloscope or other indicating device having a rise time < 0.5 ns; input capacitance of probe < 2.5 pF with shunt resistance ≥ 1 megohm.

2N2480, A

For Specifications, See 2N2060 Data.

2N2481 (SILICON)



CASE 22
(TO-18)

NPN silicon annular transistor for high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Total Device Dissipation @ 25°C Ambient Temperature (Derate 2.06 mW/°C above 25°C)	P_D	0.36	Watt
Total Device Dissipation @ 25°C Case Temperature (Derate 6.9 mW/°C above 25°C)	P_D	1.2	Watts
Junction Temperature	T_J	200	°C
Storage Temperature	T_{stg}	-65 to + 200	°C

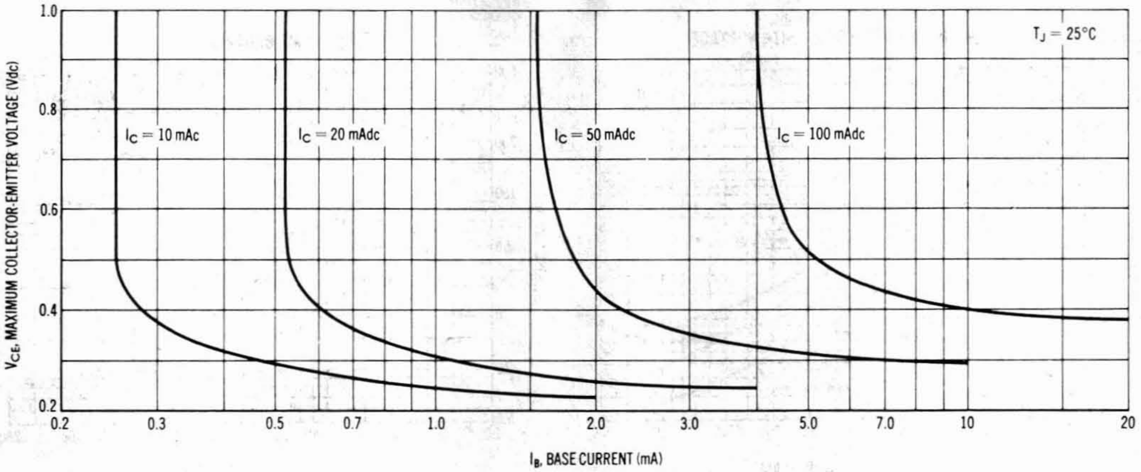
2N2481 (Continued)

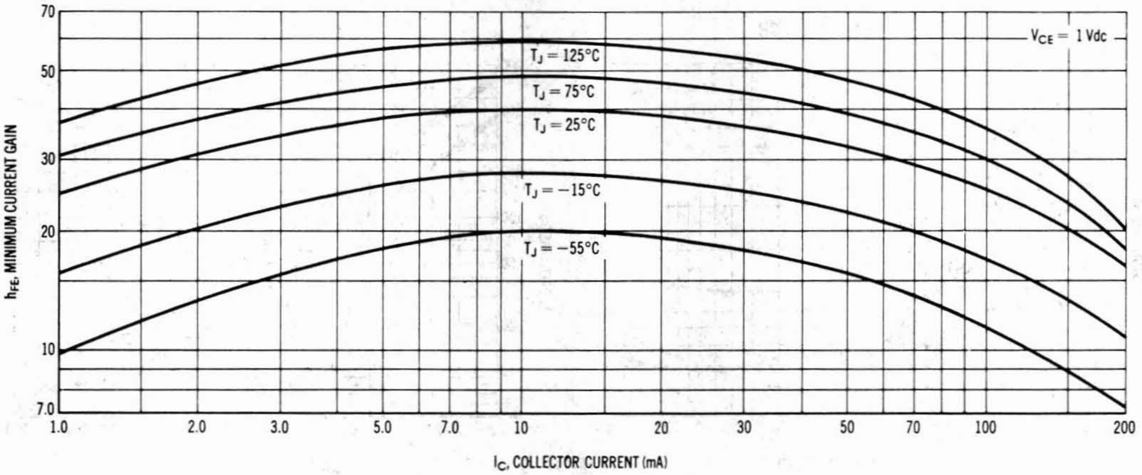
ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

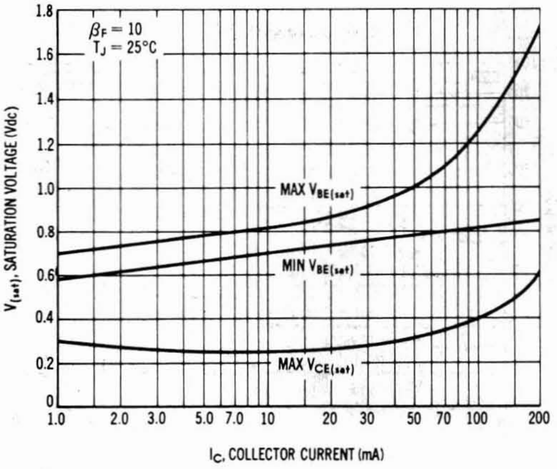
Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5	---	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 30 mAdc, I_B = 0)	BV_{CEO}	15	---	Vdc
Collector-Emitter Breakdown Voltage (I_C = 1.0 μAdc, V_{BE} = 0)	BV_{CES}	30	---	Vdc
Collector Leakage Current (V_{CE} = 20 Vdc, V_{BE} = 3 Vdc) (V_{CE} = 20 Vdc, V_{BE} = 3 Vdc, T_A = 150°C)	I_{CEX}	 --- ---	 .050 15	μAdc
Base Leakage Current (V_{CE} = 20 Vdc, V_{BE} = 3 Vdc)	I_{BL}	---	50	nAdc
Emitter Cutoff Current (V_{EB} = 4.0 Vdc, I_C = 0)	I_{EBO}	---	100	nAdc
DC Forward Current Transfer Ratio (I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)* (I_C = 150 mAdc, V_{CE} = 1.0 Vdc)*	h_{FE}	 25 40 20 20	 --- 120 --- ---	---
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)*	$V_{CE\ (sat)}$	 --- ---	 0.25 0.40	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)*	$V_{BE\ (sat)}$	 0.7 ---	 0.82 1.25	Vdc
Output Capacitance (V_{CB} = 5 V, I_C = 0, f = 1 MHz)	C_{ob}	---	5	pF
Input Capacitance (V_{EB} = 0.5 V, f = 1 MHz)	C_{ib}	---	7	pF
Small-Signal Forward Current Transfer Ratio (V_{CE} = 10 V, I_C = 10 mA, f = 100 MHz)	h_{fe}	3	---	---
Small-Signal, Short-Circuit, Input Impedance (Real part) (I_C = 10 mA, V_{CE} = 10 V, f = 250 MHz)	$Re(h_{ie})$	---	60	ohms
Turn-On Time (I_C = 100 mA, I_{B1} = 10 mA, $V_{BE\,(off)}$ = 2 V) (I_C = 10 mA, I_{B1} = 1.0 mA, $V_{BE\,(off)}$ = 2 V)	t_{on}	 --- ---	 40 75	ns
Turn-Off Time (I_C = 100 mA, I_{B1} = 10 mA, I_{B2} = 5 mA) (I_C = 10 mA, I_{B1} = 1.0 mA, I_{B2} = 0.5 mA)	t_{off}	 --- ---	 55 45	ns
Storage Time (I_C = 10 mA, I_{B1} = 10 mA, I_{B2} = 10 mA)	t_s	---	20	ns

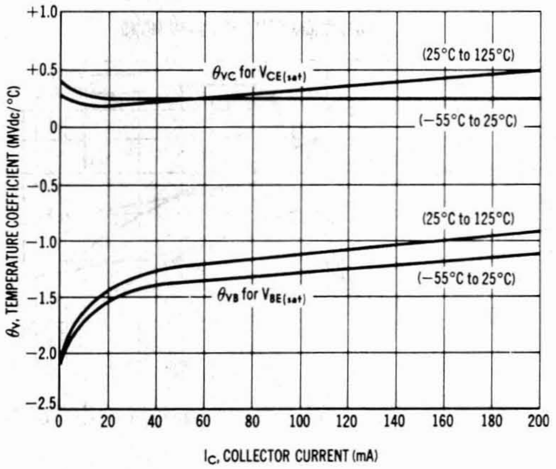
*Pulse width ≦ 300 μs, Duty Cycle ≦ 2%

2N2481 (Continued)


COLLECTOR SATURATION VOLTAGE CHARACTERISTICS

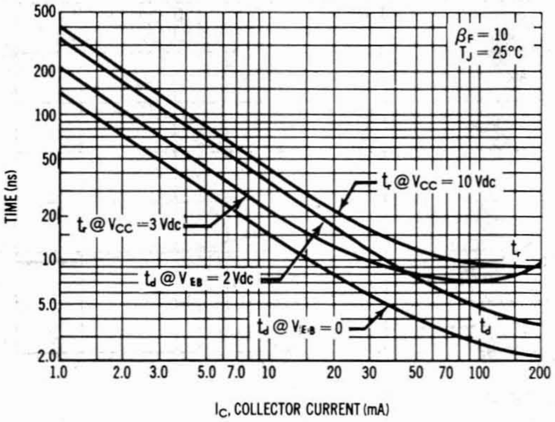

MINIMUM CURRENT GAIN CHARACTERISTICS


LIMITS OF SATURATION VOLTAGES

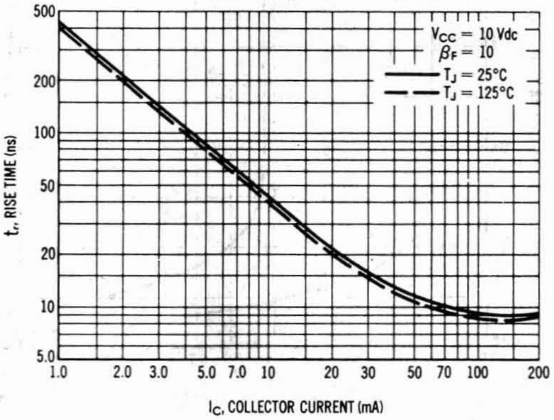

TYPICAL TEMPERATURE COEFFICIENTS

TYPICAL SWITCHING CHARACTERISTICS

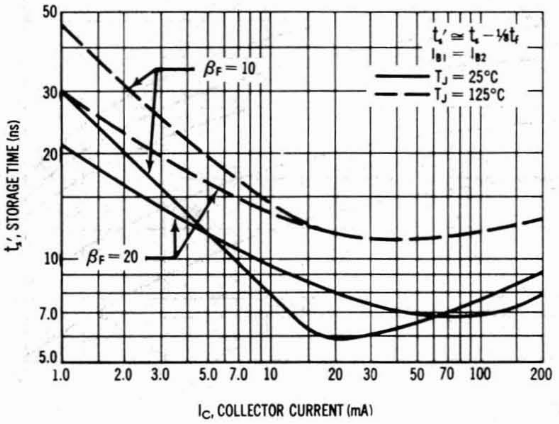
TURN-ON TIME VARIATIONS WITH VOLTAGE



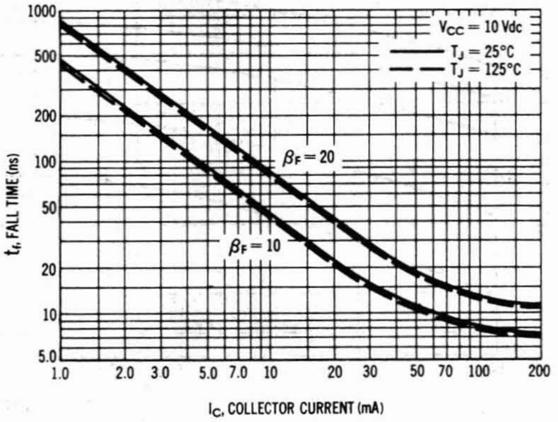
RISE TIME BEHAVIOR



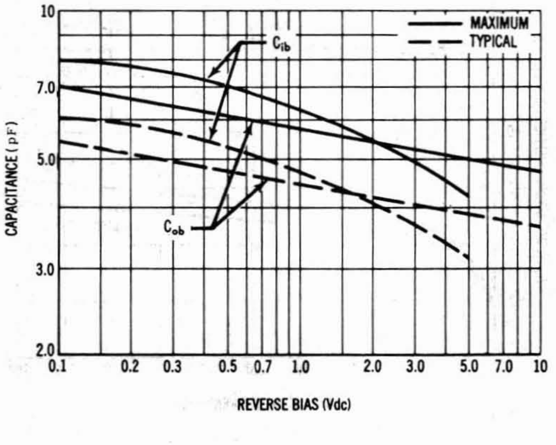
STORAGE TIME BEHAVIOR



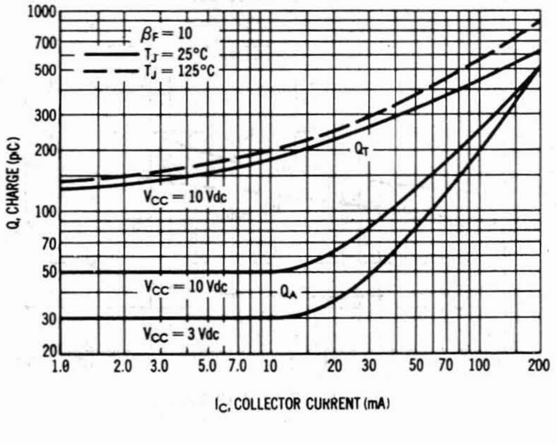
FALL TIME BEHAVIOR



JUNCTION CAPACITANCE VARIATIONS



MAXIMUM CHARGE DATA



2N2490 thru 2N2493 (GERMANIUM)

CASE 5
(TO-36)

PNP germanium power transistors for general purpose power and switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N2490	2N2491	2N2492	2N2493	Unit
Collector-Base Voltage	V_{CB}	70	60	80	100	Volts
Collector-Emitter Voltage	V_{CES}	60	50	70	85	Volts
Emitter-Base Voltage	V_{EB}	40	30	60	80	Volts
Collector Current	I_C	15				Amp
Power Dissipation at $T_C = 25^{\circ}C$	P_D	170				Watts
Junction Temperature Range	T_J	-65 to +110				$^{\circ}C$

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current (V_{CB} = -2 Vdc)		I_{CBO}	—	0.2	mAdc
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = -40 Vdc)	2N2490		—	3.0	
(V_{EB} = -30 Vdc)	2N2491		—	3.0	
(V_{EB} = -60 Vdc)	2N2492		—	2.0	
(V_{EB} = -80 Vdc)	2N2493		—	3.0	
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = -70 Vdc, V_{BE} = 1.5 Vdc)	2N2490		—	3.0	
(V_{CE} = -60 Vdc, V_{BE} = 1.5 Vdc)	2N2491		—	3.0	
(V_{CE} = -80 Vdc, V_{BE} = 1.5 Vdc)	2N2492		—	2.0	
(V_{CE} = -100 Vdc, V_{BE} = 1.5 Vdc)	2N2493		—	3.0	
(V_{CE} = -35 Vdc, V_{BE} = 1.5 Vdc, $T_C = +100^{\circ}C$)	2N2490,2N2491		—	35	
(V_{CE} = -40 Vdc, V_{BE} = 1.5 Vdc, $T_C = +100^{\circ}C$)	2N2492		—	35	
(V_{CE} = -50 Vdc, V_{BE} = 1.5 Vdc, $T_C = +100^{\circ}C$)	2N2493		—	35	
Collector-Emitter Breakdown Voltage (I_C = 1 A, I_B = 0)	2N2490	V_{CEO}	50	—	Volts
	2N2491		40	—	
	2N2492		65	—	
	2N2493		75	—	
Base-Emitter Voltage		V_{BE}			Vdc
(I_C = 5 Adc, V_{CE} = -2 Vdc)	2N2490,2N2491		—	0.9	
	2N2492,2N2493		—	0.8	
(I_C = 12 Adc, V_{CE} = -2 Vdc)			—	1.5	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 12 Adc, I_B = 2 Adc)	2N2490, 2N2491		—	0.7	
	2N2492, 2N2493		—	0.5	
DC Current Gain		h_{FE}			—
(I_C = 1 Adc, V_{CE} = -2 Vdc)	2N2490		45	—	
	2N2491		65	—	
	2N2492, 2N2493		50	—	
(I_C = 5 Adc, V_{CE} = -2 Vdc)	2N2490		20	40	
	2N2491		35	70	
	2N2492, 2N2493		25	50	
(I_C = 5 Adc, V_{CE} = -2 Vdc, $T_A = -65^{\circ}C$)	2N2490		15	—	
	2N2491		25	—	
	2N2492, 2N2493		20	—	
(I_C = 12 Adc, V_{CE} = -2 Vdc)	2N2490		8	—	
	2N2491		12	—	
	2N2492, 2N2493		10		
Common Emitter Cutoff Frequency (I_C = 5A, V_{CE} = -6 V)		$f_{\alpha e}$	5.0	—	kHz
Turn-On Time (I_C = 5 A, $I_{B1} = I_{B2}$ = 0.5 A)		t_{on}	—	25	µs
Turn-Off Time (I_C = 5 A, $I_{B1} = I_{B2}$ = 0.5 A)		t_{off}	—	15	µs

2N2501 (SILICON)

CASE 22
(TO-18)

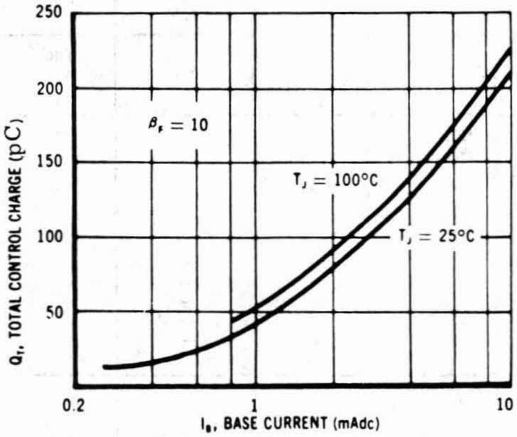
Collector connected to case

NPN silicon annular transistor for high-speed switching applications.

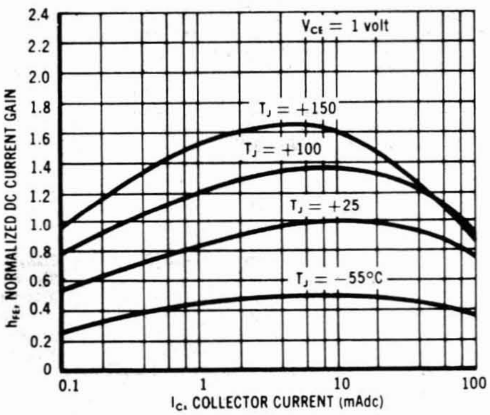
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Emitter-Base Voltage	V_{EB}	6	Vdc
Total Device Dissipation @ 25°C Ambient Temperature (Derate 2.06 mW/°C above 25°C)	P_D	0.36	Watts
Junction Temperature	T_J	+200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Total Device Dissipation @ 25°C Case Temperature (Derate 6.9 mW/°C above 25°C)	P_D	1.2	Watts

TOTAL CONTROL CHARGE



NORMALIZED CURRENT GAIN CHARACTERISTICS

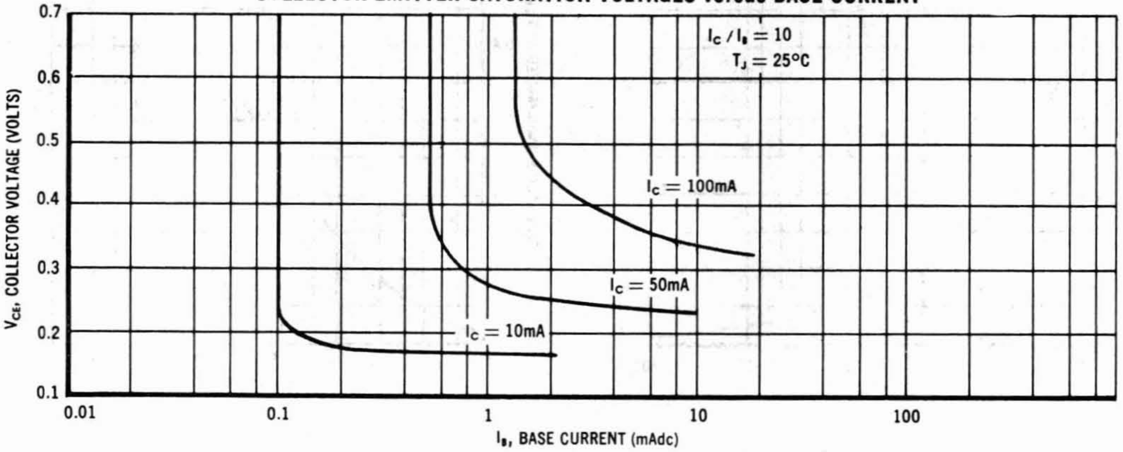


ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	BV_{CBO}	40	–	Vdc
Collector-Emitter Breakdown Voltage (I_C = 30 mAdc, I_B = 0, Pulsed)	BV_{CEO}	20	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)	BV_{EBO}	6	–	Vdc
Collector Leakage Current (V_{CE} = 20 Vdc, V_{BE} = 3 Vdc)	I_{CEX}	–	25	nAdc
Base Leakage Current (V_{CE} = 20 Vdc, V_{BE} = 3 Vdc) (V_{CE} = 20 Vdc, V_{BE} = 3 Vdc, T_A = 150°C)	I_{BL}	– –	25 50	nAdc µAdc
DC Forward Current Transfer Ratio* (I_C = 100 µAdc, V_{CE} = 1 Vdc) (I_C = 1 mAdc, V_{CE} = 1 Vdc) (I_C = 10 mAdc, V_{CE} = 1 Vdc) (I_C = 10 mAdc, V_{CE} = 1 Vdc, T_A = -55°C) (I_C = 50 mAdc, V_{CE} = 1 Vdc) (I_C = 100 mAdc, V_{CE} = 1 Vdc) (I_C = 500 mAdc, V_{CE} = 5 Vdc)	h_{FE}	20 30 50 20 40 30 10	– – 150 – – – –	–
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{CE(sat)}$	– – –	0.2 0.3 0.4	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{BE(sat)}$	– – –	0.85 1.0 1.2	Vdc
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	–	4	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	–	7	pF
Small Signal Forward Current Transfer Ratio (V_{CE} = 20 Vdc, I_C = 10 mAdc, f = 100 MHz)	h_{fe}	3.5	–	–
Current-Gain-Bandwidth Product (V_{CE} = 20 Vdc, I_C = 10 mAdc)	f_T	350	–	MHz
Charge Storage Time Constant (I_C = I_{B1} = I_{B2} = 10 mAdc)	τ_S	–	15	ns
Total Control Charge (I_C = 10 mAdc, I_B = 1 mAdc)	Q_T	–	60	pC
Active Region Time Constant (I_C = 10 mAdc)	τ_A	–	2.5	ns

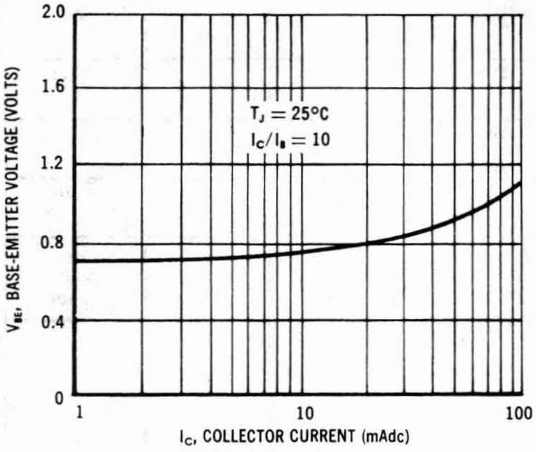
*Pulse Test: Pulse width ≦ 300 µs, duty cycle ≦ 2%

COLLECTOR-EMITTER SATURATION VOLTAGES versus BASE CURRENT

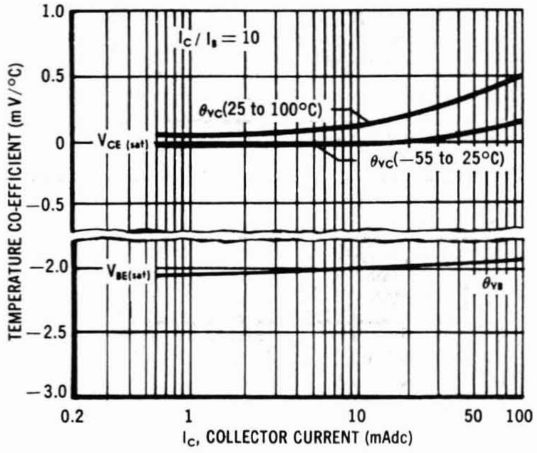


2N2501 (Continued)

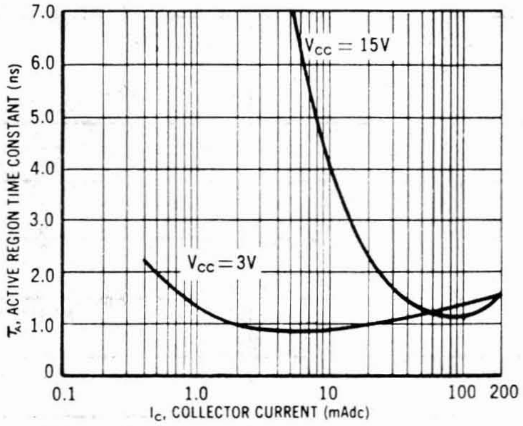
BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT



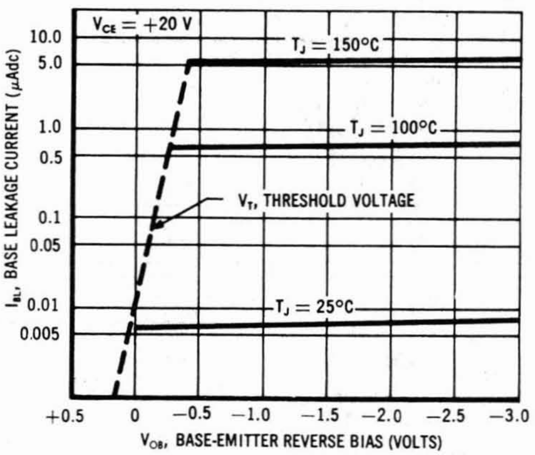
TEMPERATURE COEFFICIENTS



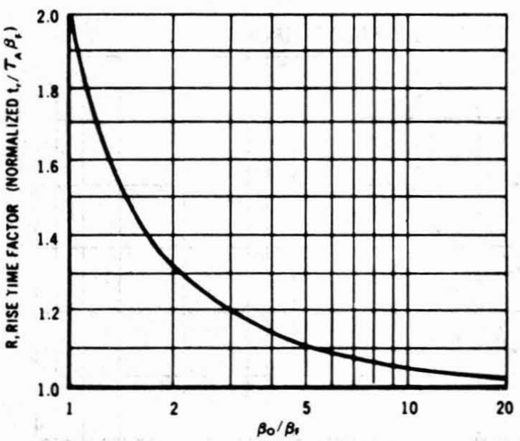
ACTIVE REGION TIME CONSTANT



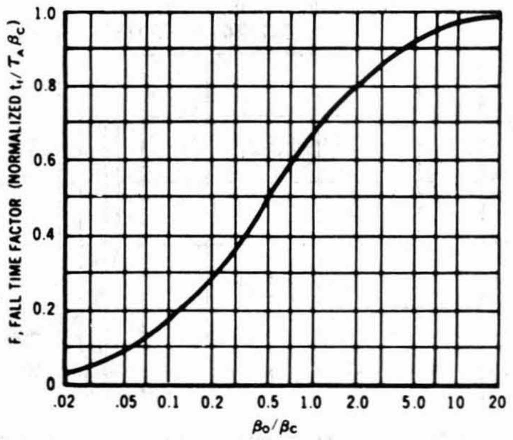
COMMON EMITTER DC LEAKAGE CHARACTERISTICS



RISE TIME FACTOR

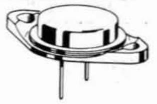


FALL TIME FACTOR

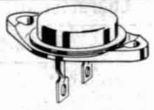


2N2526 (GERMANIUM)
2N2527
2N2528

PNIP germanium power transistors for high-voltage power switching applications.



CASE 11A
(TO-3 modified)



CASE 4-04
(TO-41)

For units with solder lugs attached, specify devices MP2526 etc. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N2526	2N2527	2N2528	Unit
Collector-Emitter Voltage	V_{CE}	80	120	160	Vdc
Collector-Base	V_{CB}	80	120	160	Vdc
Emitter-Base Voltage	V_{EB}	5.0			Vdc
Collector Current - Continuous	I_C	10			Adc
Base Current	I_B	5.0			Adc
Emitter Reverse Current (Surge 60 Hz Recurrent)	I_E	1.5			Adc
Total Device Dissipation @ $T_C = 25°C$	P_D	85			Watts
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110			°C

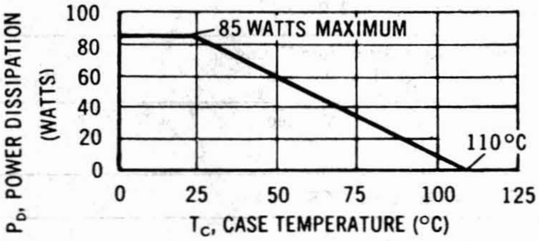
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.0	°C/W

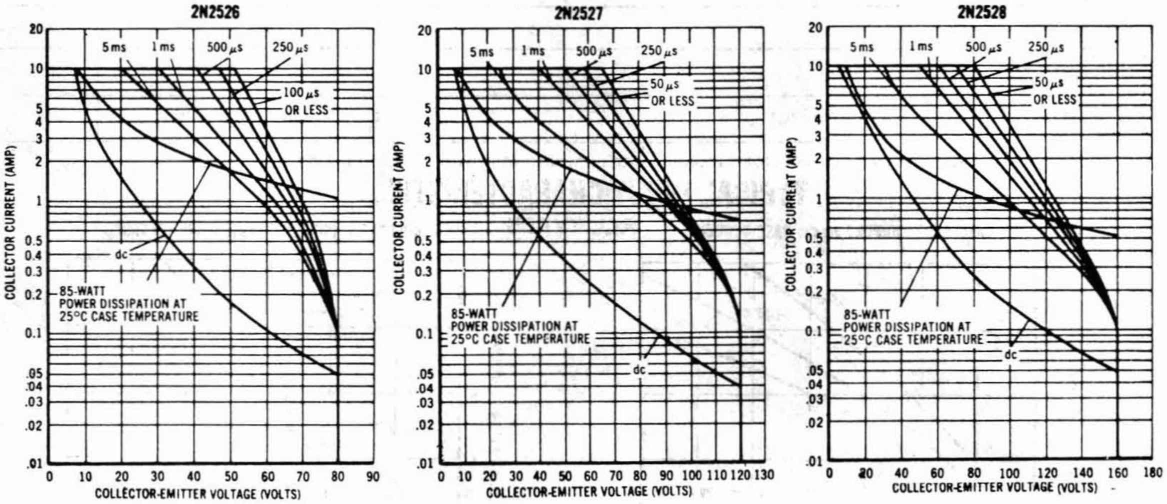
POWER-TEMPERATURE DERATING CURVE

The maximum continuous power is related to maximum junction temperature by the thermal resistance factor. This curve has a value of 85 watts at a case temperature of 25°C and is 0 watts at 110°C with a linear relation between the two temperatures such that:

$$\text{Allowable } P_D = \frac{110° - T_C}{1.0} \text{ Watts}$$



SAFE OPERATING AREAS



2N2526 2N2527 2N2528

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N2526 thru 2N2528 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, I_B = 0)	2N2526	$BV_{CEO(sus)}$*	80	-	-	Volts
	2N2527		120	-	-	
	2N2528		160	-	-	
Emitter-Base Breakdown Voltage (I_E = 50 mAdc, I_C = 0)		BV_{EBO}	5.0	-	-	Vdc
Collector Cutoff Current*		I_{CEX}*				mAdc
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100°C)	2N2526		-	-	35	
(V_{CE} = 120 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100°C)	2N2527		-	-	35	
(V_{CE} = 160 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 100°C)	2N2528		-	-	35	
Collector-Emitter Cutoff Current		I_{CER}				mAdc
(V_{CE} = 80 Vdc, R_{BE} = 100 ohms)	2N2526		-	-	25	
(V_{CE} = 120 Vdc, R_{BE} = 100 ohms)	2N2527		-	-	25	
(V_{CE} = 160 Vdc, R_{BE} = 100 ohms)	2N2528		-	-	25	
Collector Cutoff Current		I_{CBO}				mAdc
(V_{CB} = 80 Vdc, I_E = 0)	2N2526		-	-	3.0	
(V_{CB} = 120 Vdc, I_E = 0)	2N2527		-	-	3.0	
(V_{CB} = 160 Vdc, I_E = 0)	2N2528		-	-	3.0	
(V_{CB} = 2.0 Vdc, I_E = 0)			-	-	150	μAdc

ON CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
DC Current Gain (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	20	-	50	-
DC Transconductance (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	g_{FE}	4.0	6.0	-	mhos
Collector-Emitter Saturation Voltage (I_C = 10 Adc, I_B = 1.0 Adc)	$V_{CE(sat)}$	-	0.5	0.8	Vdc
Base-Emitter Saturation Voltage (I_C = 10 Adc, I_B = 1.0 Adc)	$V_{BE(sat)}$	-	0.8	1.2	Vdc

DYNAMIC CHARACTERISTICS

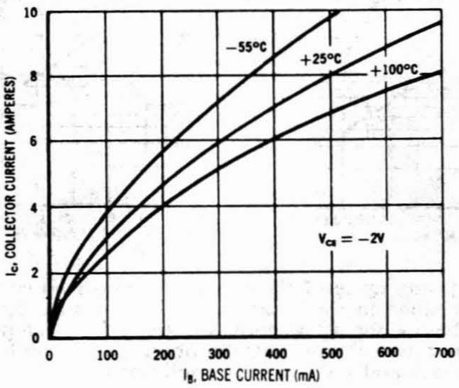
Characteristic	Symbol	Min	Typ	Max	Unit
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 12 Vdc, f = 30 kHz)	h_{fe}	10	15	-	-
Rise Time	t_r	-	5.5	-	μs
Storage Time	t_s	-	1.2	-	μs
Fall Time	t_f	-	2.0	-	μs

*To avoid excessive heating of collector junction, perform this test with a sweep method.

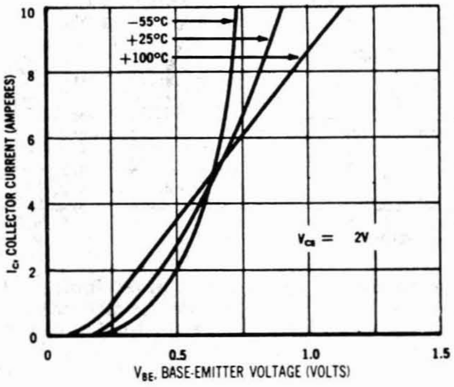
TYPICAL INPUT CHARACTERISTICS

ALL TYPES

COLLECTOR CURRENT versus BASE CURRENT

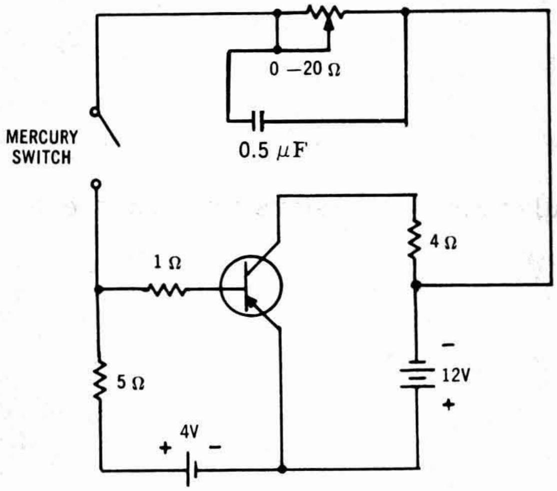


COLLECTOR CURRENT versus DRIVE VOLTAGE

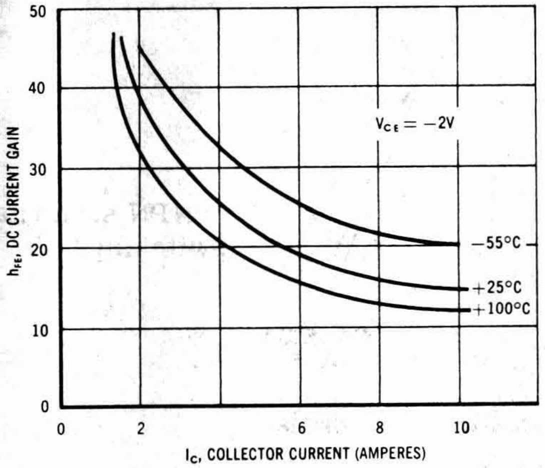


SWITCHING TEST CIRCUIT

PULSE CONDITIONS ; $I_C = 3$ Adc, $I_B = 300$ mAdc


0 −20 Ω
0.5 μF
MERCURY SWITCH
1 Ω
4 Ω
5 Ω
−
12V
+
4V
+
−

DC CURRENT GAIN versus COLLECTOR CURRENT



2N2537 thru 2N2540 (SILICON)

NPN silicon annular Star transistors for high-speed switching.

CASE 22
(TO-18)
2N2539
2N2540

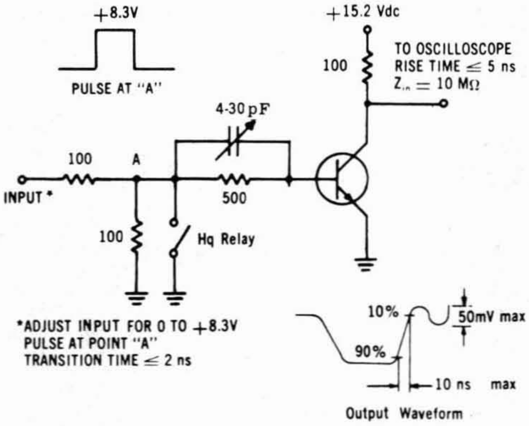
CASE 31
(TO-5)
2N2537
2N2538

Collector connected to case

MAXIMUM RATINGS

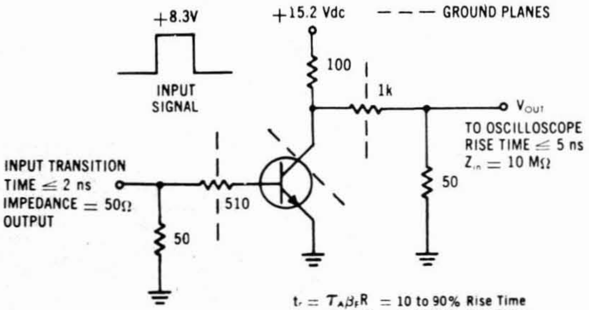
Rating	Symbol	2N2537 2N2538 (TO-5)	2N2539 2N2540 (TO-18)	Unit
Collector-Base Voltage	V_{CB}	60	60	Vdc
Collector-Emitter Voltage	V_{CEO}	30	30	Vdc
Collector-Emitter Voltage	V_{CER}	40	40	Vdc
Emitter-Base Voltage	V_{EB}	5	5	Vdc
Total Device Dissipation 25°C Case Temperature Derate above 25°C	P_D	3 17.2	1.8 10.3	Watts mW/°C
Total Device Dissipation 25°C Ambient Temperature Derate above 25°C	P_D	0.8 4.57	0.5 2.86	Watts mW/°C
Junction Temperature	T_J	-65 to +200		°C
Storage Temperature	T_{stg}	-65 to + 200		°C

TOTAL CONTROL CHARGE TEST CIRCUIT


+8.3V
PULSE AT "A"
+15.2 Vdc
100
TO OSCILLOSCOPE
RISE TIME ≤ 5 ns
Z_{in} = 10 MΩ
4-30 pF
100
A
INPUT *
500
100
Hq Relay
10%
50mV max
90%
10 ns max
Output Waveform

*ADJUST INPUT FOR 0 TO +8.3V
PULSE AT POINT "A"
TRANSITION TIME ≤ 2 ns

ACTIVE REGION TIME CONSTANT TEST CIRCUIT


+8.3V
INPUT SIGNAL
+15.2 Vdc
— — — GROUND PLANES
100
1k
V_{OUT}
TO OSCILLOSCOPE
RISE TIME ≤ 5 ns
Z_{in} = 10 MΩ
50
INPUT TRANSITION
TIME ≤ 2 ns
IMPEDANCE = 50Ω
OUTPUT
510
50

$t_r = T_A \beta_F R$ = 10 to 90% Rise Time
$t_f = T_A \beta_C F$ = 10 to 90% Fall Time

$$R = \frac{\beta_O}{\beta_F} \ln\left(\frac{\beta_O}{\beta_O - 0.9\beta_F}\right)$$

$$F = \frac{\beta_O}{\beta_C} \ln\left(1 + \frac{\beta_O}{\beta_C}\right)$$

$\beta_O = h_{FE}$ at Edge of Saturation
$\beta_C = I_C$ in Saturation / I_{B2} (Base "OFF" Current)
$\beta_F = I_C$ in Saturation / I_{B1} (Base "ON" Current)

$$T_A = T_{RE} \approx T_{FE}$$

$$T_{RE} = \frac{I_{B1}}{I_{CS}} t_r$$

2N2537 thru 2N2540 (continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

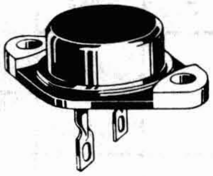
Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0) (V_{CB} = 40 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 – –	 0.250 200	μAdc
Emitter Cutoff Current (V_{EB} = 3 Vdc, I_C = 0)	I_{EBO}	–	0.05	μAdc
Collector Cutoff Current (V_{BE} = 0.2 Vdc, V_{CE} = 20 Vdc)	I_{CEX}	–	0.250	μAdc
Base Cutoff Current (V_{BE} = 0.2 Vdc, V_{CE} = 20 Vdc) (V_{BE} = 0.2 Vdc, V_{CE} = 20 Vdc, T_A = 150°C)	I_{BL}	 – –	 0.250 200	μAdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	–	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, pulsed, I_B = 0)	BV_{CEO}	30	–	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, pulsed, $R_{BE} \leqq 10\ \Omega$)	BV_{CER}	40	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5	–	Vdc
Collector Saturation Voltage * (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{CE(sat)}$	 – –	 0.45 1.6	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc) * (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{BE(sat)}$	 – –	 1.3 2.6	Vdc
DC Forward Current Transfer Ratio (I_C = 1 mAdc, V_{CE} = 10 Vdc) 2N2537, 2N2539 2N2538, 2N2540 (I_C = 10 mAdc, V_{CE} = 10 Vdc) 2N2537, 2N2539 2N2538, 2N2540 (I_C = 150 mAdc, V_{CE} = 10 Vdc)* 2N2537, 2N2539 2N2538, 2N2540 (I_C = 500 mAdc, V_{CE} = 10 Vdc)* 2N2537, 2N2539 2N2538, 2N2540	h_{FE}	 20 35 30 50 50 100 20 30	 – – – – 150 300 – –	–
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	–	8	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	–	25	pF
Small Signal Forward Current Transfer Ratio (V_{CE} = 20 Vdc, I_C = 20 mAdc, f = 100 MHz)	h_{fe}	2.5	–	–

*Pulse Test: Pulse width ≦ 300 μs, duty cycle ≦ 2%

SWITCHING CHARACTERISTICS

Characteristic	Symbol	Max.	Unit
Total Control Charge	Q_T	750	pC
Storage Time ($I_C = I_{B1} = I_{B2}$ = 20 mAdc, V_{CC} = 5 V)	τ_S	20	ns
Active Region Time Constant	τ_A	2.0	ns
Turn-on Time ($I_{B1} = I_{B2}$ = 15 mAdc, I_C = 150 mAdc, V_{CC} = 7 Vdc, R_L = 40 Ω)	t_{on}	40	ns
Turn-off Time ($I_{B1} = I_{B2}$ = 15 mAdc, I_C = 150 mAdc, V_{CC} = 7 Vdc, R_L = 40 Ω)	t_{off}	40	ns

2N2573 thru 2N2579 (SILICON)



Industrial-type, silicon controlled rectifiers in a "diamond" package for applications requiring a high surge-current rating or low thermal resistance.

CASE 61 (TO-41) **CASE 54** (TO-3 Modified)

For units with pins (TO-3 Modified) specify devices MCR649AP-1(2N2573) thru MCR649AP-7(2N2579).

MAXIMUM RATINGS ($T_J = 125°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*	$V_{ROM(rep)}$*		Volts
2N2573		25	
2N2574		50	
2N2575		100	
2N2576		200	
2N2577		300	
2N2578		400	
2N2579		500	
Forward Current RMS (all conduction angles)	I_f	25	Amp
Circuit Fusing Considerations (T_J = -65° to +125°C, t ≤ 8.3 ms)	I^2t	275	A^2s
Peak Surge Current (One Cycle, 60 Hz, T_J = -65 to +125°C)	$I_{FM(surge)}$	260	Amp
Peak Gate Power - Forward	P_{GFM}	5.0	Watts
Average Gate Power - Forward	$P_{GF(AV)}$	0.5	Watt
Peak Gate Current - Forward	I_{GFM}	2.0	Amp
Peak Gate Voltage - Forward	V_{GFM}	10	Volts
Reverse	V_{GRM}	5.0	
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

*V_{ROM} for all types can be applied on a continuous dc basis without incurring damage.

V_{ROM} ratings apply for zero or negative gate voltage.

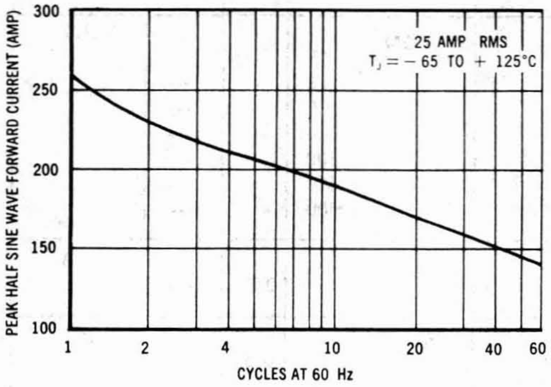
ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage*	V_{FOM}*				Volts
(T_J = 125°C) 2N2573		25	—	—	
2N2574		50	—	—	
2N2575		100	—	—	
2N2576		200	—	—	
2N2577		300	—	—	
2N2578		400	—	—	
2N2579		500	—	—	
Peak Forward Blocking Current (Rated V_{FOM} with gate open, T_J = 125°C)	I_{FOM}	—	0.6	5.0	mA
Peak Reverse Blocking Current (Rated V_{ROM}, T_J = 125°C)	I_{ROM}	—	0.6	5.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 100 Ω)	I_{GT}	—	20	40	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 100 Ω)	V_{GT}	—	1.0	3.5	Volts
(Anode Voltage = Rated V_{FOM}, R_L = 100Ω, T_J = 125°C)	V_{GNT}	0.3	—	3.5	
Forward On Voltage (I_F = 20 Adc)	V_F	—	1.1	1.4	Volts
Holding Current (Anode Voltage = 7 Vdc, Gate Open)	I_{HO}	—	20	—	mA
Turn-On Time (t_d + t_r) (I_G = 50 mA, I_F = 10A)	t_{on}	—	1.0	—	µs
Turn-Off Time (I_F = 10 A, I_R = 10 A, dv/dt = 20 V/µs, T_J = 125°C) (V_{FXM} = rated voltage) (V_{RXM} = rated voltage)	t_{off}	—	30	—	µs
Forward Voltage Application Rate (Gate Open, T_J = 125°C)	dv/dt	—	30	—	V/µs
Thermal Resistance (Junction to Case)	θ_{JC}	—	1.0	1.5	°C/W

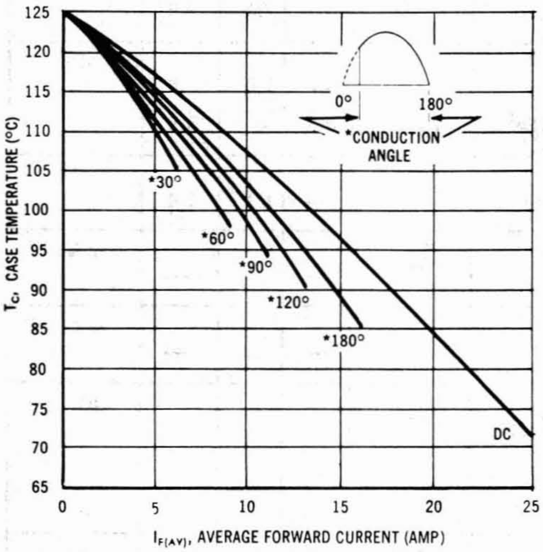
*V_{FOM} for all types can be applied on a continuous dc basis without incurring damage.

V_{FOM} ratings apply for zero or negative gate voltage.

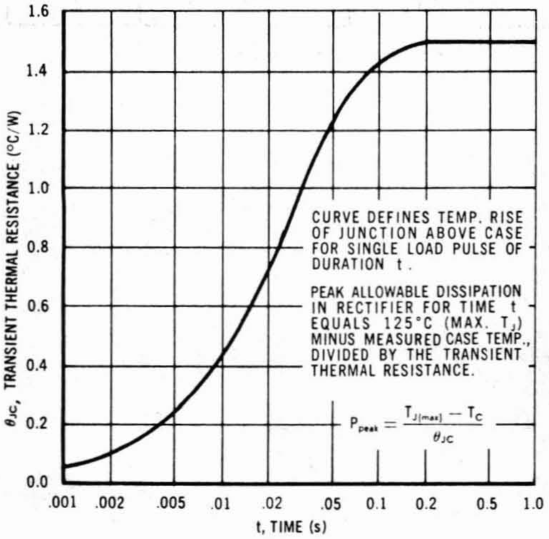
MAXIMUM ALLOWABLE NON-RECURRENT SURGE CURRENT



MAXIMUM ALLOWABLE CASE TEMPERATURE



MAXIMUM TRANSIENT THERMAL RESISTANCE JUNCTION TO CASE

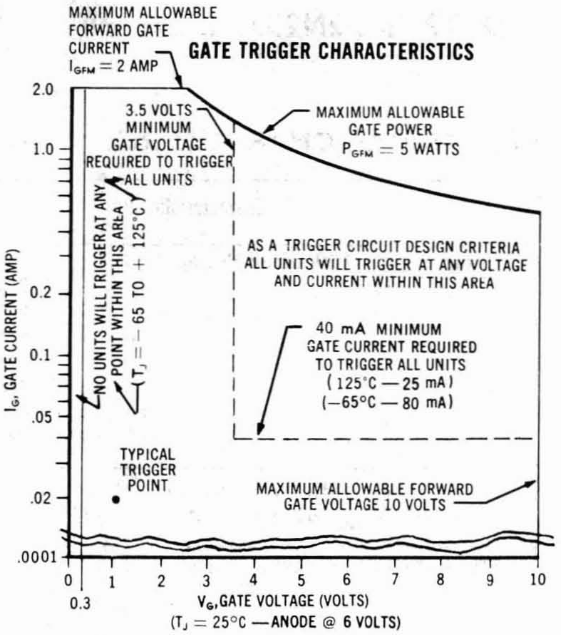


CURVE DEFINES TEMP. RISE OF JUNCTION ABOVE CASE FOR SINGLE LOAD PULSE OF DURATION t.

PEAK ALLOWABLE DISSIPATION IN RECTIFIER FOR TIME t EQUALS 125°C (MAX. T_J) MINUS MEASURED CASE TEMP., DIVIDED BY THE TRANSIENT THERMAL RESISTANCE.

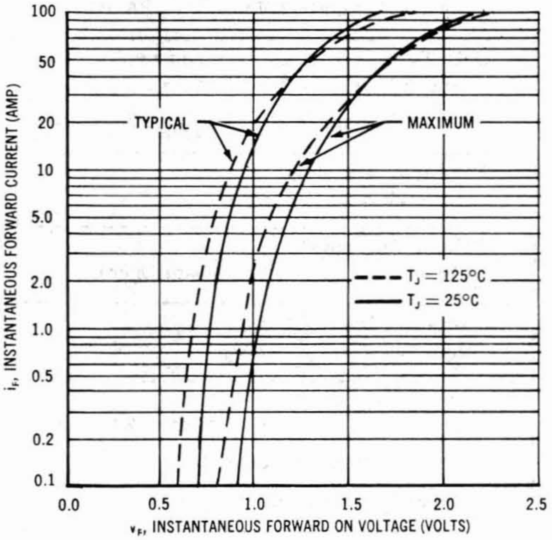
$$P_{peak} = \frac{T_{J(max)} - T_C}{\theta_{JC}}$$

GATE TRIGGER CHARACTERISTICS

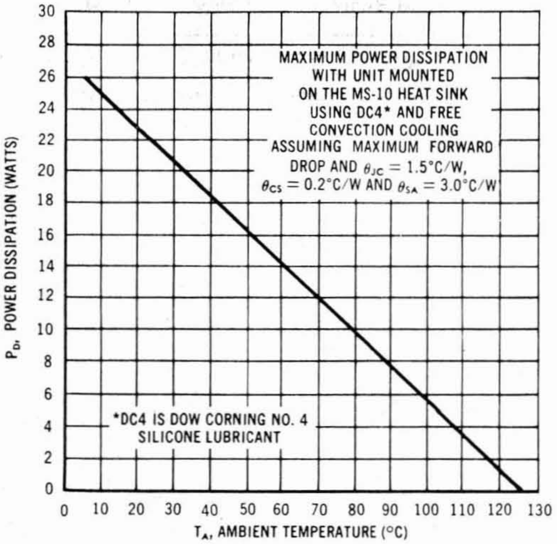


AS A TRIGGER CIRCUIT DESIGN CRITERIA ALL UNITS WILL TRIGGER AT ANY VOLTAGE AND CURRENT WITHIN THIS AREA

LOW CURRENT LEVEL



POWER DERATING CURVE



MAXIMUM POWER DISSIPATION WITH UNIT MOUNTED ON THE MS-10 HEAT SINK USING DC4* AND FREE CONVECTION COOLING ASSUMING MAXIMUM FORWARD DROP AND $\theta_{JC} = 1.5°C/W$, $\theta_{CS} = 0.2°C/W$ AND $\theta_{SA} = 3.0°C/W$

*DC4 IS DOW CORNING NO. 4 SILICONE LUBRICANT

2N2604 (SILICON)
2N2605

CASE 26
(TO-46)

Collector electrically
connected to case

PNP silicon annular transistors designed for low-level, low noise, high gain amplifiers from audio to high frequency range.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	45	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current	I_C	30	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	400 2.28	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	45	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	6.0	-	Vdc
Collector Cutoff Current (V_{CE} = 45 Vdc, V_{BE} = 0) (V_{CE} = 45 Vdc, V_{BE} = 0, T_A = 170°C)	I_{CES}	- -	10 10	nAdc μAdc
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0)	I_{CBO}	-	10	nAdc
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	2.0	nAdc

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Max	Unit
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			-
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc) 2N2604 2N2605		40 100	120 300	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C) 2N2604 2N2605		10 20	- -	
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc) 2N2604 2N2605		60 150	- -	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc) 2N2604 2N2605		- -	350 600	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc)	$V_{CE(sat)}$	-	0.5	Vdc
Base-Emitter Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc)	V_{BE}	0.7	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 30 MHz)	f_T	30	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	6.0	pF
Input Impedance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	25	35	Ohms
Voltage Feedback Ratio (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	10	X 10^{-4}
Small-Signal Current Gain (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz) 2N2604 2N2605	h_{fe}	60 150	350 600	-
Output Admittance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	1.0	μmhos
Real Part of Input Impedance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 100 MHz)	Re(h_{ie})	-	200	Ohms
Noise Figure (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_G = 10 k ohms, 2N2604 BW = 10 Hz to 15.7 kHz) 2N2605	NF	- -	4.0 3.0	dB

2N2635 (GERMANIUM)

CASE 22
(TO-18)

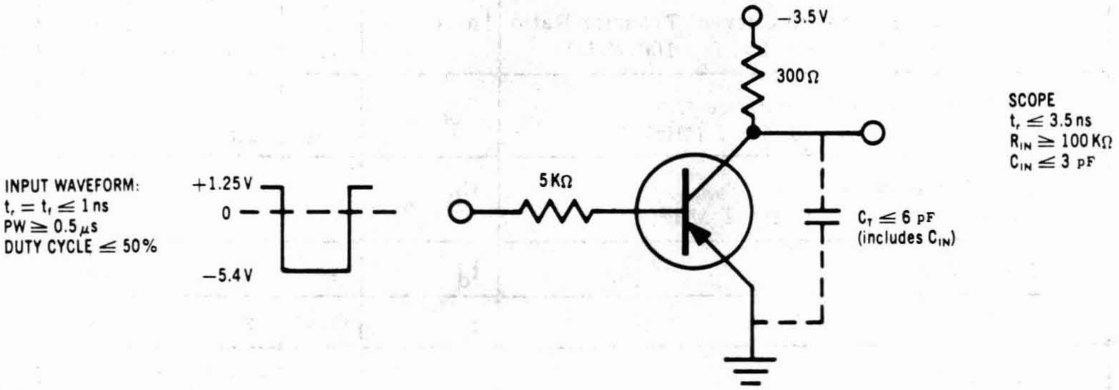
Collector connected to case

PNP germanium epitaxial mesa transistor for high-speed switching applications.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	30	Vdc
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Emitter-Base Voltage	V_{EB}	2.5	Vdc
Collector Current (Continuous)	I_C	100	mAdc
Junction Temperature	T_J	+100	^oC
Storage Temperature	T_{stg}	-65 to + 100	^oC
Device Dissipation @ 25°C Ambient Temperature (Derate 2mW/^{o}C above 25°C)	P_D	150	mW

SWITCHING TIME TEST CIRCUIT


INPUT WAVEFORM:
$t_r = t_f \leq 1$ ns
$PW \geq 0.5\,\mu s$
DUTY CYCLE ≤ 50%
+1.25 V
0
−5.4 V
5 KΩ
−3.5 V
300 Ω
$C_T \leq 6$ pF
(includes C_{IN})
SCOPE
$t_r \leq 3.5$ ns
$R_{IN} \geq 100$ KΩ
$C_{IN} \leq 3$ pF

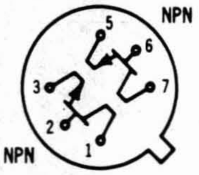
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μ Adc, I_E = 0)	BV_{CBO}	30	50	---	Vdc
Collector-Emitter Breakdown Voltage (I_C = 2 mAdc, I_B = 0)	BV_{CEO}	15	30	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μ Adc, I_C = 0)	BV_{EBO}	2.5	4.5	---	Vdc
Collector-Base Cutoff Current	I_{CBO}				μ Adc
(V_{CB} = 25V, I_E = 0)		---	1	5	
(V_{CB} = 25V, I_E = 0, T_A = +55°C)		---	5	20	
Emitter-Base Cutoff Current (V_{EB} = 1V, I_C = 0)	I_{EBO}	---	2	20	μ Adc
Static Forward Current Transfer Ratio	h_{FE}				---
(I_C = 10 mA, V_{CE} = 0.5V)		30	---	---	
(I_C = 50 mA, V_{CE} = 1V)		45	---	300	
(I_C = 50 mA, V_{CE} = 1V, T_A = -55°C)		25	---	---	
(I_C = 100 mA, V_{CE} = 1V)		30	---	---	
Base-Emitter Voltage	V_{BE}				Vdc
(I_C = 10 mA, I_B = 0.5 mA)		---	0.36	0.45	
(I_C = 50 mA, I_B = 2.5 mA)		---	0.47	0.70	
(I_C = 50 mA, I_B = 2.5 mA, T_A = -55°C)		---	0.56	0.85	
(I_C = 100 mA, I_B = 10 mA)		---	0.57	0.90	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$				Vdc
(I_C = 10 mA, I_B = 0.5 mA)		---	0.13	0.20	
(I_C = 50 mA, I_B = 2.5 mA)		---	0.20	0.40	
(I_C = 50 mA, I_B = 2.5 mA, T_A = +55°C)		---	0.22	0.45	
(I_C = 100 mA, I_B = 10 mA)		---	0.23	0.75	
Small-Signal Forward Current Transfer Ratio (I_C = 30 mA, V_{CE} = 2V, f = 100 MHz)	$\|h_{fe}\|$	1.5	---	---	---
Collector Output Capacitance (V_{CB} = 5 V, I_E = 0, f = 1 MHz)	C_{ob}	---	2.5	5	pF
Input Capacitance (V_{BE} = 1V, I_C = 0, f = 1 MHz)	C_{ib}	---	---	4	pF
Delay Time	t_d	---	15	20	ns
Rise Time	t_r	---	20	30	ns
Storage Time	t_s	---	100	185	ns
Fall Time	t_f	---	35	65	ns

2N2639 thru 2N2644 (SILICON)

Dual NPN silicon annular transistors designed for low-level, low-noise differential amplifier applications. Can be used in complementary circuits with 2N3806 series or 2N2802 series, for TO-89 flat packages see 2N3043-2N3048 series.

CASE 32C



PINS 4 AND 8 OMITTED

Pin Connections, Bottom View

MAXIMUM RATINGS (T

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	45		Vdc
Collector-Base Voltage	V_{CB}	45		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	30		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 1.72	600 3.43	mW mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	600 3.43	1200 6.87	mW mW/°C

2N2639 thru 2N2644 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	45	—	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 5 Vdc, I_B = 0)	I_{CEO}	—	0.010	μAdc
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0) (V_{CB} = 45 Vdc, I_E = 0, T_A = +150°C)	I_{CBO}	— —	0.010 10	μAdc
Emitter-Base Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)	I_{EBO}	—	0.010	μAdc
ON CHARACTERISTICS				
DC Current Gain*	h_{FE}*			—
(I_C = 10 μAdc, V_{CE} = 5 Vdc) 2N2639, 2N2640, 2N2641 2N2642, 2N2643, 2N2644		50 100	300 300	
(I_C = 10 μAdc, V_{CE} = 5 Vdc, T_A = -55°C) 2N2639, 2N2640, 2N2641 2N2642, 2N2643, 2N2644		10 20	— —	
(I_C = 100 μAdc, V_{CE} = 5 Vdc) 2N2639, 2N2640, 2N2641 2N2642, 2N2643, 2N2644		55 110	— —	
(I_C = 1 mAdc, V_{CE} = 5 Vdc) 2N2639, 2N2640, 2N2641 2N2642, 2N2643, 2N2644		65 130	— —	
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 0.5 mAdc)	$V_{CE(sat)}$*	—	1.0	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 0.5 mAdc)	$V_{BE(sat)}$*	0.6	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 20 MHz)	f_T	35	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	8	pF
Input Impedance (I_C = 1 mAdc, V_{CB} = 5 Vdc, f = 1 kHz)	h_{ib}	25k	32k	Ohms
Reverse Voltage Transfer Ratio (I_C = 1 mAdc, V_{CB} = 5 Vdc, f = 1 kHz)	h_{rb}	—	600	X 10^{-6}
Small-Signal Current Gain (I_C = 1 mAdc, V_{CB} = 5 Vdc, f = 1 kHz) 2N2639, 2N2640, 2N2641 2N2642, 2N2643, 2N2644	h_{fe}	65 130	600 600	—
Output Admittance (I_C = 1 mAdc, V_{CB} = 5 Vdc, f = 1 kHz)	h_{ob}	—	1.0	μmhos
Noise Figure (I_C = 10 μAdc, V_{CB} = 5 Vdc, R_S = 10k ohms, Bandwidth = 10 Hz to 15 kHz)	NF	—	4	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 10 μAdc, V_{CE} = 5 Vdc) 2N2639, 2N2642 2N2640, 2N2643	h_{FE1}/h_{FE2}**	0.9 0.8	1.0 1.0	—
Base Voltage Differential (I_C = 10 μAdc, V_{CE} = 5 Vdc) 2N2639, 2N2642 2N2640, 2N2643	$\lvert V_{BE1} - V_{BE2}\rvert$	— —	5 10	mVdc
Base Voltage Differential Temperature Gradient (I_C = 10 μAdc, V_{CE} = 5 Vdc, T_A = -55 to +125°C) 2N2639, 2N2642 2N2640, 2N2643	$\frac{\Delta\lvert V_{BE1} - V_{BE2}\rvert}{\Delta T_A}$	— —	10 20	μV/°C

*Pulse Test: Pulse Width = 300 μs; Duty Cycle ≤ 2%

**The lowest h_{FE} reading is taken as h_{FE1} for this test.

2N2646 (SILICON)
2N2647

Silicon annular PN unijunction transistors designed for use in pulse and timing circuits, sensing circuits and thyristor trigger circuits.

CASE 22A
(TO-18 Modified)
(Lead 3 connected to case)

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	P_D	300*	mW
RMS Emitter Current	I_e	50	mA
Peak Pulse Emitter Current**	i_e	2**	Amp
Emitter Reverse Voltage	V_{B2E}	30	Volts
Interbase Voltage	V_{B2B1}	35	Volts
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

* Derate 3.0 mW/°C increase in ambient temperature. The total power dissipation (available power to Emitter and Base-Two) must be limited by the external circuitry.

** Capacitor discharge — 10 μF or less, 30 volts or less.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Intrinsic Standoff Ratio (V_{B2B1} = 10 V) (Note 1)	2N2646 2N2647	η	0.56 0.68	— —	0.75 0.82	—
Interbase Resistance (V_{B2B1} = 3 V, I_E = 0)		R_{BB}	4.7	7.0	9.1	K ohms
Interbase Resistance Temperature Coefficient (V_{B2B1} = 3 V, I_E = 0, T_A = -55°C to +125°C)		αR_{BB}	0.1	—	0.9	%/°C
Emitter Saturation Voltage (V_{B2B1} = 10 V, I_E = 50 mA) (Note 2)		$V_{EB1(sat)}$	—	3.5	—	Volts
Modulated Interbase Current (V_{B2B1} = 10 V, I_E = 50 mA)		$I_{B2(mod)}$	—	15	—	mA
Emitter Reverse Current (V_{B2E} = 30 V, I_{B1} = 0)	2N2646 2N2647	I_{EO}	— —	0.005 0.005	12 0.2	μA
Peak Point Emitter Current (V_{B2B1} = 25 V)	2N2646 2N2647	I_P	— —	1.0 1.0	5.0 2.0	μA
Valley Point Current (V_{B2B1} = 20 V, R_{B2} = 100 ohms) (Note 2)	2N2646 2N2647	I_V	4.0 8.0	6.0 10	— 18	mA
Base-One Peak Pulse Voltage (Note 3, Figure 3)	2N2646 2N2647	V_{OB1}	3.0 6.0	5.0 7.0	— —	Volts

NOTES

1. Intrinsic standoff ratio, η, is defined by equation:

$$\eta = \frac{V_P - V_{(EB1)}}{V_{B2B1}}$$

Where V_P = Peak Point Emitter Voltage
V_{B2B1} = Interbase Voltage
$V_{(EB1)}$ = Emitter to Base-One Junction Diode Drop
(≈0.5 V @ 10 μA)

2. Use pulse techniques: PW ≈ 300 μs duty cycle ≤2% to avoid internal heating due to interbase modulation which may result in erroneous readings.

3. Base-One Peak Pulse Voltage is measured in circuit of Figure 3. This specification is used to ensure minimum pulse amplitude for applications in SCR firing circuits and other types of pulse circuits.

FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

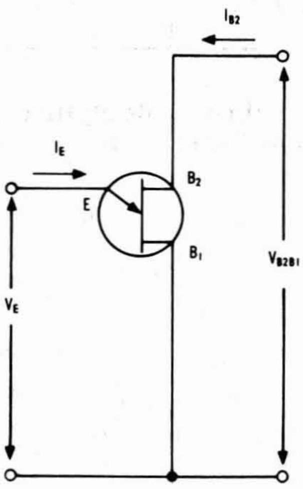


FIGURE 2 — STATIC EMITTER CHARACTERISTIC CURVES

(Exaggerated to Show Details)

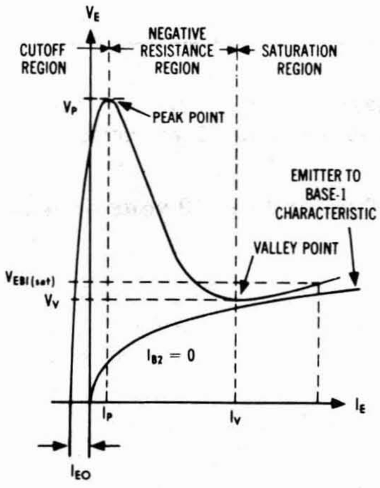
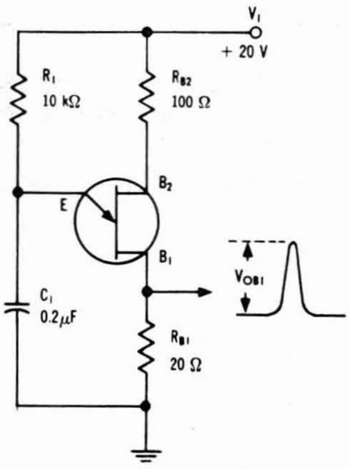


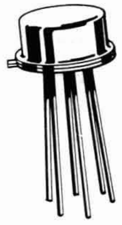
FIGURE 3 — V_{OB1} TEST CIRCUIT

(Typical Relaxation Oscillator)

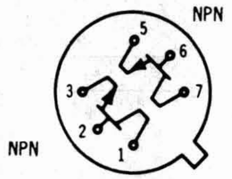


2N2652 (SILICON)
2N2652A

Dual NPN silicon transistors for use as a differential amplifier.



CASE 32 C



PINS 4 AND 8 OMITTED

Pin Connections, Bottom View

All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	60		Vdc
Collector-Base Voltage	V_{CB}	100		Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Collector Current	I_C	500		mAdc
Operating Junction Temperature Range	T_J	-65 to +200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ T_A = 25°C	P_D	0.3	0.6	Watt
Derate above 25°C		1.72	3.43	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	1.0	2.0	Watts
T_C = 100°C		0.57	1.14	Watt
Derate above 25°C		5.7	11.4	mW/°C

2N2652, 2N2652A (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 20 mAdc, I_B = 0)	BV_{CEO}*	60	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	100	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) 2N2652 2N2652A (V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C) 2N2652 2N2652A	I_{CBO}	- - - -	0.010 0.002 15 10	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0) 2N2652 2N2652A	I_{EBO}	- -	0.010 0.002	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)	h_{FE}	35 50 15	- 200 -	-
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$	-	1.2	Vdc
Base-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	60	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	15	pF
Input Capacitance (V_{BE} = 0, 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	-	85	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{ie}	1.0	10.5	k ohms
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20	35	ohms
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	50	300	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{oe}	4.0	50	μmhos
Noise Figure (I_C = 0.3 mAdc, V_{CE} = 10 Vdc, R_S = 510 ohms, B. W. = 1.0 Hz, f = 1.0 kHz)	NF		8.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N2652 2N2652A (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N2652 2N2652A	h_{FE1}/h_{FE2}**	0.85 0.9 0.85 0.9	1.0 1.0 1.0 1.0	-
Base Voltage Differential (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	$\lvert V_{BE1}-V_{BE2}\rvert$	- -	3.0 3.0	mVdc
Base Voltage Differential Gradient (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55 to +125°C)	$\dfrac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$	-	10	μV/°C

* Pulse Test: Pulse Width $\leq$ 300 μs, Duty Cycle $\leq$ 2.0%.

** The lowest of the two h_{FE} readings is taken as h_{FE1} for the purpose of measurement.

JAN 2N2708 (SILICON)

CASE 20
(TO-72)

NPN silicon annular transistor designed for low power IF and RF use in VHF/UHF amplifier, mixer and oscillator applications.

Active Elements Isolated From Case

MAXIMUM RATINGS (T_A = 25° ± 3°C — unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	35	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.2 1.14	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	0.3 1.72	Watt mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

TABLE I – GROUP A INSPECTION (T_A = 25°C ± 3°C – unless otherwise noted)

The fourth lead (case) shall be floating except for the following tests: G_{pe}, $r_b'C_c$, and NF.

Examination or Test	MIL-STD-750 Method	Symbol	Limits Min	Limits Max	Unit	LTPD
SUBGROUP 1						
Visual and Mechanical Examination	2071	-	-	-	-	10
SUBGROUP 2						
Collector-Base Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	-	10	nAdc	5
Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	3001 Condition D	BV_{CBO}	35	-	Vdc	
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	3026 Condition D	BV_{EBO}	3.0	-	Vdc	
Collector-Emitter Breakdown Voltage (I_C = 3.0 mAdc, I_B = 0, Pulsed, Note 1)	3011 Condition D	BV_{CEO}	20	-	Vdc	
Forward-Current Transfer Ratio (V_{CE} = 2.0 Vdc, I_C = 2.0 mAdc)	3076	h_{FE}	30	200	-	
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	3066	$V_{BE(sat)}$	-	1.0	Vdc	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	3071	$V_{CE(sat)}$	-	0.4	Vdc	
SUBGROUP 3						
Forward-Current Transfer Ratio (V_{CE} = 15 Vdc, I_C = 2.0 mAdc, f = 1.0 kHz)	3206	h_{fe}	30	180	-	10
Output Capacitance (V_{CB} = 15 Vdc, I_E = 0, f ≥ 0.1 MHz and ≤ 1.0 MHz)	3236	C_{ob}	-	1.5	pF	
SUBGROUP 4						
Forward Current Transfer Ratio (V_{CE} = 15 Vdc, I_C = 2.0 mAdc, f = 100 MHz)	3306	h_{fe}	7.0	12	-	10
Amplifier Power Gain (Neutralized) (V_{CE} = 15 Vdc, I_C = 2.0 mAdc, f = 200 MHz)	(See Figure 1)	G_{pe}	15	22	dB	
Collector-Base Time Constant (V_{CB} = 15 Vdc, I_C = 2.0 mAdc, f = 31.9 MHz)		$r_b'C_c$	9.0	33	ps	
Noise Figure (V_{CE} = 15 Vdc, I_C = 2.0 mAdc, R_G = 50 ohms, f = 200 MHz)		NF	-	7.5	dB	
SUBGROUP 5						
High Temperature Operation: T_A = +150°C min						10
Collector-Base Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)	3036 (Notes 2 & 3)	I_{CBO}	-	1.0	μAdc	
Low-Temperature Operation: T_A = -55° $^{+0}_{-3}$°C						
Forward Current Transfer Ratio (V_{CE} = 2.0 Vdc, I_C = 2.0 mAdc)	3076 (Notes 2 & 3)	h_{FE}	10	-	-	

Note 1. Pulse Test: Pulse Width ≦ 300 μs: Duty Cycle ≦ 2.0%

Note 2. Units shall be allowed to return to and be stabilized at 25°C prior to Low-Temperature Operational Test.

Note 3. Test measurement shall be made after thermal equilibrium has been reached at the temperature specified.

JAN 2N2708 (continued)

TABLE II – GROUP B INSPECTION (T_A = 25°C ± 3°C – unless otherwise noted)

Examination or Test	MIL-STD-750 Method	Symbol	Limits Min	Limits Max	Unit	LTPD
SUBGROUP 1						
Physical Dimensions	2066	-	-	-	-	20
SUBGROUP 2						
Soldering Heat, 1 cycle	2031	-	-	-	-	10
Temperature Cycling	1051 Condition C	-	-	-	-	
Thermal Shock (glass strain)	1056 Condition A	-	-	-	-	
Moisture Resistance, (No initial conditioning)	1021	-	-	-	-	
End Point Tests: (Note 4)						
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	-	20	nAdc	
Forward-Current Transfer Ratio (V_{CE} = 2.0 Vdc, I_C = 2.0 mAdc)	3076	h_{FE}	30	-	-	
SUBGROUP 3						
Shock (1500 G, 5 blows of approx. 0.5 ms each in orientations X1, Y1, Y2, Z1, total = 20 blows)	2016 non-operating	-	-	-	-	10
Vibration, variable frequency	2056	-	-	-	-	
Vibration Fatigue, 20 G	2046 non-operating	-	-	-	-	
Constant Acceleration (centrifuge) Orientations X1, Y1, Y2, Z1 20,000 G	2006	-	-	-	-	
End Point Tests: (Note 4)						
Same as for Subgroup 2						
SUBGROUP 4						
Lead Fatigue	2036 Condition E					15
End Point Tests: (Note 4)						
Seal		-	-	$5x10^{-7}$	atm cc/s	
Per Method 112, MIL-STD-202.	Condition C Procedure IIIa Test Cond. A for Gross Leaks					
SUBGROUP 5						
Salt atmosphere	1041	-	-	-	-	20
There shall be no evidence of flaking, pitting, or other visible signs of corrosion on sample units after test subjection.						
End Point Tests: (Note 4)						
Same as for Subgroup 2						
SUBGROUP 6						
High-Temperature Life T_{stg} = +200°C min	1031 non-operating	-	-	-	-	λ = 15
End Point Tests: (Note 4)						
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	-	50	nAdc	
Forward Current Transfer Ratio (V_{CE} = 2.0 Vdc, I_C = 2.0 mAdc)	3076	h_{FE}	22.5	-	-	
SUBGROUP 7						
Steady-State Operation Life (I_C = 20 mAdc, P_T = 200 mW)	1026	-	-	-	-	λ = 15
End Point Tests: (Note 4)						
Same as for Subgroup 6						

Note 4. End-point test measurements shall be made within 4 hours.

JAN 2N2708 (continued)

TABLE III – GROUP C INSPECTION (T_A = 25°C ± 3° – unless otherwise noted)

Examination or Test	MIL-STD-750 Method	Symbol	Limits Min	Limits Max	Unit	LTPD
SUBGROUP 1						
Barometric pressure, reduced (altitude operation) Normal mounting t = 60 s	1001 Condition D	-	-	-	-	15
Collector-Base Cutoff Current (V_{CB} = 35 Vdc, I_E = 0)	3036 Condition D (Note 5)	I_{CBO}	-	1.0	μAdc	

Note 5. This test to be performed and measurement made during subjection of the sample units to the reduced barometric pressure specified.

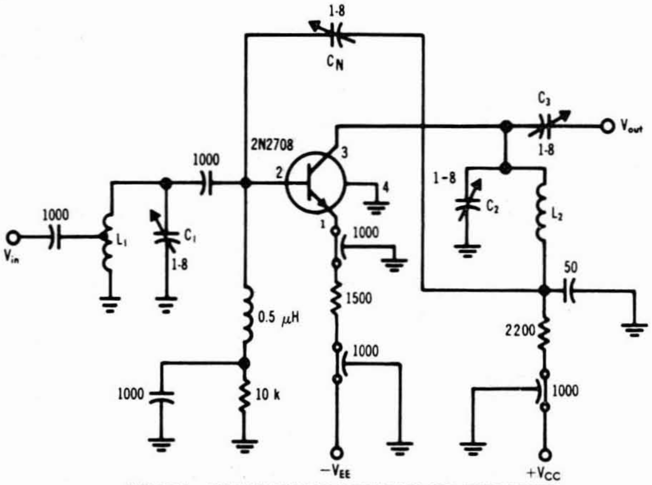


FIGURE 1 – TEST CIRCUIT FOR POWER GAIN AND NOISE FIGURE

Capacitance values in pF

L1 – 2½ turns #18 AWG wire, ⅜" ID by ½" lg.
L2 – 3 turns #22 AWG wire, ⅜" ID by ¾" lg.

Neutralization Procedure:

(A) Connect 200-MHz signal generator (with Z_{out} = 50 ohms) to input terminals of amplifier.

(B) Connect 50-ohm RF voltmeter across output terminals of amplifier.

(C) Apply V_{EE} and V_{CC}, and with signal generator adjusted for 1.0 mV output from amplifier, tune C_1, C_2, and C_3 for maximum output.

(D) Interchange connections to signal generator and output indicator.

(E) With sufficient signal applied to output terminals of amplifier, adjust C_N for minimum indication at input.

(F) Repeat steps (A), (B), and (C) to determine if retuning is necessary.

2N2710 (SILICON)

CASE 22
(TO-18)

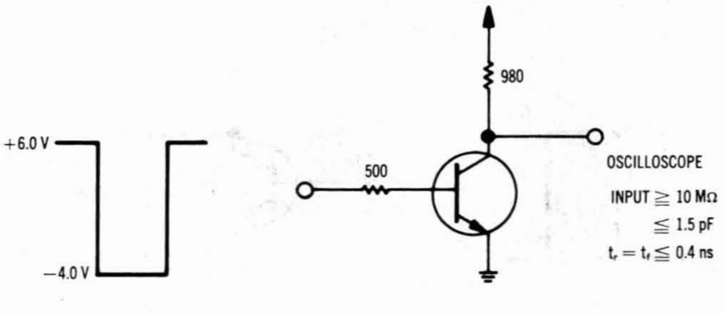
NPN silicon transistor primarily designed for high-speed, low-power saturated switching applications for industrial service.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Emitter Voltage	V_{CES}	30	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current-Continuous	I_C	500	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.36 2.1	W mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	1.2	W
Operating Junction Temperature Range	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 — STORAGE TIME TEST CIRCUIT



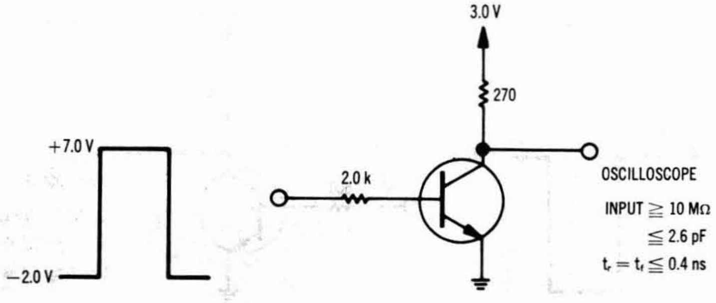
$t_r, t_f \leq 0.5$ ns
$Z_{in} = 50$ ohms

2N2710 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	20	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 μAdc, V_{BE} = 0)	BV_{CES}	30	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector-Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	-	30	nAdc
(V_{CB} = 20 VDC, I_E = 0, T_A = +150°C)		-	30	μAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	1.0	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	40	-	-
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)		40	-	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	-	0.25	Vdc
(I_C = 50 mAdc, I_B = 5.0 mAdc)		-	0.4	
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
(I_C = 50 mAdc, I_B = 5.0 mAdc)		-	1.3	
DYNAMIC CHARACTERISTICS				
Current-Gain-Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	500	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 4.0 MHz)	C_{ob}	-	4.0	pF
Turn-On Time (Figure 2) (V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = 2.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc)	t_{on}	-	20	ns
Turn-Off Time (Figure 2) (V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc)	t_{off}	-	35	ns
Charge-Storage Time (Figure 1) (V_{CC} = 10 Vdc, I_C = I_{B1} = I_{B2} = 10 mAdc)	t_s	-	15	ns

FIGURE 2 — TURN ON AND TURN OFF TIME TEST CIRCUIT



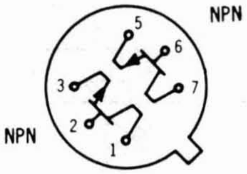
$t_r, t_f \leqq 0.5$ ns

Z_{in} = 50 ohms

2N2720 (SILICON)
2N2721

CASE 32C

Dual NPN silicon transistors for small-signal, low-power differential amplifier applications.



PINS 4 AND 8 OMITTED
Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	60		Vdc
Collector-Base Voltage	V_{CB}	80		Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current	I_C	40		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D	0.3	0.6	Watt
Derate above 25°C		1.71	3.4	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	0.6	1.2	Watts
Derate above 25°C		3.4	6.8	mW/°C

2N2720, 2N2721 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	60	-	Vdc
Collector Cutoff Current (V_{CE} = 5.0 Vdc, I_B = 0)	I_{CEO}	-	10	nAdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) (V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.01 10	μAdc
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	10	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) (I_C = 10 mAdc, V_{CE} = 5.0 Vdc)	h_{FE}	30 35 42	120 - -	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	0.65	0.85	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	80	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	6.0	pF
Input Impedance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	25	32	ohms
Voltage Feedback Ratio (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	500	X 10^{-6}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	30	200	-
Output Admittance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	1.0	μmhos
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N2720 2N2721	h_{FE1}/h_{FE2}**	0.9 0.8	1.0 1.0	-
Base Voltage Differential (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N2720 2N2721	$\lvert V_{BE1} - V_{BE2} \rvert$	- -	5.0 10	mVdc
Base Voltage Differential Gradient (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55 to +25°C) 2N2720 2N2721 (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = +25 to +125°C) 2N2720 2N2721	$\Delta(V_{BE1} - V_{BE2})$	- - - -	0.8 1.6 1.0 2.0	mV

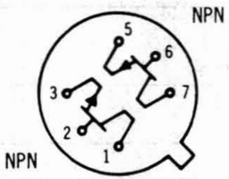
*Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2%

** The lower of the two h_{FE} readings is taken as h_{FE1} for the purpose of measurement.

2N2722 (SILICON)

CASE 32C

Dual NPN silicon transistor for small-signal, low-power differential amplifier applications.



PINS 4 AND 8 OMITTED
Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	45		Vdc
Collector-Base Voltage	V_{CB}	45		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	40		mAdc
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D	0.3	0.6	Watt
Derate above 25°C		1.7	3.4	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	0.6	1.2	Watts
Derate above 25°C		3.4	6.8	mW/°C

2N2722 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	45	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	45	-	Vdc
Collector Cutoff Current (V_{CE} = 5.0 Vdc, I_B = 0)	I_{CEO}	-	2.0	nAdc
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 30 Vdc, I_E = 0)		-	0.001	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)		-	1.0	
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	1.0	nAdc
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			-
(I_C = 1.0 μAdc, V_{CE} = 5.0 Vdc)		50	250	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc)		100	-	
(I_C = 0.1 mAdc, V_{CE} = 5.0 Vdc)		125	-	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc)	$V_{BE(sat)}$	0.65	0.85	Vdc
SMALL SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	100	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	6.0	pF
Input Impedance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	25	32	ohms
Voltage Feedback Ratio (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	600	$X\ 10^{-6}$
Small-Signal Current Gain (I_E = 0.1 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	100	700	-
Output Admittance (I_E = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	1.0	μmhos
Noise Figure (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_G = 10 k ohms, f = 10 Hz to 15.7 kHz)	NF	-	4.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 1.0 μAdc, V_{CE} = 5.0 Vdc)	h_{FE1}/h_{FE2}**	0.9	1.0	-
Base Voltage Differential (I_C = 10 μAdc, V_{CE} = 5.0 Vdc)	$\lvert V_{BE1} - V_{BE2}\rvert$	-	5.0	mVdc
Base Voltage Differential Gradient	$\Delta(V_{BE1} - V_{BE2})$			mVdc
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55 to +25°C)		-	0.8	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = +25 to +125°C)		-	1.0	

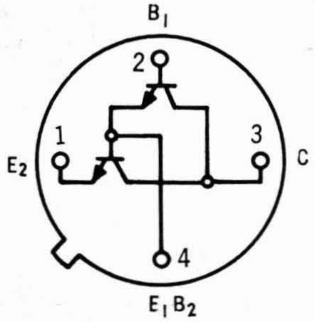
* Pulse Test: Pulse Width = 300 μs, Duty Cycle $\leq$ 2.0%.

** The lower of the two h_{FE} readings is taken as h_{FE1} for the purpose of measurement.

2N2723 thru 2N2725 (SILICON)

CASE 20(8)
(TO-72)

Two NPN silicon annular transistors connected as a darlington amplifier, and designed for applications requiring very high gain.



MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	2N2723 2N2724	2N2725	Unit
Collector Emitter Voltage	V_{CE2O}	60	45	Vdc
Collector-Base Voltage	V_{CB1}	80	45	Vdc
Emitter-Base Voltage	V_{E2B1}	12	10	Vdc
Collector Current	I_C	40	30	mAdc
Total Device Dissipation @ T_A = 25°C	P_D	0.5		Watt
Derate above 25°C		2.9		mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	1.8		Watts
T_C = 100°C		1.0		Watt
Derate above 25°C		10.5		mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

2N2723 thru 2N2725 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_{B1} = 0) 2N2723, 2N2724 2N2725	BV_{CE2O}*	60 45	- -	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_{E2} = 0) 2N2723, 2N2724 2N2725	BV_{CB1O}	80 45	- -	Vdc
Emitter-Base Breakdown Voltage (I_{E2} = 10 μAdc, I_C = 0) 2N2723, 2N2724 2N2725	BV_{E2B1O}	12 10	- -	Vdc
Collector Cutoff Current (V_{CB1} = 60 Vdc, I_E = 0) 2N2723, 2N2724 (V_{CB1} = 60 Vdc, I_E = 0, T_A = 150°C) 2N2723, 2N2724 (V_{CB1} = 30 Vdc, I_E = 0) 2N2725 (V_{CB1} = 30 Vdc, I_E = 0, T_A = 150°C) 2N2725	I_{CB1O}	- - - -	0.01 10 0.002 2.0	μAdc
Emitter Cutoff Current (V_{B1E2} = 10 Vdc, I_C = 0) 2N2723, 2N2724 (V_{B1E2} = 6.0 Vdc, I_C = 0) 2N2725	I_{E2B1O}	- -	10 1.0	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE2} = 5.0 Vdc, I_{B2} = 0) 2N2723 2N2724 (I_C = 100 μAdc, V_{CE2} = 5.0 Vdc, I_{B2} = 0) 2N2725	h_{FE}	2000 7000 2000	10,000 50,000 10,000	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_{B1} = 1.0 mAdc)	$V_{CE2(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_{B1} = 1.0 mAdc)	$V_{BE2(sat)}$	-	1.7	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (Each Unit) (I_C = 10 mAdc, V_{CE1} or V_{CE2} = 10 Vdc, f = 20 MHz)	f_T	100	-	MHz
Output Capacitance (V_{CB1} = 10 Vdc, I_{E2} = 0, f = 140 kHz) 2N2723, 2N2724	C_{ob1}	-	10	pF
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE2} = 5.0 Vdc, f = 1.0 kHz) 2N2723 2N2724 (I_C = 10 μAdc, V_{CE2} = 5.0 Vdc, f = 1.0 kHz) 2N2725	h_{fe}	1500 5000 1500	15,000 60,000 15,000	-
Noise Figure (Input Stage Only) (I_C = 50 μAdc, V_{CE} = 5.0 Vdc, R_S = 3.0 k ohms, f = 1.0 kHz, BW = 100 kHz) 2N2723 (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 1.0 kHz, BW = 100 kHz) 2N2724 (I_C = 3.0 μAdc, V_{CE} = 5.0 Vdc, R_S = 30 k ohms, f = 1.0 kHz, BW = 100 kHz) 2N2725	NF	- - -	10 6.0 6.0	dB

* Pulse Test: Pulse Width ≤12 ms, Duty Cycle ≤2.0 %.

2N2728 (GERMANIUM)

CASE 7

PNP germanium high-current power transistors especially designed for switching and power converter circuit operating from low-voltage power sources such as solar cells, thermo-electric generators, sea cells, fuel cells, and 1.5-volt batteries.

MAXIMUM RATINGS

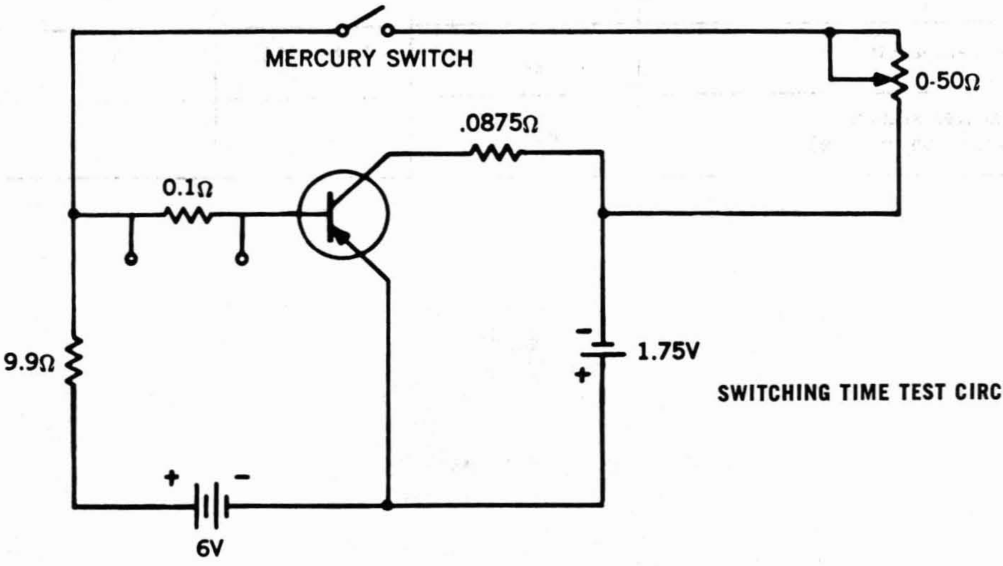
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	15	Vdc
Collector-Emitter Voltage	V_{CEO}	5.0	Vdc
Emitter-Base Voltage	V_{EB}	15	Vdc
Collector Current (continuous)	I_C	50	Adc
Base Current (continuous)	I_B	10	Adc
Total Device Dissipation @ 25°C Case Temperature	P_D	170	Watts
Operating Temperature	T_J	+110	°C
Storage Temperature	T_{stg}	-65 to +110	°C
Thermal Resistance (Junction to Case)	θ_{JC}	0.5	°C/W

2N2728 (continued)

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current V_{CE} = 15 V, V_{BE} = 1 V V_{CE} = 10 V, V_{BE} = 1 V, T_C = 100°C	I_{CEX}	- -	- -	10 35	mAdc
Emitter-Base Cutoff Current V_{EB} = 15 V	I_{EBO}	-	-	10	mAdc
Emitter Floating Potential V_{CB} = 15 V, I_E = 0	V_{EBF}	-	-	0.5	Vdc
Collector-Emitter Breakdown Voltage* I_C = 500 mA, I_B = 0	BV_{CEO}	5.0	10	-	V
DC Current Transfer Ratio I_C = 20 A, V_{CE} = 2 V	h_{FE}	40	-	130	-
Collector-Emitter Saturation Voltage I_C = 50 A, I_B = 5 A	$V_{CE(sat)}$	-	0.075	0.1	Vdc
Base-Emitter Voltage I_C = 50 A, I_B = 5 A	$V_{BE(sat)}$	-	0.85	1.0	Vdc
Common Emitter Cutoff Frequency I_C = 20 A, V_{CE} = 2 V	$f_{\alpha e}$	3.0	4.5	-	kHz
Rise Time I_C = 20 A, V_{CC} = 1.75 V, $I_{B(on)}$ = 2 A	t_r	-	18	25	μs
Storage Time V_{BE} = 6 V, R_{be} = 10 Ω	t_s	-	15	20	μs
Fall Time V_{BE} = 6 V, R_{be} = 10 Ω	t_f	-	10	15	μs

* To avoid excessive heating of the collector junction, perform these tests with an oscilloscope.

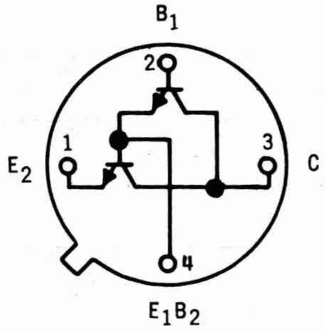


SWITCHING TIME TEST CIRCUIT

2N2785 (SILICON)

CASE 20(8)
(TO-72)

Two NPN silicon annular transistors connected as a darlington amplifier, and designed for applications requiring very high gain.



MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CE2O}	40	Vdc
Collector-Base Voltage	V_{CB1}	60	Vdc
Emitter-Base Voltage	V_{E2B1}	15	Vdc
(Pin 4 to Pin 2)		7.5	Vdc
Total Device Dissipation @ T_A = 25°C	P_D	0.5	Watt
Derate above 25°C		3.33	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	1.8	Watts
T_C = 100°C		1.0	Watt
Derate above 25°C		10	mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

2N2785 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage* (I_C = 20 mAdc, I_{B1} = 0)	BV_{CE2O}*	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 µAdc, I_{E2} = 0)	BV_{CB1O}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_{E2} = 100 µAdc, I_C = 0)	BV_{E2B1O}	15	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, I_B = 0)	I_{CEO}	-	500	nAdc
Collector Cutoff Current (V_{CB1} = 30 Vdc, I_E = 0) (V_{CB1} = 30 Vdc, I_E = 0, T_A = 150°C)	I_{CB1O}	- -	0.05 10	µAdc
Emitter Cutoff Current (V_{E2B1} = 5.0 Vdc, I_C = 0)	I_{E2B1O}	-	20	nAdc

ON CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
DC Current Gain* (I_C = 1.0 mAdc, V_{CE2} = 4.0 Vdc) (I_C = 10 mAdc, V_{CE2} = 5.0 Vdc) (I_C = 100 mAdc, V_{CE2} = 5.0 Vdc)	h_{FE} *	600 1200 2000	- - 20,000	-
Collector-Emitter Saturation Voltage (I_C = 15 mAdc, I_{B1} = 3.0 mAdc)	$V_{CE2(sat)}$	-	1.0	Vdc

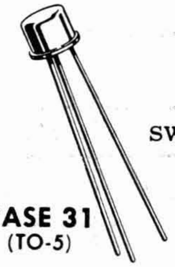
SMALL SIGNAL CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Current-Gain—Bandwidth Product (I_C = 1.0 mAdc, V_{CE2} = 5.0 Vdc, f = 10 MHz)	f_T	10	-	MHz
Output Capacitance (V_{CB1} = 10 Vdc, I_{E2} = 0, f = 1.0 MHz)	C_{ob1}	-	30	pF
Input Impedance (I_C = 1.0 mAdc, V_{CB1} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	30	80	Ohm
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE2} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	10	$x\ 10^{-4}$
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE2} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	600	-	-
Output Admittance (I_C = 1.0 mAdc, V_{CB1} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	0.5	µmhos

* Pulse Test: Pulse Width ≦ 300 µs, Duty Cycle ≦ 2.0%.

2N2800 (SILICON)
2N2801
2N2837
2N2838

CASE 22
(TO-18)



CASE 31
(TO-5)

2N2837
2N2838

2N2800
2N2801

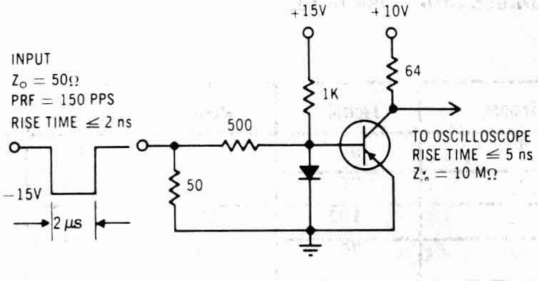
Collector connected to case

PNP silicon annular transistors for medium-speed switching applications.

MAXIMUM RATINGS

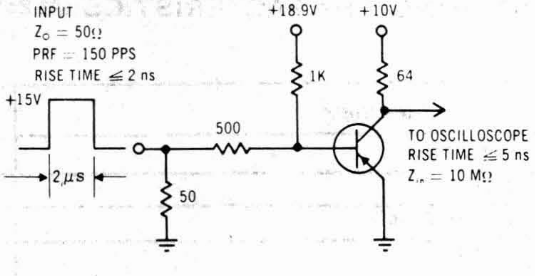
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	50	Vdc
Collector-Emitter Voltage	V_{CEO}	35	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current	I_C	800	mA
Total Device Dissipation @ 25°C Ambient Temperature 2N2800, 2N2801 – TO-5 Derating Factor Above 25°C 2N2837, 2N2838 – TO-18 Derating Factor Above 25°C	P_D	 0.8 4.57 0.5 2.86	 Watt mW/°C Watt mW/°C
Total Device Dissipation @ 25°C Case Temperature 2N2800, 2N2801 – TO-5 Derating Factor Above 25°C 2N2837, 2N2838 – TO-18 Derating Factor Above 25°C	P_D	 3 17.3 1.8 10.3	 Watts mW/°C Watts mW/°C
Junction Temperature, Operating	T_J	+200	°C
Storage Temperature	T_{stg}	-65 to +200	°C

DELAY AND RISE TIME TEST CIRCUIT



+15V
+10V
INPUT
Z₀ = 50Ω
PRF = 150 PPS
RISE TIME ≦ 2 ns
64
1K
500
TO OSCILLOSCOPE
RISE TIME ≦ 5 ns
Zin = 10 MΩ
−15V
50
2 μs

STORAGE AND FALL TIME TEST CIRCUIT



INPUT
Z₀ = 50Ω
PRF = 150 PPS
RISE TIME ≦ 2 ns
+18.9V
+10V
1K
64
+15V
500
TO OSCILLOSCOPE
RISE TIME ≦ 5 ns
Zin = 10 MΩ
2 μs
50

2N2800, 2N2801, 2N2837, 2N2838 (Continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	50	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	BV_{CEO}	35	-	Vdc
Collector Cutoff Current (V_{CE} = 25 Vdc, V_{BE} = 0.5 Vdc)	I_{CEX}	-	100	nAdc
Base Cutoff Current (V_{CE} = 25 Vdc, V_{BE} = 0.5 Vdc)	I_{BL}	-	100	nAdc
DC Forward Current Transfer Ratio (I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	h_{FE}			-
2N2800, 2N2837		20	-	
2N2801, 2N2838		30	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)*				
2N2800, 2N2837		30	90	
2N2801, 2N2838		75	225	
(I_C = 150 mAdc, V_{CE} = 1 Vdc)*				
2N2800, 2N2837		15	-	
2N2801, 2N2838		30	-	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)*				
2N2800, 2N2837		25	-	
2N2801, 2N2838		40	-	
Collector Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	0.4	
(I_C = 500 mAdc, I_B = 50 mAdc)		-	1.2	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	1.3	
(I_C = 500 mAdc, I_B = 50 mAdc)		-	1.8	
Output Capacitance (V_{CB} = 10 Vdc, f = 100 kHz)	C_{ob}	-	25	pF
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	120	-	MHz

SWITCHING CHARACTERISTICS (At 25°C unless otherwise noted)

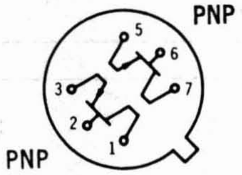
Characteristic	Symbol	Typical	Maximum	Unit
Delay Time	t_d	9	25	ns
Rise Time	t_r	25	45	ns
Storage Time	t_s	100	225	ns
Fall Time	t_f	30	45	ns

*Pulse Test: Pulse Width ≦ 300 μs, duty cycle ≦ 2%

2N2802 thru 2N2807 (SILICON)

Dual PNP silicon annular transistors designed for low-level, low-noise differential amplifier applications. Can be used in complementary circuits with 2N2639 thru 2N2644 series, for TO-89 flat packages see 2N3049, 2N3050 series.

CASE 32 C



PINS 4 AND 8 OMITTED
Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	20		Vdc
Collector-Base Voltage	V_{CB}	25		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	30		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D	250	500	mW
Derate above 25°C		1.43	2.86	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	500	1000	mW
Derate above 25°C		2.86	5.72	mW/°C

2N2802 thru 2N2807 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

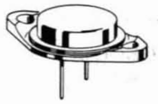
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	20	—	Vdc
Collector-Base Cutoff Current (V_{CB} = 25 Vdc, I_E = 0)	I_{CBO}	—	0.010	μAdc
(V_{CB} = 25 Vdc, I_E = 0, T_A = +150°C)		—	10	
Emitter-Base Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)	I_{EBO}	—	0.010	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 μAdc, V_{CE} = 5 Vdc) 2N2802, 2N2803, 2N2804	h_{FE}*	15	—	—
2N2805, 2N2806, 2N2807		30	—	
(I_C = 100 μAdc, V_{CE} = 5 Vdc) 2N2802, 2N2803, 2N2804		20	120	
2N2805, 2N2806, 2N2807		40	120	
(I_C = 100 μAdc, V_{CE} = 5 Vdc, T_A = -55°C) 2N2802, 2N2803, 2N2804		10	—	
2N2805, 2N2806, 2N2807		20	—	
(I_C = 1 mAdc, V_{CE} = 5 Vdc) 2N2802, 2N2803, 2N2804		20	—	
2N2805, 2N2806, 2N2807		40	—	
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$*	—	0.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$*	0.7	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 20 MHz)	f_T	60	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	8	pF
Input Impedance (I_C = 1 mAdc, V_{CB} = 5 Vdc, f = 1 kHz)	h_{ib}	25k	32k	Ohms
Reverse Voltage Transfer Ratio (I_C = 1 mAdc, V_{CB} = 5 Vdc, f = 1 kHz)	h_{rb}	—	1200	X 10^{-6}
Small-Signal Current Gain (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz) 2N2802, 2N2803, 2N2804	h_{fe}	20	200	—
2N2805, 2N2806, 2N2807		40	200	
Noise Figure (I_C = 10 μAdc, V_{CB} = 5 Vdc, R_S = 10k ohms, Bandwidth = 10 Hz to 15.7 kHz)	NF	—	4	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 100 μAdc, V_{CE} = 5 Vdc) 2N2802, 2N2805	h_{FE1}/h_{FE2}**	0.9	1.0	—
2N2803, 2N2806		0.8	1.0	
Base Voltage Differential (I_C = 100 μAdc, V_{CE} = 5 Vdc) 2N2802, 2N2805	$\|V_{BE1} - V_{BE2}\|$	—	5	mVdc
2N2803, 2N2806		—	10	
Base Voltage Differential Temperature Gradient (I_C = 100 μAdc, V_{CE} = 5 Vdc, T_A = -55 to +125°C) 2N2802, 2N2805	$\frac{\Delta(V_{BE1} - V_{BE2})}{\Delta T_A}$	—	10	μV/°C
2N2803, 2N2806		—	20	

*Pulse Test: Pulse Width ≤ 300 μs: Duty Cycle ≤ 2%

**The lowest h_{FE} reading is taken as h_{FE1} for this test.

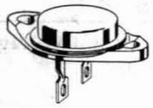
2N2832 (GERMANIUM)
2N2833
2N2834

PNP germanium transistors for switching and amplifier applications.



CASE 11A
(TO-3 modified)

Collector connected to case



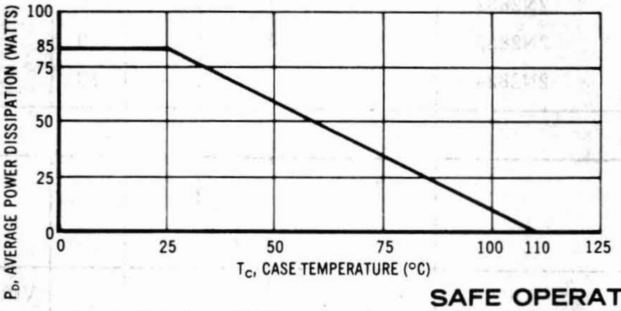
CASE 4-04
(TO-41)

For units with solder lugs attached, specify device MP2832 etc. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N2832	2N2833	2N2834	Unit
Collector-Emitter Voltage	V_{CEO}	50	75	100	Vdc
Collector-Base Voltage	V_{CB}	80	120	140	Vdc
Emitter-Base Voltage	V_{EB}	2.0			Vdc
Collector Current - Continuous	I_C	20			Adc
Base Current	I_B	5.0			Adc
Total Device Dissipation @ T_C = 25°C	P_D	85			Watts
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110			

FIGURE 1 — POWER DERATING CURVE



THESE TRANSISTORS ARE ALSO SUBJECT TO SAFE AREA CURVES AS INDICATED BY FIGURES 2, 3, 4. BOTH LIMITS ARE APPLICABLE AND MUST BE OBSERVED

SAFE OPERATING AREAS

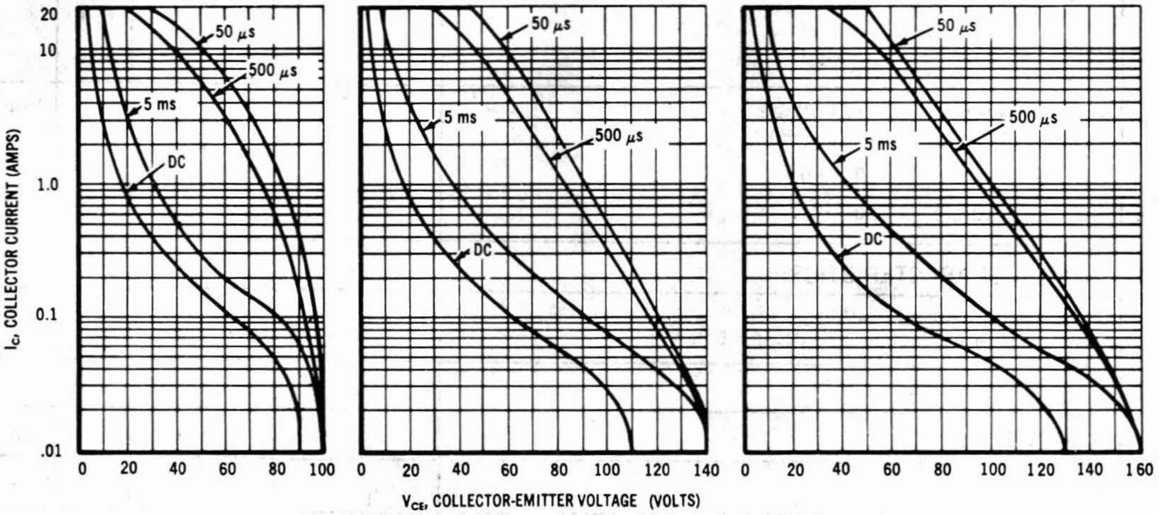


FIGURE 2 — 2N2832

FIGURE 3 — 2N2833

FIGURE 4 — 2N2834

The Safe Operating Area Curves indicate the I_C - V_{CE} limits below which the devices will not go into secondary breakdown. As secondary breakdown is independent of temperature and duty cycle, these curves can be used as long as the average power derating curve (Figure 1) is also taken into consideration to insure operation below the maximum junction temperature.

2N2832 thru 2N2834 (Continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage**		$BV_{CEO(sus)}$**				Volts
(I_C = 100 mAdc, I_B = 0)	2N2832		50	-	-	
	2N2833		75	-	-	
	2N2834		100	-	-	
Emitter-Base Breakdown Voltage		BV_{EBO}				Vdc
(I_E = 50 mAdc, I_C = 0)			2.0	-	-	
Floating Potential*		V_{EBF}*				Volts
(V_{CB} = 80 Vdc, I_E = 0)	2N2832		-	-	0.5	
(V_{CB} = 120 Vdc, I_E = 0)	2N2833		-	-	0.5	
(V_{CB} = 140 Vdc, I_E = 0)	2N2834		-	-	0.5	
Collector Cutoff Current*		I_{CES}*				mAdc
(V_{CE} = 100 Vdc, V_{BE} = 0)	2N2832		-	-	20	
(V_{CE} = 140 Vdc, V_{BE} = 0)	2N2833		-	-	20	
(V_{CE} = 160 Vdc, V_{BE} = 0)	2N2834		-	-	20	
Collector Cutoff Current**		I_{CEX}**				mAdc
(V_{CE} = 50 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = +85°C)	2N2832		-	-	40	
(V_{CE} = 75 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = +85°C)	2N2833		-	-	40	
(V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = +85°C)	2N2834		-	-	40	
Collector Cutoff Current*		I_{CBO}*				mAdc
(V_{CB} = 2.0 Vdc, I_E = 0)			-	-	0.3	
(V_{CB} = 80 Vdc, I_E = 0)	2N2832		-	-	10	
(V_{CB} = 120 Vdc, I_E = 0)	2N2833		-	-	10	
(V_{CB} = 140 Vdc, I_E = 0)	2N2834		-	-	10	
ON CHARACTERISTICS						
DC Current Gain		h_{FE}				-
(I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)			50	75	-	
(I_C = 10 Adc, V_{CE} = 2.0 Vdc)			25	-	100	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 1.0 Adc, I_B = 100 mAdc)			-	-	0.15	
(I_C = 10 Adc, I_B = 1.0 Adc)			-	-	0.30	
(I_C = 20 Adc, I_B = 2.0 Adc)			-	-	0.5	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$				Vdc
(I_C = 1.0 Adc, I_B = 100 mAdc)			-	-	0.6	
(I_C = 10 Adc, I_B = 1.0 Adc)			-	-	0.75	
(I_C = 20 Adc, I_B = 2.0 Adc)			-	-	1.0	
DYNAMIC CHARACTERISTICS						
Small Signal Current Gain		h_{fe}				-
(I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 5.0 MHz)			2.0	3.5	-	
Rise Time		t_r	-	2.0	4.0	μs
Storage Time		t_s	-	3.0	6.0	μs
Fall Time		t_f	-	1.0	2.5	μs

*SWEEP TEST: 1/2 Sine Wave, 60 Hz min.

**PULSE TEST: Pulse Width = 1.0 ms, 2.0% Duty Cycle.

FIG 5 — BASE-EMITTER SATURATION VOLTAGE VARIATIONS

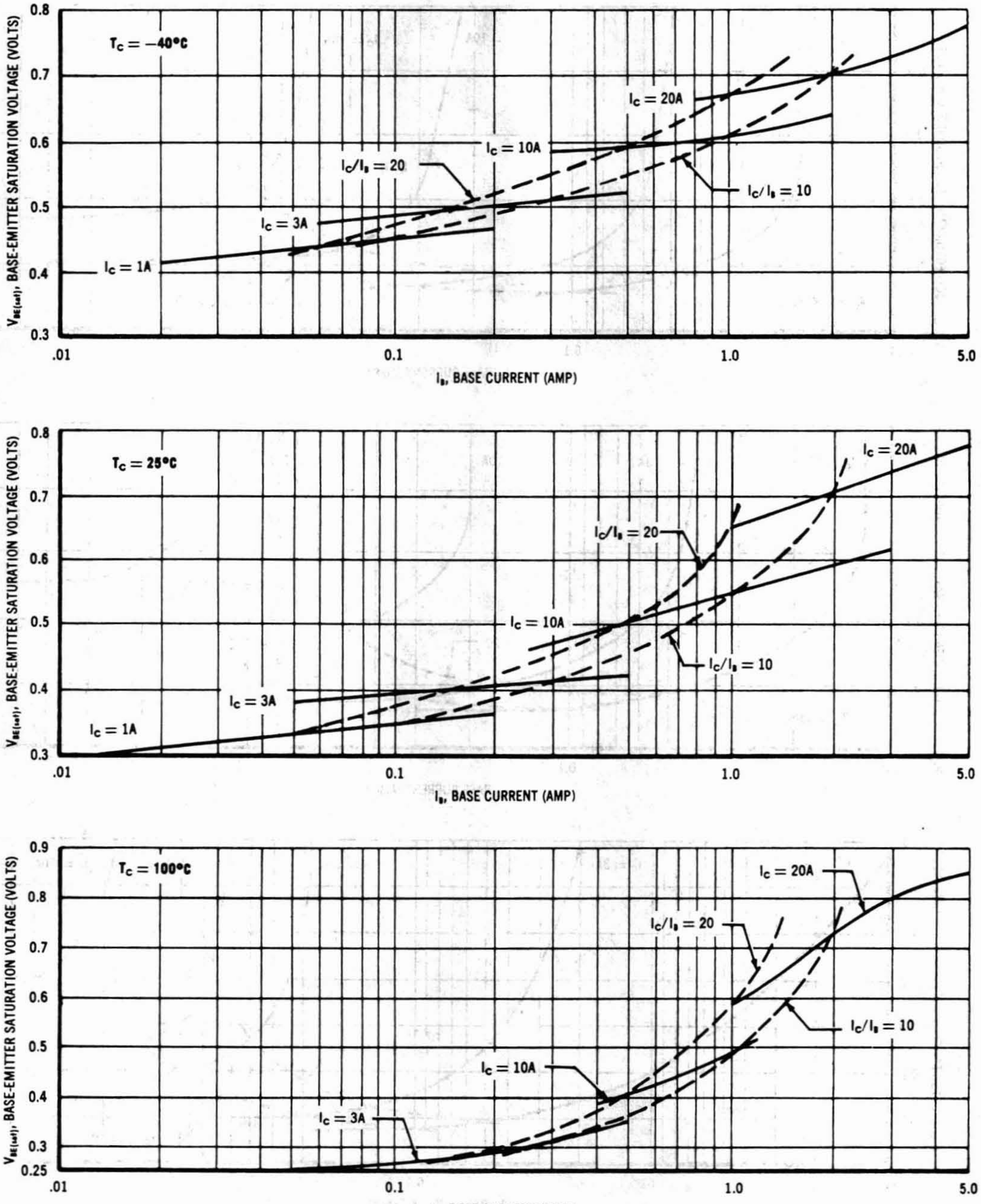


FIG 6 — COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS

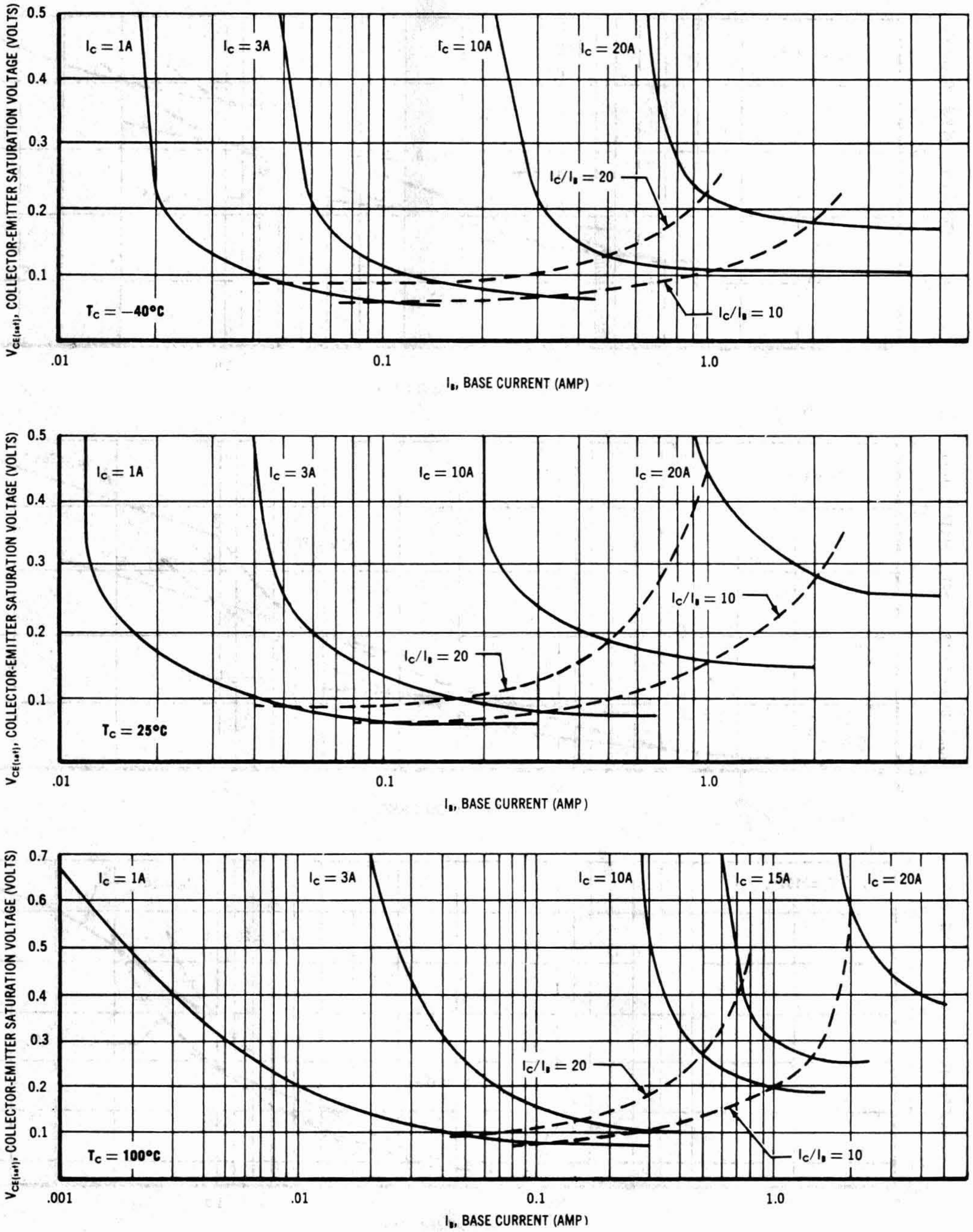


FIGURE 7 — CURRENT VARIATIONS

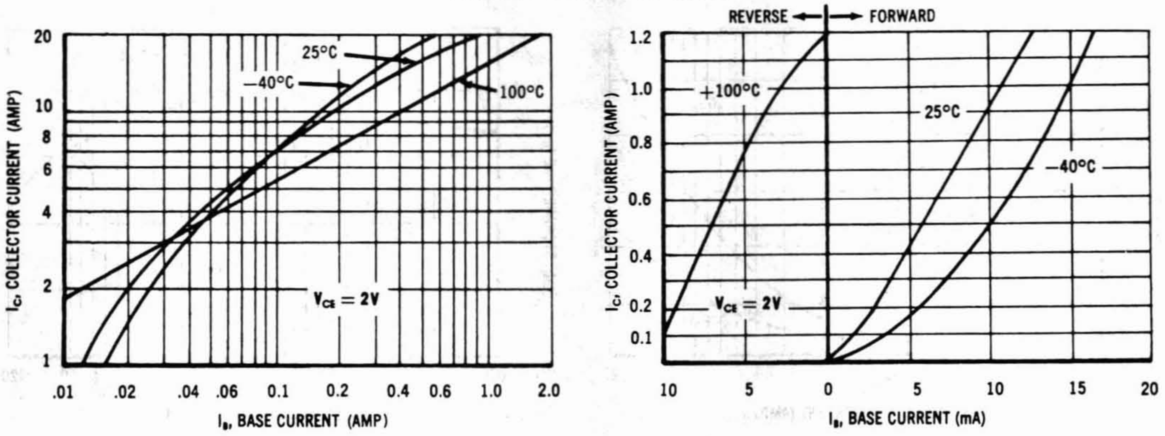


FIGURE 8 — COLLECTOR CURRENT-VOLTAGE VARIATION

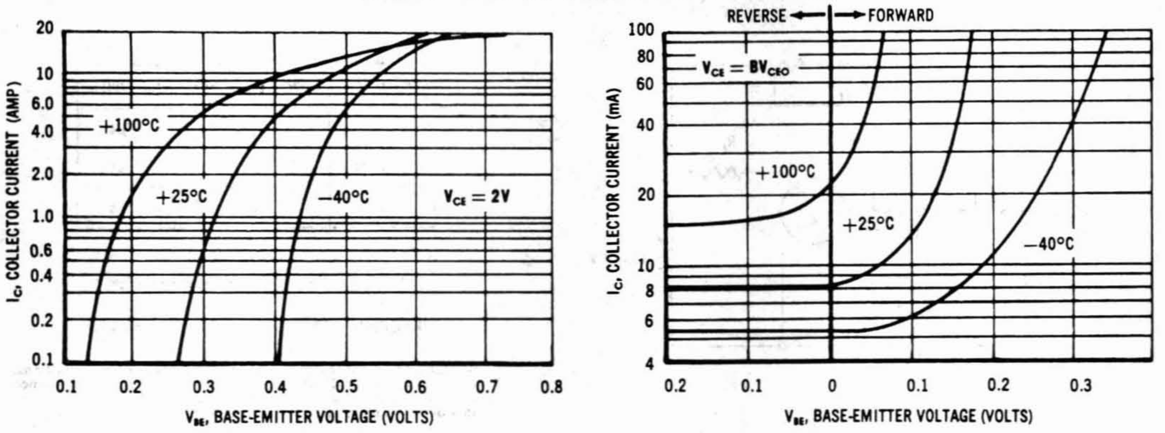


FIG 9 — BASE CURRENT-VOLTAGE VARIATIONS

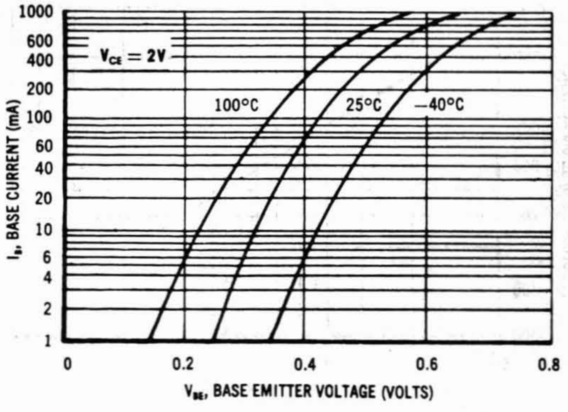


FIGURE 10 CURRENT-GAIN VARIATIONS

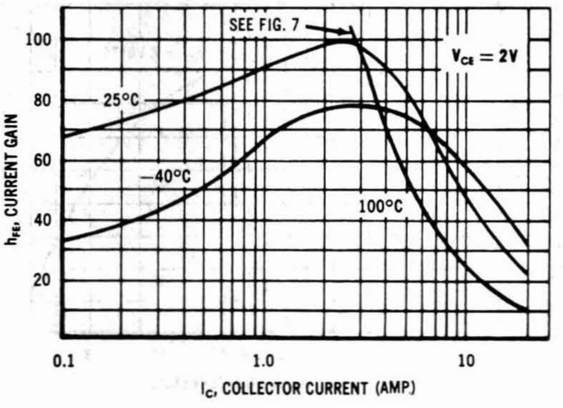


FIG 11 — RISE and FALL TIME vs COLLECTOR CURRENT

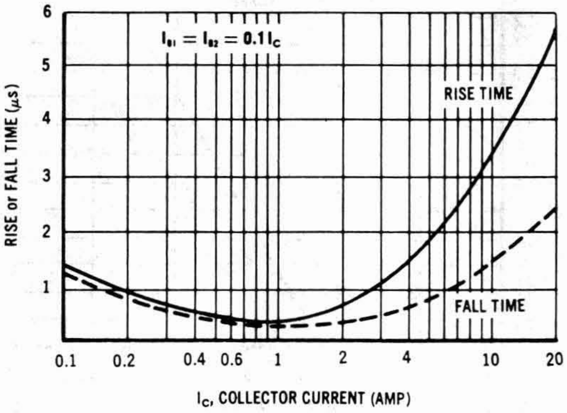


FIG 12 — STORAGE TIME vs COLLECTOR CURRENT

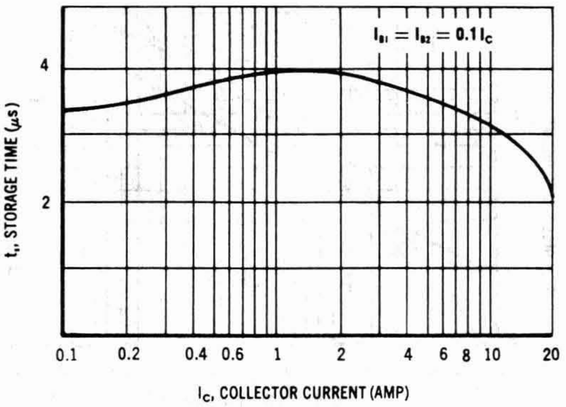
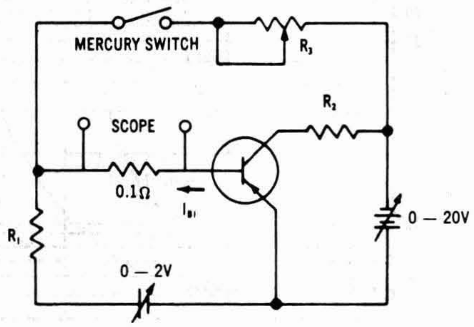


FIG 13 — SWITCHING TIME TEST CIRCUIT



Characteristic	Sym	Max	Unit
Rise Time	t_r	4	μs
Storage Time	t_s	6	μs
Fall Time	t_f	2.5	μs

ADJUST R_1, R_2, R_3, for $I_{B1} = I_{B2} = 0.1 I_C$

PULSE CONDITIONS; $I_C = 5$ AMP, $I_{B1} = 0.5$ AMP

Switching times shown are for constant current drive conditions. Faster times can be realized by the use of a lower source impedance or a speed-up capacitor. See Chapter 5 of the Motorola Switching Handbook for a more detailed explanation.

FIG 14 — CURRENT GAIN — BANDWIDTH PRODUCT vs COLLECTOR CURRENT

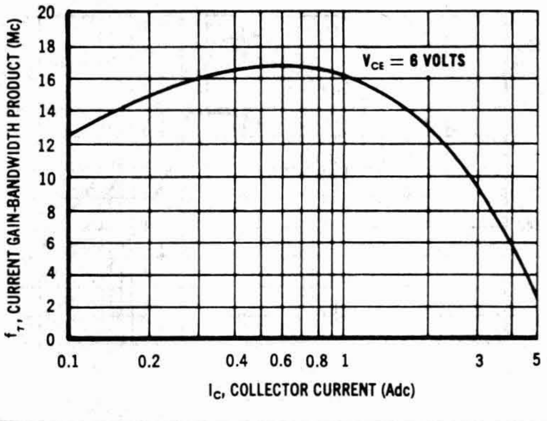
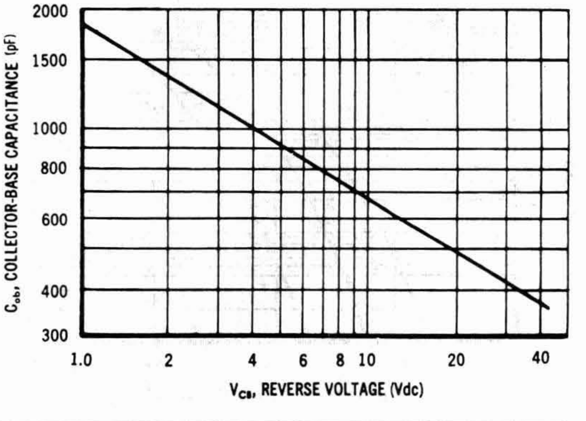


FIG 15 — OUTPUT CAPACITANCE vs REVERSE VOLTAGE

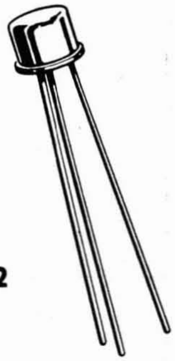


2N2837, 2N2838

For Specifications , See 2N2800 Data .

2N2845 thru 2N2848 (SILICON)

CASE 22
(TO-18)
2N2845
2N2847



CASE 31
(TO-5)
2N2846
2N2848

NPN silicon annular transistors designed for high-speed, medium-power saturated switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N2845	2N2846	2N2847	2N2848	Unit
Collector-Emitter Voltage*	V_{CEO}*	30	30	20	20	Vdc
Collector-Base Voltage	V_{CB}	60	60	60	60	Vdc
Emitter-Base Voltage	V_{EB}	5	5	5	5	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	360 2.1	800 4.6	360 2.1	800 4.6	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.9	3.0 17.2	1.2 6.9	3.0 17.2	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to 200				°C
Storage Temperature Range	T_{stg}	-65 to + 200				°C

*Applicable from 1 mA to 30 mA (Pulsed)

2N2845 thru 2N2848 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage*		$BV_{CEO(sus)}$*			Vdc
(I_C = 30 mAdc, I_B = 0)	2N2845, 2N2846		30	—	
(I_C = 30 mAdc, I_B = 0)	2N2847, 2N2848		20	—	
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)		BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)		BV_{EBO}	5.0	—	Vdc
Collector-Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0)		I_{CES}	—	0.2	μAdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)		I_{CBO}	—	200	μAdc
Base Leakage Current (V_{CE} = 30 Vdc, V_{BE} = 0)		I_{BL}	—	0.2	μAdc
ON CHARACTERISTICS					
DC Current Gain*		h_{FE}*			—
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N2845, 2N2846		30	120	
	2N2847, 2N2848		40	140	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)	2N2845, 2N2846		20	—	
	2N2847, 2N2848		30	—	
(I_C = 500 mAdc, V_{CE} = 1 Vdc)	All Types		10	—	
Collector-Emitter Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)	All Types		—	0.4	
(I_C = 500 mAdc, I_B = 50 mAdc)	2N2845, 2N2846		—	1.0	
	2N2847, 2N2848		—	0.75	
Base-Emitter Saturation Voltage*		$V_{BE(sat)}$*			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			—	1.2	
(I_C = 500 mAdc, I_B = 50 mAdc)			—	1.6	
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	250	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)		C_{ob}	—	8.0	pF
Turn-On Time (Figure 1)		t_{on}			ns
(V_{CC} = 10 Vdc, $I_C \approx$ 150 mAdc, $I_{B1} \approx$ 15 mAdc)	2N2845, 2N2846		—	40	
(V_{CC} = 6 Vdc, $I_C \approx$ 150 mAdc, $I_{B1} \approx$ 15 mAdc)	2N2847, 2N2848		—	25	
Turn-Off Time (Figure 2)		t_{off}			ns
(V_{CC} = 10 Vdc, $I_C \approx$ 150 mAdc, $I_{B1} \approx I_{B2} \approx$ 15 mAdc)	2N2845, 2N2846		—	40	
(V_{CC} = 6 Vdc, $I_C \approx$ 150 mAdc, $I_{B1} \approx I_{B2} \approx$ 15 mAdc)	2N2847, 2N2848		—	40	

*Pulse Test: Pulse Width = 300 μs; Duty Cycle = ≤ 2%

FIGURE 1 — TURN-ON TIME TEST CIRCUIT

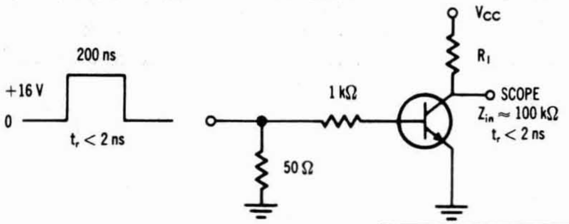
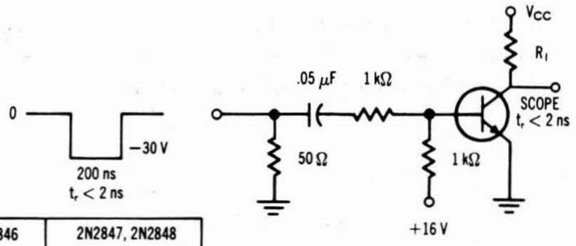


FIGURE 2 — TURN-OFF TIME TEST CIRCUIT



	2N2845, 2N2846	2N2847, 2N2848
V_{CC}	10 V	6 V
R_1	62 Ω	39 Ω

2N2857 (SILICON)
2N3839

CASE 20
(TO-72)

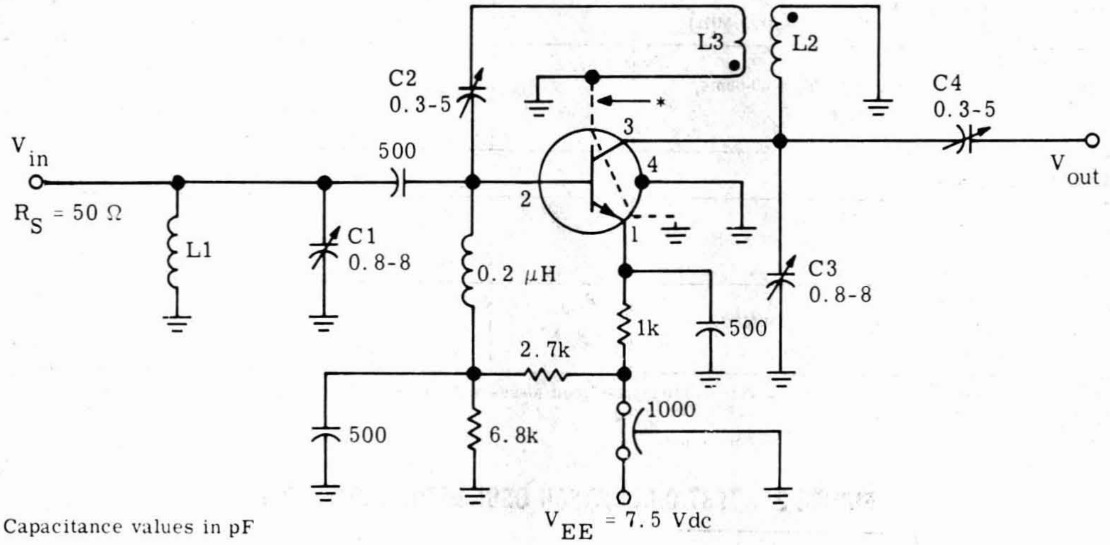
Active elements isolated from case

NPN silicon annular small-signal amplifier transistors designed for high-gain, low-noise amplifiers, oscillators, and mixers.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	2.5	Vdc
Collector Current	I_C	40	mAdc
Total Device Dissipation, T_A = 25°C Derate above 25°C	P_D	200 1.14	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

FIGURE 1 — TEST CIRCUIT FOR NOISE FIGURE AND POWER GAIN



Capacitance values in pF

L1, L2 — Silver-plated brass rod, 1-1/2" long and 1/4" dia. Install at least 1/2" from nearest vertical chassis surface.

L3 — 1/2 turn #16 AWG wire, located 1/4" from and parallel to L2

* — External interlead shield to isolate collector lead from emitter and base leads.

Neutralization Procedure:

(A) Connect 450-MHz signal generator (with R_S = 50 ohms) to input terminals of amplifier.

(B) Connect 50-ohm RF voltmeter across output terminals of amplifier.

(C) Apply V_{EE}, and with signal generator adjusted for 5 mV output from amplifier, tune C1, C3, and C4 for maximum output.

(D) Interchange connections to signal generator and RF voltmeter.

(E) With sufficient signal applied to output terminals of amplifier, adjust C2 for minimum indication at input.

(F) Repeat steps (A), (B), and (C) to determine if retuning is necessary.

2N2857, 2N3839 (continued)

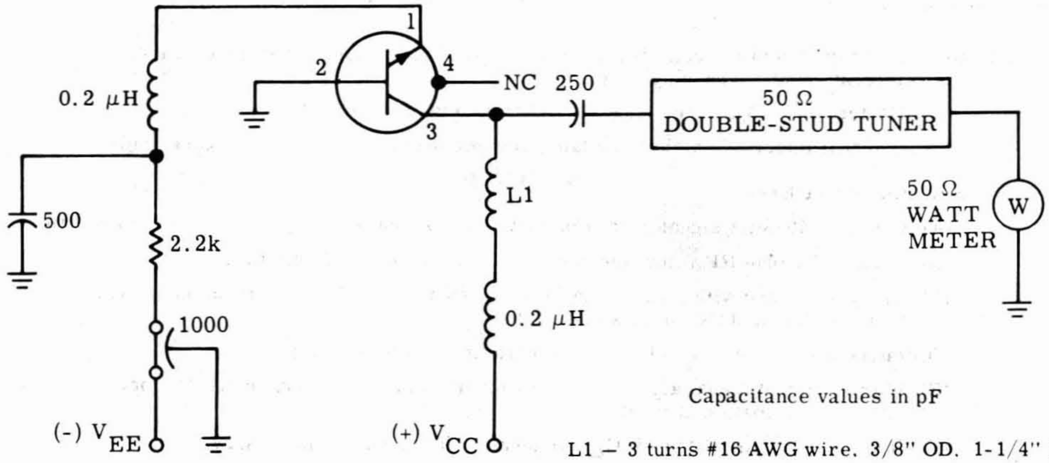
ELECTRICAL CHARACTERISTICS (T_A = 25° C and case grounded unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 3.0 mAdc, I_B = 0)	BV_{CEO}	15	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	BV_{CBO}	30	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	2.5	-	-	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 150° C)	I_{CBO}	- -	- -	0.01 1.0	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 3.0 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	30	-	150	-
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 5.0 mAdc, V_{CE} = 6.0 Vdc, f = 100 MHz)	f_T	1000	-	-	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 0.1 to 1.0 MHz, emitter and case guarded)	C_{cb}	-	-	1.0	pF
Small-Signal Current Gain (I_C = 2.0 mAdc, V_{CE} = 6.0 Vdc, f = 1.0 kHz)	h_{fe}	50	-	220	-
Collector-Base Time Constant (I_E = 2.0 mAdc, V_{CB} = 6.0 Vdc, f = 31.9 MHz)	$r_b'C_c$	-	-	15	ps
Noise Figure (I_C = 1.5 mAdc, V_{CE} = 10 Vdc, R_S = 50 ohms, f = 450 MHz) 2N2857 2N3839	NF	- -	3.7† 3.1†	4.5* 3.9*	dB
FUNCTIONAL TEST					
Common-Emitter Amplifier Power Gain (I_C = 1.5 mAdc, V_{CE} = 6.0 Vdc, f = 450 MHz, Figure 1)	G_{pe}	12.5	-	19	dB
Oscillator Power Output (I_E = 12 mAdc, V_{CE} = 10 Vdc, f = 500 MHz, Figure 2, fourth lead not connected)	P_{out}	30	-	-	mW

* Noise figure measurements include corrections for input-circuit losses and second-stage post-amplifier contributions per EIA-NEMA Standard #RS-311.

† Measured in circuit of Figure 1 with no corrections.

FIGURE 2 — TEST CIRCUIT FOR OSCILLATOR POWER OUTPUT



Capacitance values in pF

L1 — 3 turns #16 AWG wire, 3/8" OD, 1-1/4" long

2N2894 (SILICON)

CASE 22
(TO-18)

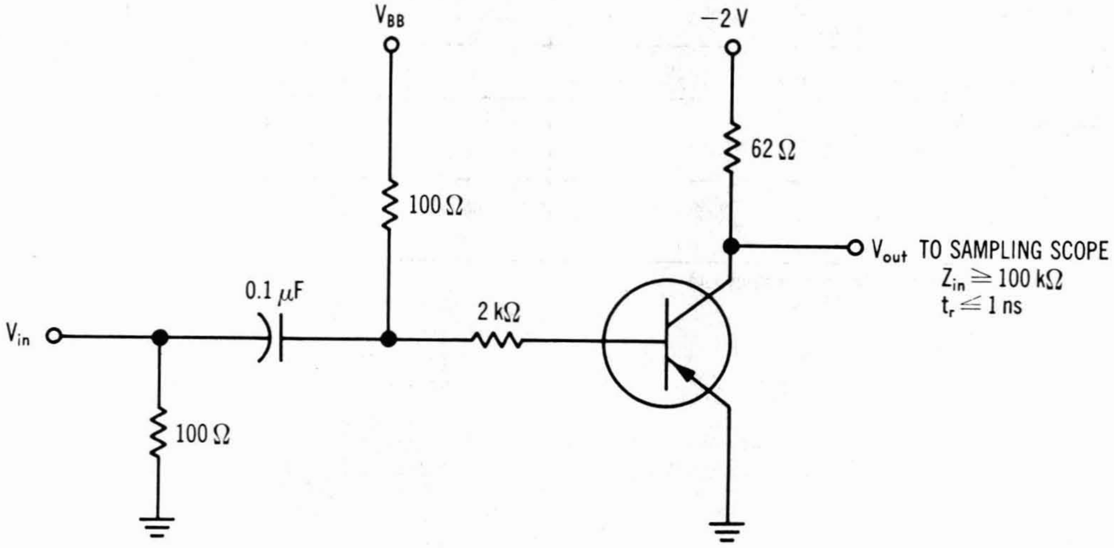
PNP silicon annular transistor designed for low-level, high-speed switching applications.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage *	V_{CEO}*	12	Vdc
Collector-Base Voltage	V_{CB}	12	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector Current-Continuous	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	360 2.06	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1200 6.85	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

*Applicable from 0.01 to 10 mAdc.

FIGURE 1 — SWITCHING TIME TEST CIRCUIT


V_{BB}
−2 V
62 Ω
100 Ω
V_{out} TO SAMPLING SCOPE
$Z_{in} \geq 100$ kΩ
$t_r \leq 1$ ns
0.1 μF
2 kΩ
V_{in}
100 Ω

2N2894 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	12	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 μAdc, V_{BE} = 0)	BV_{CES}	12	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	12	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4	—	Vdc
Collector-Cutoff Current (V_{CE} = 6 Vdc, V_{BE} = 0)	I_{CES}	—	80	nAdc
Collector-Cutoff Current (V_{CB} = 6 Vdc, I_E = 0, T_A = 125°C)	I_{CBO}	—	10	μAdc
Base Current (V_{CE} = 6 Vdc, V_{BE} = 0)	I_B	—	80	nAdc
ON CHARACTERISTICS				
DC Current Gain*	h_{FE}*			—
(I_C = 10 mAdc, V_{CE} = 0.3 Vdc)		30	—	
(I_C = 30 mAdc, V_{CE} = 0.5 Vdc)		40	150	
(I_C = 30 mAdc, V_{CE} = 0.5 Vdc, T_A = -55°C)		17	—	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)		25	—	
Collector-Emitter Saturation Voltage*	$V_{CE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		—	0.15	
(I_C = 30 mAdc, I_B = 3 mAdc)		—	0.2	
(I_C = 100 mAdc, I_B = 10 mAdc)		—	0.5	
Base-Emitter Saturation Voltage*	$V_{BE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		0.78	0.98	
(I_C = 30 mAdc, I_B = 3 mAdc)		0.85	1.2	
(I_C = 100 mAdc, I_B = 10 mAdc)		—	1.7	
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 30 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	400	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	6.0	pF
Input Capacitance (V_{BE} = -0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	—	6.0	pF
Turn-On Time, Figure 1 (V_{CC} = 2 Vdc, $V_{BE(off)}$ = 3 Vdc, I_C = 30 mAdc, I_{B1} = 1.5 mAdc)	t_{on}	—	60	ns
Turn-Off Time, Figure 1 (V_{CC} = 2 Vdc, I_C = 30 mAdc, I_{B1} = I_{B2} = 1.5 mAdc)	t_{off}	—	90	ns

*Pulse Test: Pulse Width = 300 μs; Duty Cycle = 1%

2N2895 (SILICON)
2N2896
2N2897

CASE 22
(TO-18)

NPN silicon annular transistors designed for small-signal amplifier and general purpose switching applications.

MAXIMUM RATINGS

Rating	Symbol	2N2895	2N2896	2N2897	Unit
Collector-Emitter Voltage	V_{CEO}	65	90	45	Vdc
Collector-Emitter Voltage	V_{CER}	80	140	60	Vdc
Collector-Base Voltage	V_{CB}	120	140	60	Vdc
Emitter-Base Voltage	V_{EB}	← 7.0 →			Vdc
Collector Current	I_C	← 1.0 →			Adc
Total Device Dissipation @ $T_A = 25°C$	P_D	← 0.5 →			Watt
Derate above 25°C		← 2.86 →			mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D	← 1.8 →			Watts
Derate above 25°C		← 10.3 →			mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

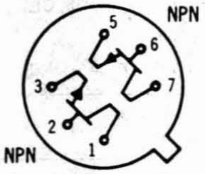
Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, I_B = 0)	2N2895	$BV_{CEO(sus)}$*	65	-	Vdc
	2N2896		90	-	
	2N2897		45	-	
Collector-Emitter Breakdown Voltage* (I_C = 100 mAdc, R_{BE} = 10 ohms)	2N2895	BV_{CER}*	80	-	Vdc
	2N2896		140	-	
	2N2897		60	-	
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	2N2895	BV_{CBO}	120	-	Vdc
	2N2896		140	-	
	2N2897		60	-	
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)		BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)	2N2895	I_{CBO}	-	0.002	μAdc
	2N2896		-	0.01	
	2N2897		-	0.05	
(V_{CB} = 60 Vdc, I_E = 0, T_A = +150°C)	2N2895		-	2.0	
	2N2897		-	50	
(V_{CB} = 90 Vdc, I_E = 0)	2N2896		-	0.01	
(V_{CB} = 90 Vdc, I_E = 0, T_A = +150°C)	2N2896		-	10	
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	2N2895	I_{EBO}	-	0.002	μAdc
	2N2896		-	0.01	
	2N2897		-	0.05	
ON CHARACTERISTICS					
DC Current Gain (I_C = 10 μAdc, V_{CE} = 10 Vdc)	2N2895	h_{FE}	10	-	-
(I_C = 100 μAdc, V_{CE} = 10 Vdc)	2N2895		20	-	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	2N2896, 2N2897		35	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N2895		35	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)	2N2895, 2N2896		20	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)*	2N2895		40 *	120 *	
	2N2896		60 *	200 *	
	2N2897		50 *	200 *	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)*	2N2895		25 *	-	
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	2N2895, 2N2896	$V_{CE(sat)}$*	-	0.6	Vdc
	2N2897		-	1.0	
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	2N2895, 2N2896	$V_{BE(sat)}$*	-	1.2	Vdc
	2N2897		-	1.3	
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	2N2895, 2N2896	f_T	120	-	MHz
	2N2897		100	-	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	15	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	-	80	pF
Small-Signal Current Gain (I_C = 5.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N2895	h_{fe}	50	200	-
	2N2896, 2N2897		50	275	
Noise Figure (I_C = 0.3 mAdc, V_{CE} = 10 Vdc, R_S = 500 ohms, f = 1.0 kHz, BW = 15 kHz)	2N2895	NF	-	8.0	dB

* Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 1.8%.

2N2903 (SILICON)
2N2903A

Dual NPN silicon transistors designed for differential amplifier applications.

CASE 32C



PINS 4 AND 8 OMITTED

Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	30		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Collector Current	I_C	50		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Power Dissipation @ T_A = 25°C	P_D	200	300	mW
Derate above 25°C		1.14	1.71	mW/°C
Power Dissipation @ T_C = 25°C	P_D	600	1200	mW
T_C = 100°C		350	700	mW
Derate above 25°C		3.43	6.86	mW/°C

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25 C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	30	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 μAdc, I_C = 0)	BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.01 15	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	0.01	μAdc

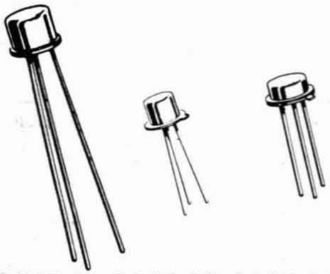
* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 μAdc, V_{CE} = 5.0 Vdc) (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C) (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)	h_{FE}	 60 25 125 60	 - - 625 -	-
Collector-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 0.5 mAdc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 0.5 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 5.0 mAdc, V_{CE} = 10 Vdc, f = 30 MHz)	f_T	60	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	8.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	10	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{ie}	1.0	-	k ohm
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{re}	-	6.0	$X\ 10^{-4}$
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	150	600	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{oe}	5.0	30	μmhos
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20	30	ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{rb}	-	5.0	$X\ 10^{-4}$
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ob}	-	0.2	μmho
Noise Figure (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 1.0 kHz)	NF	-	7.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N2903 2N2903A	h_{FE1}/h_{FE2}**	 0.8 0.9	 1.0 1.0	-
Base Voltage Differential (I_C = 10 μAdc, V_{CE} = 5.0 Vdc) 2N2903 2N2903A	$\lvert V_{BE1}-V_{BE2}\rvert$	 - -	 10 5.0	mVdc
Base Voltage Differential Gradient (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C to +125°C) 2N2903 2N2903A	$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$	 - -	 20 10	μV/°C

** Lowest h_{FE} reading is taken as h_{FE1} for this ratio.

2N2904, A thru 2N2907, A (SILICON)
2N3485, A, 2N3486, A



CASE 31 (TO-5)
2N2904, A
2N2905, A

CASE 22 (TO-18)
2N2906, A
2N2907, A

CASE 26 (TO-46)
2N3485, A
2N3486, A

PNP silicon annular Star transistors for high-speed switching, complementary circuitry and DC to VHF amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage 2N2904/2907, 2N3485, 2N3486 2N2904A/2907A, 2N3485A, 2N3486A	V_{CEO}	 40 60	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	600	mAdc
Total Device Dissipation @ T_A = 25°C TO-5: 2N2904, 2N2904A, 2N2905, 2N2905A TO-18: 2N2906, 2N2906A, 2N2907, 2N2907A TO-46: 2N3485, 2N3485A, 2N3486, 2N3486A Derate above 25°C TO-5: 2N2904, 2N2904A, 2N2905, 2N2905A TO-18: 2N2906, 2N2906A, 2N2907, 2N2907A TO-46: 2N3485, 2N3485A, 2N3486, 2N3486A	P_D	 600 400 400 3.43 2.28 2.28	 mW mW/°C
Total Device Dissipation @ T_C = 25°C TO-5: 2N2904, 2N2904A, 2N2905, 2N2905A TO-18: 2N2906, 2N2906A, 2N2907, 2N2907A TO-46: 2N3485, 2N3485A, 2N3486, 2N3486A Derate above 25°C TO-5: 2N2904, 2N2904A, 2N2905, 2N2905A TO-18: 2N2906, 2N2906A, 2N2907, 2N2907A TO-46: 2N3485, 2N3485A, 2N3486, 2N3486A	P_D	 3.0 1.8 2.0 17.2 10.3 11.43	 Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to +200	°C
Storage Temperature Range	T_{stg}	-65 to +300	°C

2N2904, A-2N2907, A and 2N3485, A, 2N3486, A (Continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0) 2N2904/2907, 2N3485, 2N3486	BV_{CEO}*	40	-	-	Vdc
2N2904A/2907A, 2N3485A, 2N3486A		60	-	-	
Collector-Base Breakdown Voltage (I_C = 10 Adc, I_E = 0)	BV_{CBO}	60	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 Adc, I_C = 0)	BV_{EBO}	5.0	-	-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)	I_{CEX}	-	-	50	nAdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) 2N2904/2907, 2N3485, 2N3486	I_{CBO}	-	-	0.020	μAdc
2N2904A/2907A, 2N3485A, 2N3486A		-	-	0.010	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C) 2N2904/2907, 2N3485, 2N3486		-	-	20	
2N2904A/2907A, 2N3485A, 2N3486A		-	-	10	
Base Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)	I_{BL}	-	-	50	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) 2N2904, 2N2906, 2N3485	h_{FE}	20	-	-	-
2N2905, 2N2907, 2N3486		35	-	-	
2N2904A, 2N2906A, 2N3485A		40	-	-	
2N2905A, 2N2907A, 2N3486A		75	-	-	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc) 2N2904, 2N2906, 2N3485		25	-	-	
2N2905, 2N2907, 2N3486		50	-	-	
2N2904A, 2N2906A, 2N3485A		40	-	-	
2N2905A, 2N2907A, 2N3486A		100	-	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc) 2N2904, 2N2906, 2N3485		35	-	-	
2N2905, 2N2907, 2N3486		75	-	-	
2N2904A, 2N2906A, 2N3485A		40	-	-	
2N2905A, 2N2907A, 2N3486A		100	-	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)* 2N2904, A, 2N2906, A, 2N3485, A		40	-	120	
2N2905, A, 2N2907, A, 2N3486, A		100	-	300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)* 2N2904, 2N2906, 2N3485		20	-	-	
2N2905, 2N2907, 2N3486		30	-	-	
2N2904A, 2N2906A, 2N3485A		40	-	-	
2N2905A, 2N2907A, 2N3486A		50	-	-	
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$*	-	-	0.4	Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)		-	-	1.6	
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)*	$V_{BE(sat)}$	-	-	1.3	Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)		-	-	2.6	
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	200	-	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	-	8.0	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	-	30	pF
SWITCHING CHARACTERISTICS					
Turn-On Time (Figure 1)	t_{on}	-	26	45	ns
Delay Time (Figure 1)	t_d	-	6.0	10	ns
Rise Time (Figure 1)	t_r	-	20	40	ns
Turn-Off Time (Figure 2)	t_{off}	-	70	100	ns
Storage Time (Figure 2)	t_s	-	50	80	ns
Fall Time (Figure 2)	t_f	-	20	30	ns
Total Switching Time (Figure 3)	t_{total}	-	12	-	ns

* Pulse Test: Pulse Width = 300 μs, Duty Cycle ≤ 2.0%.

2N2904, A-2N2907, A and 2N3485, A, 2N3486, A (Continued)

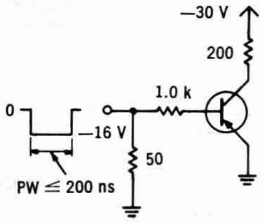


FIGURE 1 — SATURATED TURN-ON SWITCHING-TIME TEST CIRCUIT

−30 V
200
1.0 k
0
−16 V
50
PW ≤ 200 ns

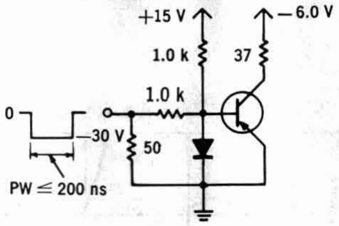


FIGURE 2 — SATURATED TURN-OFF SWITCHING TIME TEST CIRCUIT

+15 V
−6.0 V
1.0 k
37
1.0 k
0
−30 V
50
PW ≤ 200 ns

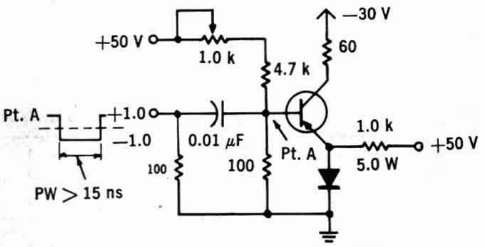


FIGURE 3 — NON-SATURATED SWITCHING-TIME TEST CIRCUIT

+50 V
1.0 k
4.7 k
−30 V
60
Pt. A
+1.0
−1.0
0.01 μF
100
100
Pt. A
1.0 k
5.0 W
+50 V
PW > 15 ns

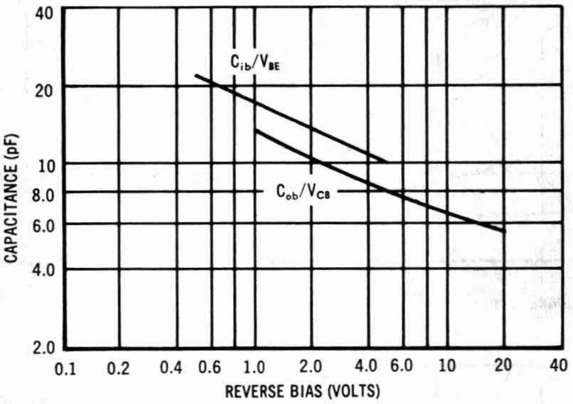


FIGURE 4 — CAPACITANCE VARIATIONS versus VOLTAGE

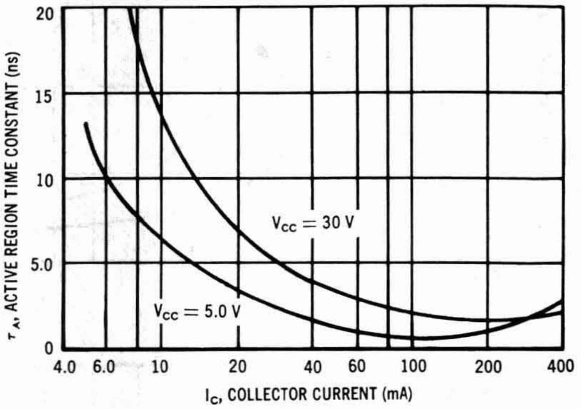


FIGURE 5 — ACTIVE REGION TIME CONSTANT versus COLLECTOR CURRENT

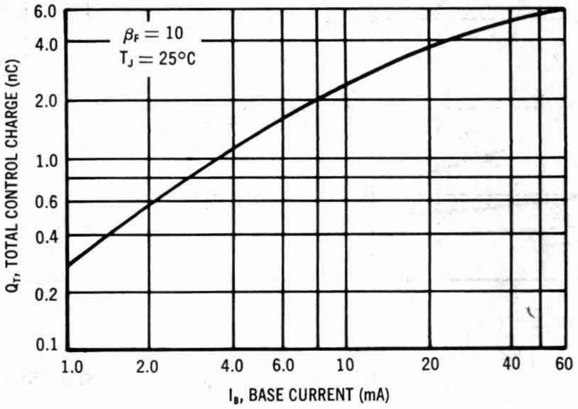


FIGURE 6 — TOTAL CONTROL CHARGE versus BASE CURRENT

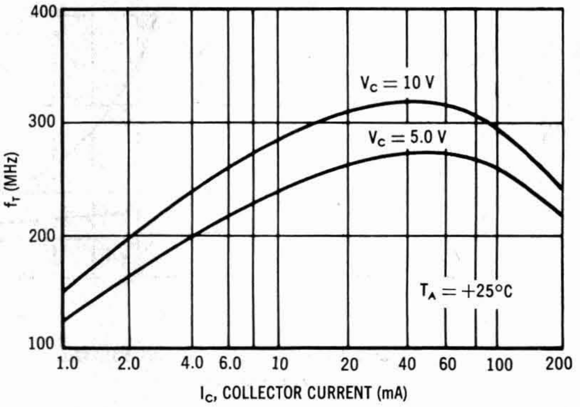


FIGURE 7 — CURRENT GAIN-BANDWIDTH PRODUCT versus COLLECTOR CURRENT

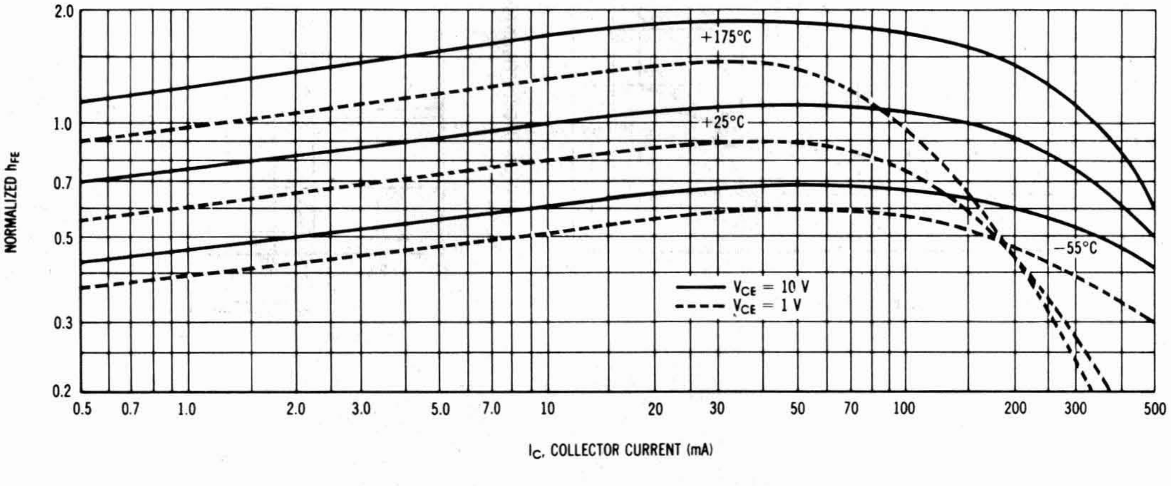


FIGURE 8 — CURRENT GAIN versus COLLECTOR CURRENT

FIGURE 9 — COLLECTOR SATURATION VOLTAGE versus BASE CURRENT

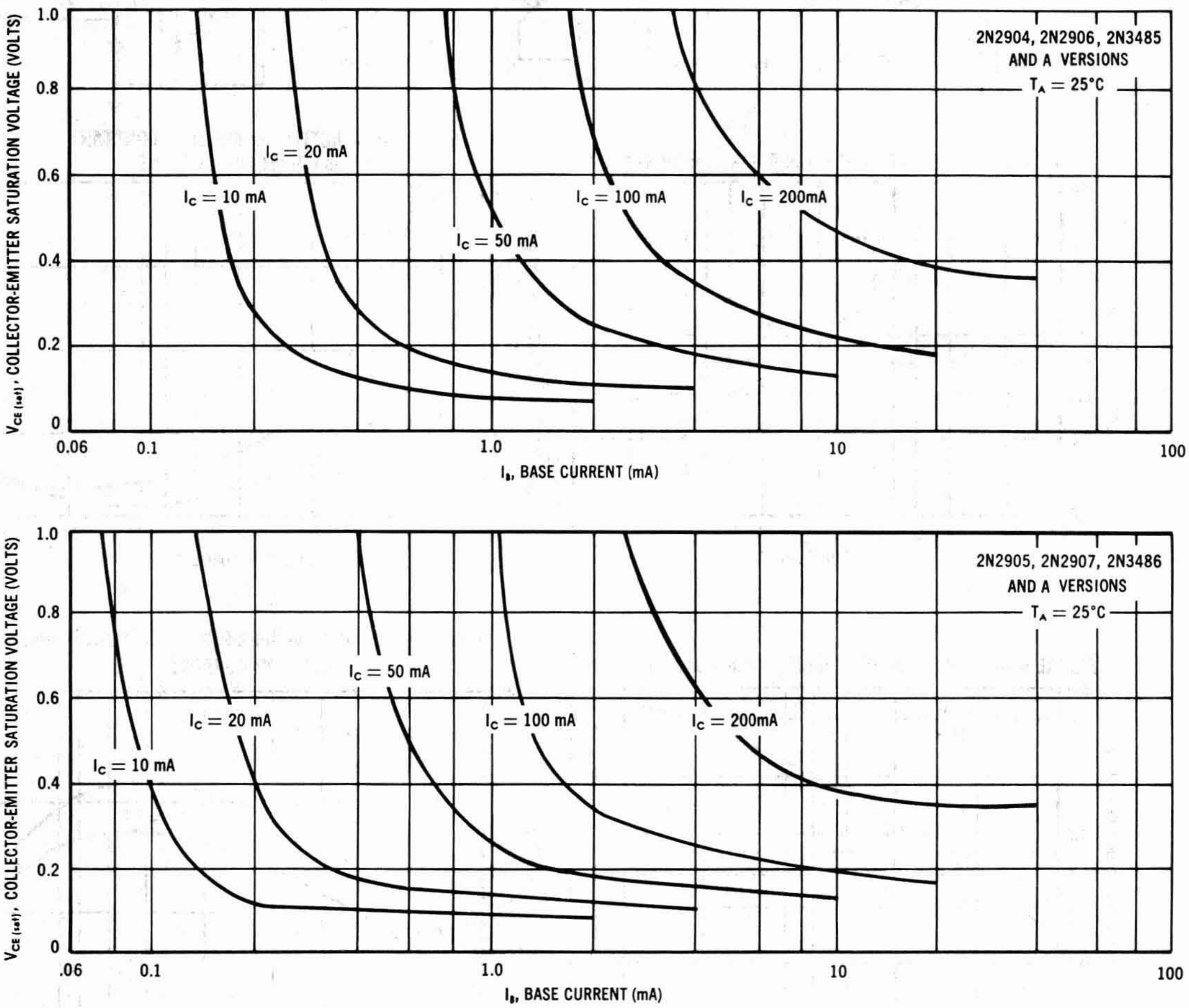


FIGURE 10 — BASE SATURATION VOLTAGE versus BASE CURRENT

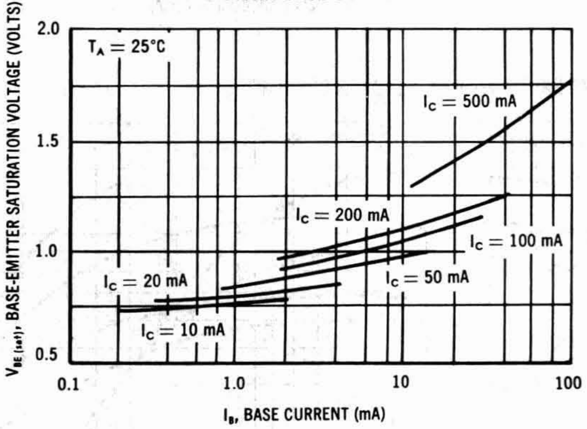
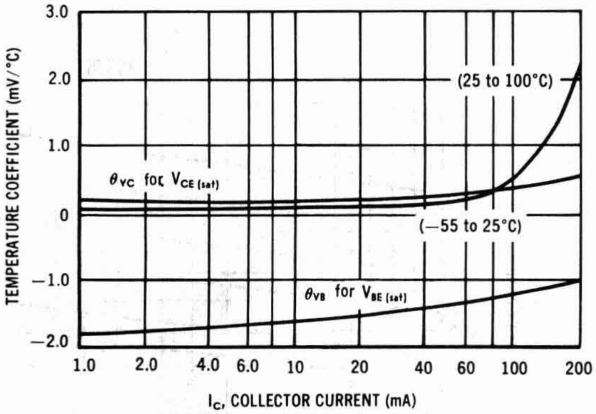


FIGURE 11 — TEMPERATURE COEFFICIENTS



2N2912 (GERMANIUM)

CASE 8

PNP high-speed, high-frequency power transistor especially designed for switching and power converter circuits operating from low-voltage power sources such as solar cells, thermo-electric generators, sea cells, fuel cells and 1.5 volt batteries.

MAXIMUM RATINGS

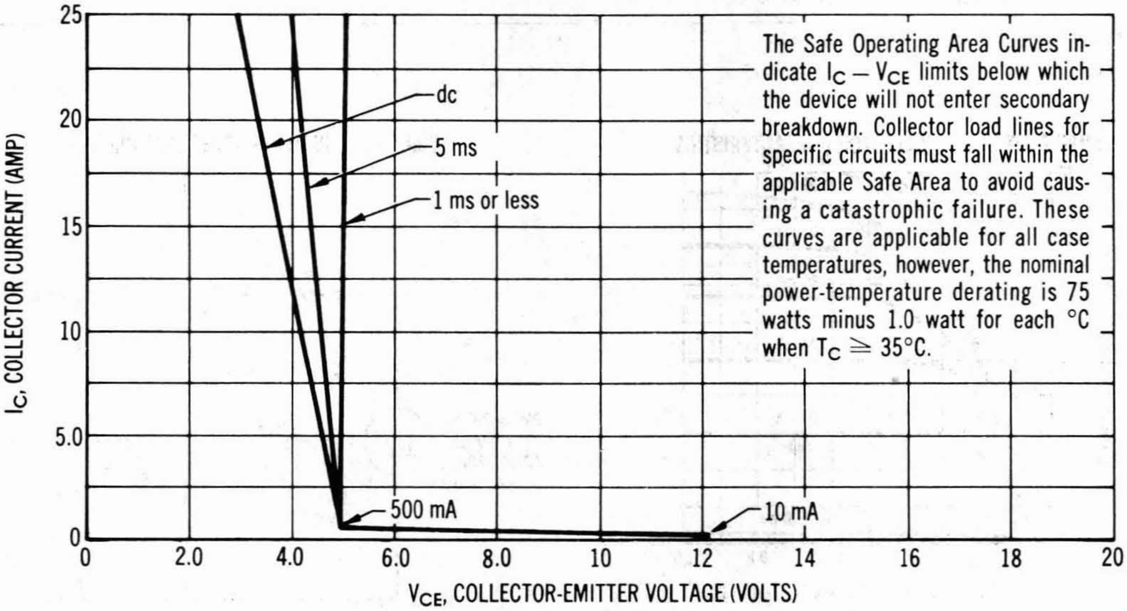
Rating	Symbol	Rating	Unit
Collector-Emitter Voltage	V_{CEO}	5.0	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	1.5	Vdc
Collector Current-Continuous	I_C	25	Adc
Base Current-Continuous	I_B	3.0	Adc
Total Device Dissipation @ T_C = 35°C Derate above 35°C	P_D	75 1.0	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110	°C

Lead temperature 1/16" from case for 10 seconds = 240°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.0	°C/W
Thermal Resistance, Case to Ambient	θ_{CA}	30	°C/W

FIGURE 1 — ACTIVE-REGION SAFE OPERATING AREA



The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the device will not enter secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a catastrophic failure. These curves are applicable for all case temperatures, however, the nominal power-temperature derating is 75 watts minus 1.0 watt for each °C when $T_C \geq 35°C$.

2N2912 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 500 mAdc, I_B = 0)		BV_{CEO}*	5.0	—	Vdc
Collector-Emitter Sustaining Voltage* (I_C = 500 mAdc, I_B = 0)		$BV_{CEO(sus)}$*	5.0	—	Vdc
Collector Cutoff Current (V_{CE} = 15 Vdc, V_{BE} = 0)		I_{CES}	—	10	mAdc
Collector Cutoff Current (V_{CE} = 15 Vdc, R_{BE} = 5.0 ohms)		I_{CER}	—	10	mAdc
Collector Cutoff Current (V_{CE} = 15 Vdc, $V_{BE(off)}$ = 0.2 Vdc) (V_{CE} = 5.0 Vdc, $V_{EB(off)}$ = 0.2 Vdc, T_C = 85°C)		I_{CEX}	— —	10 15	mAdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)		I_{CBO}	—	10	mAdc
Emitter Cutoff Current (V_{BE} = 1.5 Vdc, I_C = 0)		I_{EBO}	—	50	mAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 10 Adc, V_{CE} = 2.0 Vdc) (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	2	h_{FE}	150 200	— 800	—
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc) (I_C = 25 Adc, I_B = 2.5 Adc)	2	$V_{CE(sat)}$	— —	0.12 0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 0.5 Adc) (I_C = 25 Adc, I_B = 2.5 Adc)		$V_{BE(sat)}$	— —	0.5 1.2	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc, f = 1.0 MHz)		f_T	10	—	MHz
Rise Time (V_{CC} = 10 Vdc, I_C = 5.0 Adc)	3	t_r	—	2.0	µs
Storage Time (V_{CC} = 10 Vdc, I_C = 5.0 Adc)	3	t_s	—	10	µs
Fall Time (V_{CC} = 10 Vdc, I_C = 5.0 Adc)	3	t_f	—	2.0	µs

*Sweep Test: 1/2 Cycle sine wave, 60 Hz

FIGURE 2 — TYPICAL COLLECTOR CHARACTERISTICS

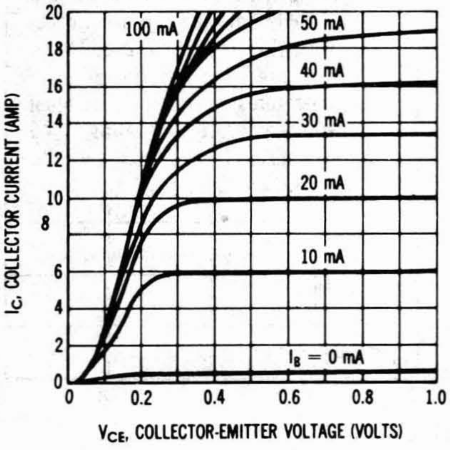
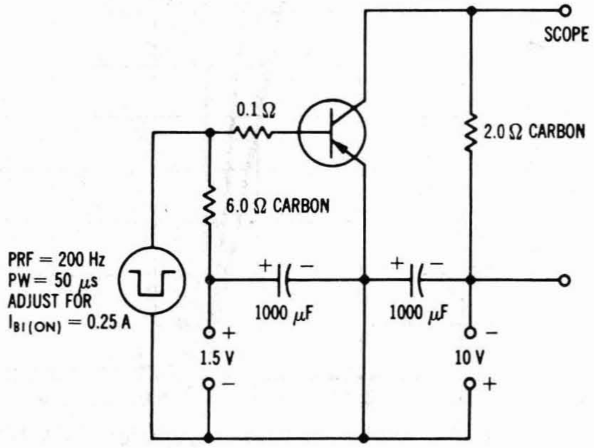
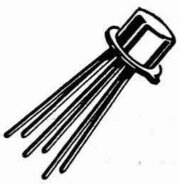


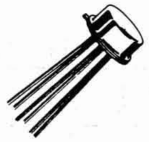
FIGURE 3 — SWITCHING-TIME TEST CIRCUIT



2N2913 thru 2N2920
2N2972 thru 2N2979

Dual NPN silicon annular transistors, especially designed for low-level, low-noise differential-amplifier applications, feature very high Beta guaranteed from 10 μAdc to 1.0 mAdc and excellent noise characteristics.

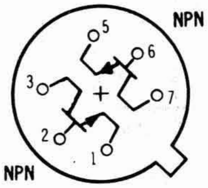




CASE 35
(TO-71)

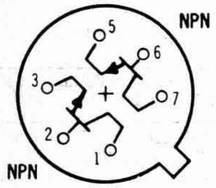
CASE 32C

2N2972
thru
2N2979



Pins 4 and 8 omitted

2N2913
thru
2N2920



Pin Connections, Bottom View
All Leads Electrically Isolated From Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	2N2913-18 2N2972-77	2N2919-20 2N2978-79	Unit
Collector-Emitter Voltage	V_{CEO}	45	60	Vdc
Collector-Base Voltage	V_{CB}	45	60	Vdc
Emitter-Base Voltage	V_{EB}	6.0		
Collector Current	I_C	30		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ T_A = 25°C	P_D			
Case 32C		300	600	mW
Derate above 25°C		1.7	3.4	mW/°C
Case 35		250	300	mW
Derate above 25°C		1.43	1.72	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D			
Case 32C		750	1500	mW
Derate above 25°C		4.3	8.6	mW/°C
Case 35		500	750	mW
Derate above 25°C		2.85	4.3	mW/°C

2N2913 thru 2N2920, 2N2972 thru 2N2979 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage (I_C = 10 mAdc, I_B = 0)	2N2913 thru 18, 2N2972 thru 77	$BV_{CEO(sus)}$	45		-	Vdc
	2N2919, 2N2920, 2N2978, 2N2979		60		-	
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N2913 thru 18, 2N2972 thru 77	BV_{CBO}	45		-	Vdc
	2N2919, 2N2920, 2N2978, 2N2979		60		-	
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	6.0		-	Vdc
Collector Cutoff Current (V_{CE} = 5.0 Vdc, I_B = 0)		I_{CEO}	-	-	0.002	μAdc
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0)	2N2913 thru 18, 2N2972 thru 77	I_{CBO}	-	-	0.010	μAdc
	2N2919, 2N2920, 2N2978, 2N2979		-	-	0.002	
(V_{CB} = 45 Vdc, I_E = 0, T_A = 150°C)	All Types		-	-	10	
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	-	0.002	μAdc
ON CHARACTERISTICS						
DC Current Gain* (I_C = 10 μAdc, V_{CE} = 5.0 Vdc)	2N2913, 15, 17, 19, 2N2972, 74, 76, 78	h_{FE}*	60	-	240	-
	2N2914, 16, 18, 20, 2N2973, 75, 77, 79		150	-	600	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)	2N2913, 15, 17, 19, 2N2972, 74, 76, 78		15	-	-	
	2N2914, 16, 18, 20, 2N2973, 75, 77, 79		30	-	-	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	2N2913, 15, 17, 19, 2N2972, 74, 76, 78		100	-	-	
	2N2914, 16, 18, 20, 2N2973, 75, 77, 79		225	-	-	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	2N2913, 15, 17, 19, 2N2972, 74, 76, 78		150	-	-	
	2N2914, 16, 18, 20, 2N2973, 75, 77, 79		300	-	-	
Collector-Emitter Saturation Voltage (I_C = 1.0 mAdc, I_B = 0.1 mAdc)		$V_{CE(sat)}$	-	-	0.35	Vdc
Base-Emitter On Voltage (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)		$V_{BE(on)}$	-	-	0.7	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 20 MHz)		f_T	60	-	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)		C_{ob}	-	4.0	6.0	pF
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ib}	25	28	32	ohms
Output Admittance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)		h_{ob}	-	-	1.0	μmhos
Noise Figure (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 1.0 kHz, BW = 200 Hz)	2N2914, 16, 18, 20, 2N2973, 75, 77, 79	NF	-	2.0	3.0	dB
	2N2913, 15, 17, 19, 2N2972, 74, 76, 78		-	3.0	4.0	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 10 Hz to 15.7 kHz, BW = 10 kHz)	2N2914, 16, 18, 20, 2N2973, 75, 77, 79		- -	2.0	3.0	
	2N2913, 15, 17, 19, 2N2972, 74, 76, 78			3.0	4.0	
DC Current Gain Ratio** (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	2N2917, 18, 2N2976, 77	h_{FE1}/h_{FE2}**	0.8	-	1.0	-
	2N2915, 16, 19, 20, 2N2974, 75, 78, 79		0.9	-	1.0	
Base Voltage Differential (I_C = 10 μAdc to 1.0 mAdc, V_{CE} = 5.0 Vdc)	2N2917, 18, 2N2976, 77	$\lvert V_{BE1}-V_{BE2}\rvert$	-	-	10	mVdc
	2N2915, 16, 19, 20, 2N2974, 75, 78, 79		-	-	5.0	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	2N2917, 18, 2N2976, 77		-	-	5.0	
	2N2915, 16, 19, 20, 2N2974, 75, 78, 79		-	-	3.0	
Base Voltage Differential Gradient (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C to +25°C)	2N2917, 18, 2N2976, 77	$\Delta(V_{BE1}-V_{BE2})$	-	-	1.6	mVdc
	2N2915, 16, 19, 20, 2N2974, 75, 78, 79		-	-	0.8	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = +25°C to +125°C)	2N2917, 18, 2N2976, 77		-	-	2.0	
	2N2915, 16, 19, 20, 2N2974, 75, 78, 79		-	-	1.0	

* Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

** The lowest h_{FE} reading is taken as h_{FE1} for this ratio.

2N2929 (GERMANIUM)

CASE 31
(TO-5)

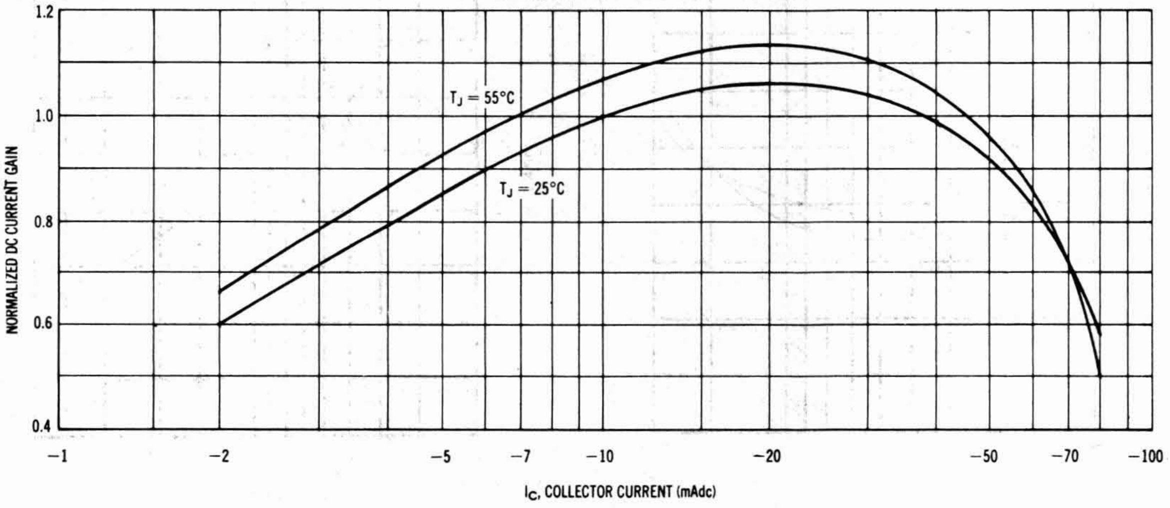
PNP germanium epitaxial mesa transistor for low noise, broadband, power and driver amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Volts
Collector-Emitter Voltage	V_{CES}	25	Volts
Collector-Emitter Voltage	V_{CEO}	10	Volts
Emitter-Base Voltage	V_{EB}	0.75	Volts
Collector Current	I_C	100	mA
Total Device Dissipation @ $T_A = 25^{o}C$ Derate above $25^{o}C$	P_D	300 4	mW $mW/^{o}C$
Total Device Dissipation @ $T_C = 25^{o}C$ Derate above $25^{o}C$	P_D	750 10	mW $mW/^{o}C$
Junction Temperature	T_J	100	^{o}C
Storage Temperature Range	T_{stg}	-65 to +100	^{o}C

NORMALIZED DC CURRENT GAIN CHARACTERISTICS

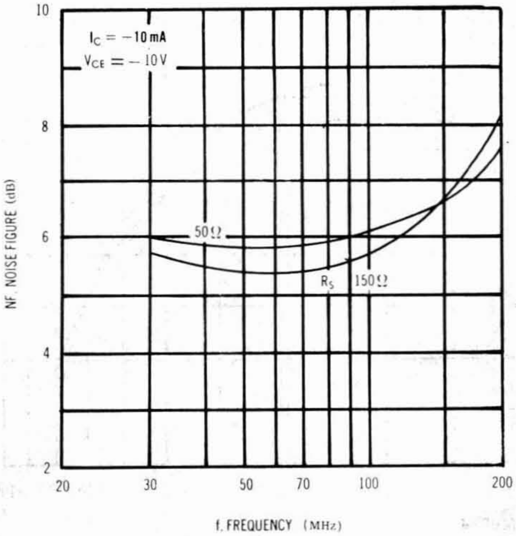


2N2929 (Continued)

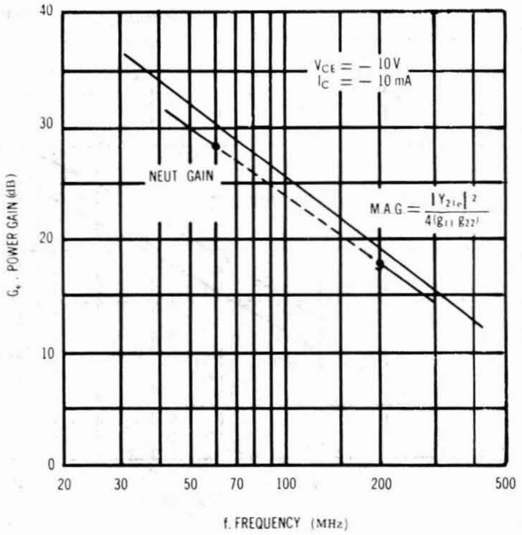
ELECTRICAL CHARACTERISTICS

Characteristic	Sym	Test Conditions	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	I_C = 100 μAdc, I_E = 0	25	45	—	Vdc
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 100 μAdc, V_{EB} = 0	25	45	—	Vdc
Collector-Emitter Breakdown Voltage	BV_{CEO}	I_C = 10 mAdc, I_B = 0	10	20	—	Vdc
Emitter-Base Breakdown Voltage	BV_{EBO}	I_E = 1 mAdc, I_C = 0	0.75	1.5	—	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 10 Vdc, I_E = 0	—	0.15	5	μAdc
		V_{CB} = 10 Vdc, I_E = 0, T_A = +55°C	—	—	50	
Emitter Cutoff Current	I_{EBO}	V_{EB} = 0.5 Vdc, I_C = 0	—	1	100	μAdc
DC Forward Current Transfer Ratio	h_{FE}	V_{CE} = 10 Vdc, I_C = 10 mAdc	10	30	100	—
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 50 mAdc, I_B = 10 mAdc	—	0.15	0.5	Vdc
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	I_C = 50 mAdc, I_B = 10 mAdc	—	0.55	1.0	Vdc
Small-Signal Forward Current Transfer Ratio	h_{fe}	I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1 kHz	10	35	120	—
Current Gain - Bandwidth Product	f_T	I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz	800	1100	1400	MHz
		I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz	1000	1250	1600	
		I_C = 40 mAdc, V_{CE} = 10 Vdc, f = 100 MHz	700	1200	—	
Collector-Base Time Constant	$r_b' C_c$	V_{CB} = 10 Vdc, I_E = 20 mAdc, f = 31.8 MHz	10	25	40	ps
Real Part of Small-Signal Short Circuit Input Impedance	$Re(h_{ie})$	I_C = 10 mA, V_{CE} = 10 V, f = 1000 MHz	—	45	75	ohms
Collector-Base Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz	—	1.75	2.5	pF
Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 10 mAdc, f = 60 MHz	26	28	—	dB
		V_{CE} = 10 Vdc, I_C = 10 mAdc, f = 200 MHz	—	16	—	
Noise Figure	NF	V_{CE} = 10 Vdc, I_C = 2 Adc, f = 200 MHz R_G = 50 Ω	—	5.5	—	dB

NOISE FIGURE versus FREQUENCY



MAXIMUM AVAILABLE GAIN versus FREQUENCY



2N2944 (SILICON)
2N2945
2N2946

PNP silicon annular transistors designed for low-level, high-speed chopper applications.

CASE 26
(TO-46)

Collector electrically
connected to case

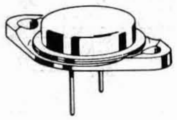
MAXIMUM RATINGS

Rating	Symbol	2N2944	2N2945	2N2946	Unit
Emitter-Collector Voltage	V_{ECO}	10	20	35	Vdc
Collector-Base Voltage	V_{CB}	15	25	40	Vdc
Emitter-Base Voltage	V_{EB}	15	25	40	Vdc
Collector Current	I_C	← 100 →			mAdc
Total Device Dissipation @ $T_A = 25°C$	P_D	← 500 →			mW
Derate above 25°C		← 2.8 →			mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D	← 2.0 →			Watts
Derate above 25°C		← 11.4 →			mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector Cutoff Current		I_{CBO}				nAdc
($V_{CB} = 15$ Vdc, $I_E = 0$)	2N2944		-	-	0.1	
($V_{CB} = 25$ Vdc, $I_E = 0$)	2N2945		-	-	0.2	
($V_{CB} = 40$ Vdc, $I_E = 0$)	2N2946		-	-	0.5	
Emitter Cutoff Current		I_{EBO}				nAdc
($V_{EB} = 15$ Vdc, $I_C = 0$)	2N2944		-	-	0.1	
($V_{EB} = 25$ Vdc, $I_C = 0$)	2N2945		-	-	0.2	
($V_{EB} = 40$ Vdc, $I_C = 0$)	2N2946		-	-	0.5	
ON CHARACTERISTICS						
DC Current Gain		h_{FE}				-
($I_C = 1.0$ mAdc, $V_{CE} = 0.5$ Vdc)	2N2944		80	180	-	
	2N2945		40	160	-	
	2N2946		30	130	-	
Forward Current Transfer Ratio (inverted connection)		$h_{FE(inv)}$				-
($I_C = 200\ \mu$Adc, $V_{CE} = 0.5$ Vdc)	2N2944		6.0	20	-	
	2N2945		4.0	17	-	
	2N2946		3.0	15	-	
Offset Voltage		$V_{EC(off)}$				mVdc
($I_B = 200\ \mu$Adc, $I_E = 0$)	2N2944		-	0.18	0.3	
	2N2945		-	0.23	0.5	
	2N2946		-	0.27	0.8	
($I_B = 1.0$ mAdc, $I_E = 0$)	2N2944		-	0.4	0.6	
	2N2945		-	0.5	1.0	
	2N2946		-	0.6	2.0	
($I_B = 2.0$ mAdc, $I_E = 0$)	2N2944		-	0.8	1.0	
	2N2945		-	0.9	1.6	
	2N2946		-	1.0	2.5	
DYNAMIC CHARACTERISTICS						
Current-Gain–Bandwidth Product		f_T				MHz
($I_C = 1.0$ mAdc, $V_{CE} = 6.0$ Vdc, f = 1.0 MHz)	2N2944		10	15	-	
	2N2945		5.0	13	-	
	2N2946		3.0	12	-	
Output Capacitance ($V_{CB} = 6.0$ Vdc, $I_E = 0$, f = 500 kHz)		C_{ob}	-	3.2	10	pF
Input Capacitance ($V_{EB} = 6.0$ Vdc, $I_C = 0$, f = 500 kHz)		C_{ib}	-	1.9	6.0	pF
Dynamic On Series Resistance		$r_{ec(on)}$				Ohms
($I_C = 100\ \mu$Adc, $I_B = 1.0$ mAdc, $I_E = 0$, f = 1.0 kHz)	2N2944		-	4.0	20	
	2N2945		-	4.5	35	
	2N2946		-	5.0	45	

2N2947 (SILICON)
2N2948



NPN silicon annular transistors for power amplifier applications to 100 MHz.

CASE 1
(TO-3)

Collector connected to case

MAXIMUM RATINGS*

Rating	Symbol	2N2947	2N2948	Unit
Collector-Base Voltage	V_{CB}	60	40	Vdc
Collector-Emitter Voltage	V_{CES}	60	40	Vdc
Emitter - Base Voltage	V_{EB}	3	2	Vdc
Collector-Current (continuous)	I_C	1.5		Adc
Base-Current (continuous)	I_B	500		mAdc
Power Input (Nominal)	P_{in}	5.0		Watts
Power Output (Nominal)	P_{out}	20.0		Watts
Total Device Dissipation @ 25°C Case Temperature Derating Factor above 25°C	P_D	25.0 167		Watts mW/°C
Junction Temperature	T_J	175		°C
Storage Temperature Range	T_{stg}	-65 to + 175		°C

*The maximum ratings as given for dc conditions can be exceeded on a pulse basis. See electrical characteristics.

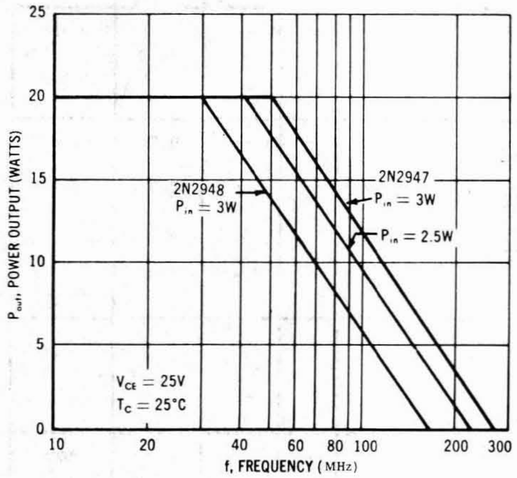
2N2947, 2N2948 (Continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

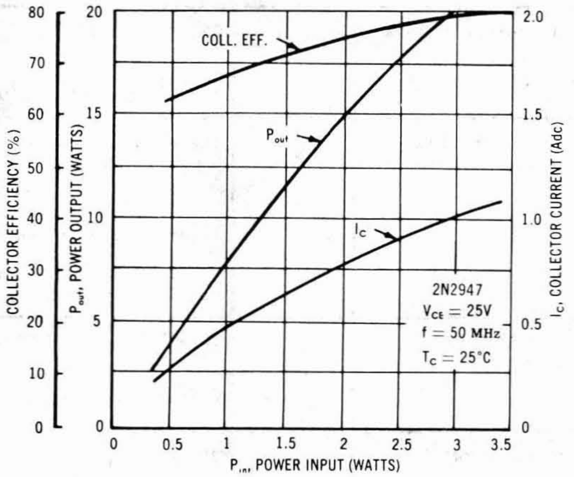
Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Collector-Emitter Sustain Voltage	$V_{CES\,(sus)}$*	2N2947: $I_C = 0.250$ A, $R_{BE} = 0$ 2N2948: $I_C = 0.250$A, $R_{BE} = 0$	90 80	120 100	-- --	Volts
Collector-Emitter-Open Base Sustain Voltage	$V_{CEO(sus)}$*	2N2947: $I_C = 0.250$A, $I_B = 0$ 2N2948: $I_C = 0.250$A, $I_B = 0$	40 20	-- --	-- --	Volts
Collector-Emitter Current	I_{CES}	2N2947: $V_{CE} = 60$ Vdc, $V_{BE} = 0$ $V_{CE} = 50$ Vdc, $V_{BE} = 0$, $T_C = 175°C$ 2N2948: $V_{CE} = 40$ Vdc, $V_{BE} = 0$ $V_{CE} = 30$ Vdc, $V_{BE} = 0$, $T_C = 175°C$	-- -- -- --	-- -- -- --	0.5 1.0 0.5 1.0	mAdc
Collector Cutoff Current	I_{CBO}	2N2947: $V_{CB} = 50$ Vdc, $I_E = 0$ 2N2948: $V_{CB} = 30$ Vdc, $I_E = 0$	-- --	-- --	1 1	μAdc
Emitter Cutoff Current	I_{EBO}	2N2947: $V_{EB} = 3$ Vdc, $I_C = 0$ 2N2948: $V_{EB} = 2$ Vdc, $I_C = 0$	-- --	-- --	100 100	μAdc
DC Current Gain	h_{FE}	2N2947: $I_C = 400$ mAdc, $V_{CE} = 2$Vdc 2N2948: $I_C = 400$ mAdc, $V_{CE} = 2$ Vdc Both Types: $I_C = 1$ Adc, $V_{CE} = 2$ Vdc	2.5 2.5 2.5	-- -- --	35 100 --	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	$I_C = 1.0$ Adc, $I_B = 500$ mAdc	--	--	0.5	Vdc
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	$I_C = 1.0$ Adc, $I_B = 500$ mAdc	--	--	2.0	Vdc
AC Current Gain	$\|h_{fe}\|$	$V_{CE} = 2.0$ Vdc, $I_C = 400$ mAdc, f = 50 MHz	2.0	--	--	
Collector Output Capacitance	C_{ob}	$V_{CB} = 25$ Vdc, $I_E = 0$, f = 100 kHz	--	--	60	pF
Power Input	P_{in}	$P_{out} = 15$ W, f = 50 MHz, $V_{CE} = 25$ Vdc	--	2.0	3.0	Watts
Efficiency	η	$I_{C(max)} = 1$A 2N2947	60	80	--	%
Power Input	P_{in}	$P_{out} = 15$ W, f = 30 MHz, $V_{CE} = 25$ Vdc	--	2.0	3.0	Watts
Efficiency	η	$I_{C(max)} = 1.0$ A 2N2948	60	70	--	%

* Pulse Measurement: Pulse Width ≦ 100 μs, Duty Cycle = 2.0%.

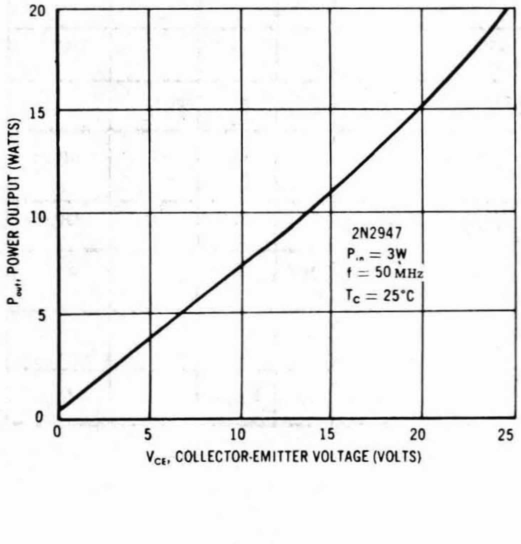
POWER OUTPUT versus FREQUENCY



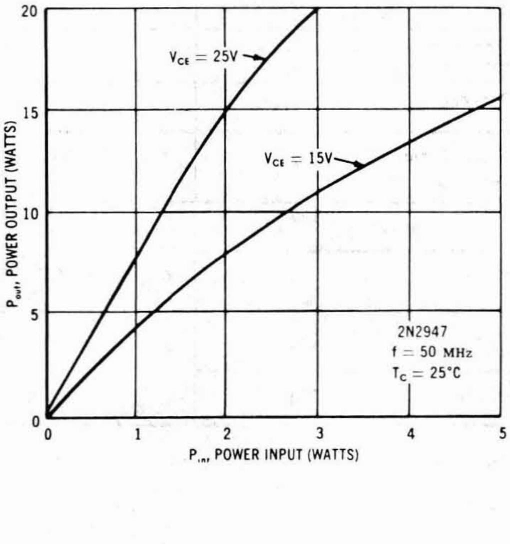
OUTPUT CHARACTERISTICS versus POWER INPUT



POWER OUTPUT versus COLLECTOR VOLTAGE



POWER OUTPUT versus POWER INPUT



2N2949 (SILICON)
2N2950

CASE 23
(TO-107)
2N2949

CASE 24
(TO-102)
2N2950

NPN silicon annular transistors for power amplifier and driver applications to 100 MHz.

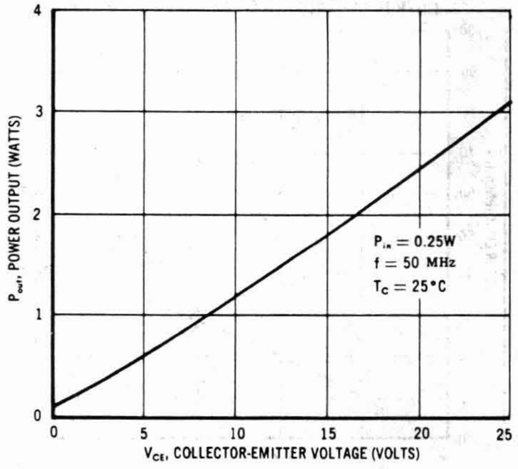
Collector connected to case;
stud isolated from case

MAXIMUM RATINGS*

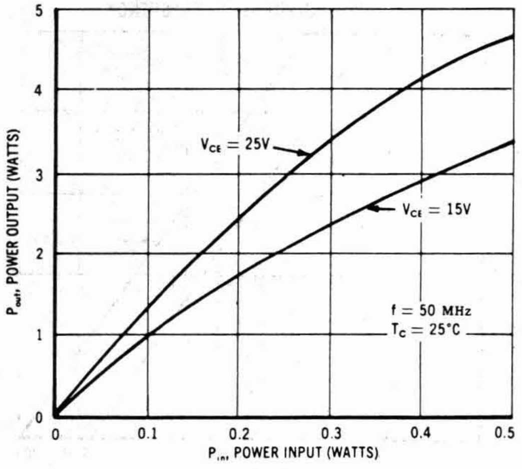
<table>
<tr><th>Rating</th><th>Symbol</th><th colspan="2">Value</th><th>Unit</th></tr>
<tr><td>Collector-Base Voltage</td><td>V_{CB}</td><td colspan="2">60</td><td>Vdc</td></tr>
<tr><td>Collector-Emitter Voltage</td><td>V_{CES}</td><td colspan="2">60</td><td>Vdc</td></tr>
<tr><td>Emitter - Base Voltage</td><td>V_{EB}</td><td colspan="2">3.0</td><td>Vdc</td></tr>
<tr><td>Collector Current (Continuous)</td><td>I_C</td><td colspan="2">0.7</td><td>Adc</td></tr>
<tr><td>Base Current (Continuous)</td><td>I_B</td><td colspan="2">100</td><td>mAdc</td></tr>
<tr><td>RF Input Power (Nom)</td><td>P_{in}</td><td colspan="2">1.0</td><td>Watt</td></tr>
<tr><td>RF Output Power (Nom)</td><td>P_{out}</td><td colspan="2">5.0</td><td>Watts</td></tr>
<tr><td>Total Device Dissipation
(25°C Case temperature)
(Derating Factor above 25°C)</td><td>P_D</td><td colspan="2">6.0
40</td><td>Watts
mW/°C</td></tr>
<tr><td rowspan="2">Total Device Dissipation at
25° Ambient
(Derating Factor above 25°C)</td><td rowspan="2">P_D</td><td>2N2949</td><td>2N2950</td><td rowspan="2">Watt
mW/°C</td></tr>
<tr><td>0.5
3.33</td><td>0.7
4.67</td></tr>
<tr><td>Junction Temperature</td><td>T_J</td><td colspan="2">175</td><td>°C</td></tr>
<tr><td>Storage Temperature Range</td><td>T_{stg}</td><td colspan="2">-65 to + 175</td><td>°C</td></tr>
</table>

* The maximum ratings as given for dc conditions can be exceeded on a pulse basis. See Electrical Characteristics.

POWER OUTPUT versus COLLECTOR VOLTAGE



POWER OUTPUT versus POWER INPUT

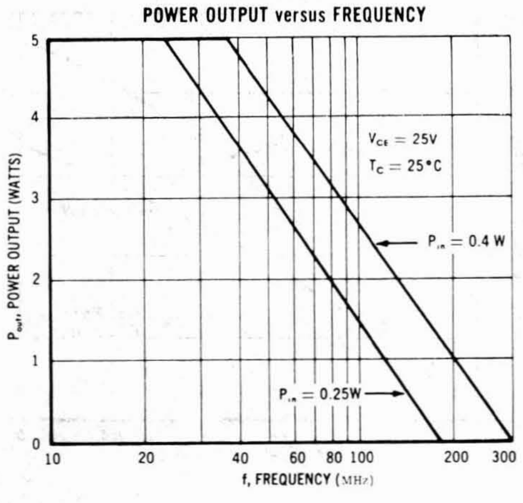


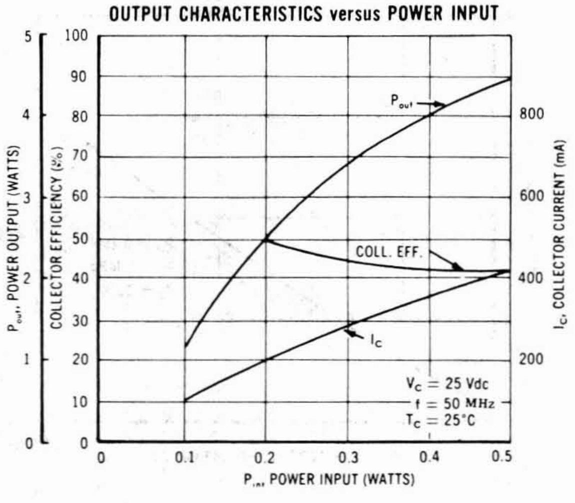
2N2949, 2N2950 (Continued)

ELECTRICAL CHARACTERISTICS $T_A = 25°C$ unless otherwise noted

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Collector-Emitter Sustain Voltage	$V_{CES(sus)}^*$	I_C=0.250 A, R_{BE}= 0	85	120	--	Volts
Collector Emitter-Open Base Sustain Voltage	$V_{CEO(sus)}^*$	I_C=0.250A, I_B=0	40	--	--	Volts
Collector-Emitter Current	I_{CES}	V_{CE}= 60 Vdc, V_{BE}=0	--	--	100	μAdc
		V_{CE} =50 Vdc, V_{BE}= 0 T_C= + 175°C	--	--	500	
Collector - Cutoff Current	I_{CBO}	V_{CB}=50 Vdc, I_E=0	--	--	0.1	μAdc
Emitter-Cutoff Current	I_{EBO}	V_{EB}= 3 Vdc, I_C=0	--	--	100	μAdc
DC Current Gain	h_{FE}	V_{CE}= 2.0 Vdc I_C= 40 mAdc	5.0	--	100	--
		V_{CE}=2.0 Vdc I_C= 400 mAdc	5.0	--	--	--
Collector -Emitter Saturation Voltage	$V_{CE(sat)}$	I_C= 400 mAdc, I_B= 80 mAdc	--	--	0.5	Vdc
Emitter-Base Saturation Voltage	$V_{BE(sat)}$	I_C=400 mAdc, I_B=80mAdc	--	--	2.0	Vdc
AC Current Gain	$\|h_{fe}\|$	V_{CE}=2.0 Vdc I_C=40 mAdc, f=50 MHz	2.0	--	--	--
Collector Output Capacitance	C_{ob}	V_{CB}= 25 Vdc, I_E=0 f=100 kHz	--	--	20	pF
Power Input	P_{in}	P_{out}=3.5 watts, f=50 MHz V_{CE}=25 Vdc, $I_{C(max)}$=325 mA	--	--	0.35	Watt
Efficiency	η		43	--	--	%

* Pulse Width ≤ 100μs, Duty Cycle = 2%





2N2951 (SILICON)
2N2952

CASE 31
(TO-5)
2N2951

CASE 22
(TO-18)
2N2952

NPN silicon annular Star transistors for power amplifier applications to 100 MHz.

Collector connected to case

MAXIMUM RATINGS*

Rating	Symbol	Value		Units
Collector-Base Voltage	V_{CB}	60		Vdc
Collector-Emitter Voltage	V_{CES}	60		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current (continuous)	I_C	250		mAdc
Base Current (continuous)	I_B	50		mAdc
		2N2951	2N2952	
Total Device Dissipation (25°C Case Temperature) (Derate above 25°C)	P_D	3 20	1.8 12	Watts mW/°C
Total Device Dissipation (25°C Ambient Temperature) (Derate above 25°C)	P_D	0.8 5.33	0.5 3.33	mW/°C
Junction Temperature	T_J	-65 to 175		°C
Storage Temperature Range	T_{stg}	-65 to 175		°C

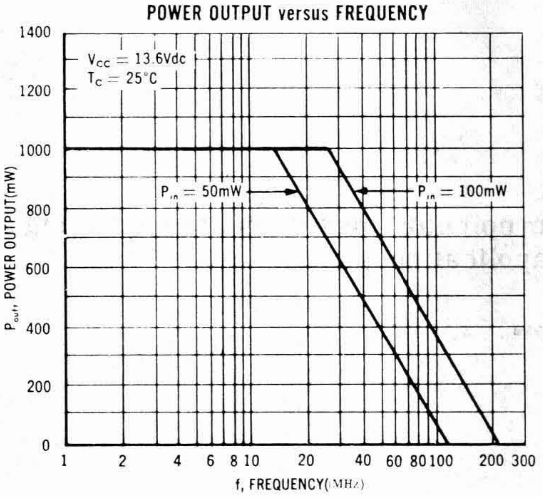
* The maximum ratings as given for dc conditions can be exceeded on a pulse basis. See Electrical Characteristics.

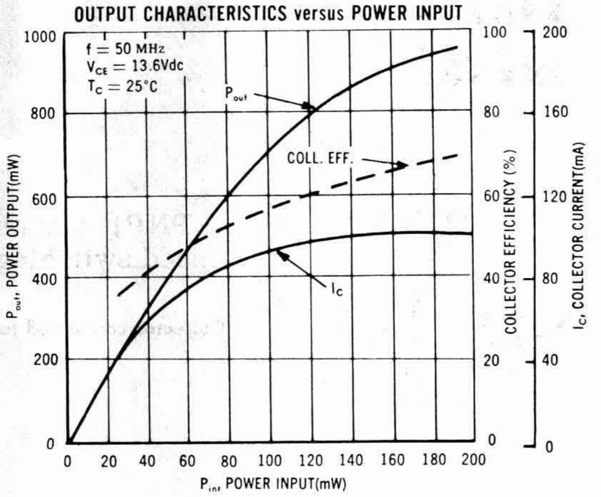
2N2951, 2N2952 (Continued)

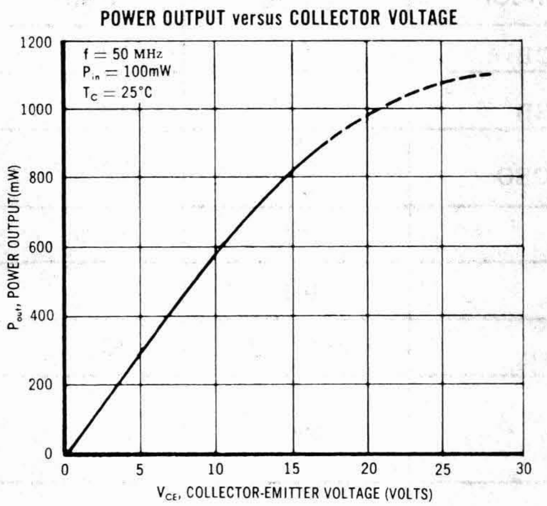
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Conditions	Min	Max	Unit
Collector-Emitter Current	I_{CES}	V_{CE} = 60Vdc, V_{BE} = 0 V_{CE} = 50Vdc, V_{BE} = 0, T_C = 175°C	-- --	100 500	μAdc μAdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 50 Vdc, I_E = 0	--	0.1	μAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 5 Vdc, I_C = 0	--	100	μAdc
DC Current Gain	h_{FE}	I_C = 10 mAdc, V_{CE} = 10Vdc I_C = 150mAdc, V_{CE} = 10 Vdc*	20 20	150 --	-- --
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 150 mAdc, I_B = 15 mAdc	--	0.5	Vdc
Base-Emitter Saturation Voltage	$V_{BE}(sat)$	I_C = 150 mAdc, I_B = 15 mAdc	--	2.0	Vdc
Collector-Emitter Sustain Voltage	$V_{CES(sus)}$*	I_C = 100 mA, R_{BE} = 0	30	--	Volts
Collector-Emitter Open Base Sustain Voltage	$V_{CEO(sus)}$*	I_C = 100 mA, I_B = 0	20	--	Volts
AC Current Gain	$\lvert h_{fe} \rvert$	V_{CE} = 10 Vdc, I_C = 10 mAdc f = 50 MHz	4.0	--	--
Collector Output Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz	--	8	pF
Power Input	P_{in}	Test Circuit Fig. 1 P_{out} = 600 mW f = 50 MHz V_{CE} = 13.6 Vdc $I_{C(max)}$ = 125 mA	--	100	mW
Efficiency	η		35	--	%

*Pulse Width = 100 μs, Duty Cycle = 2%


POWER OUTPUT versus FREQUENCY


OUTPUT CHARACTERISTICS versus POWER INPUT


POWER OUTPUT versus COLLECTOR VOLTAGE

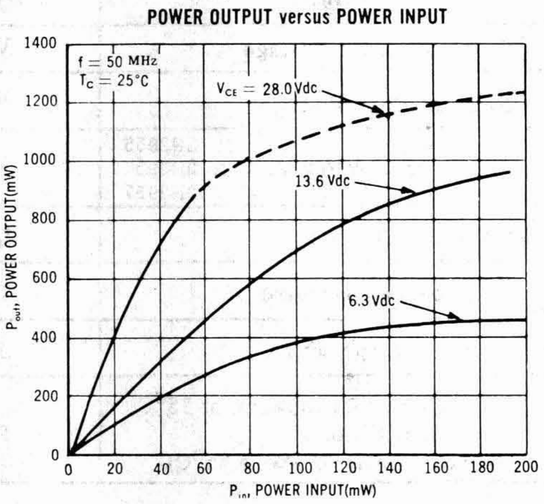
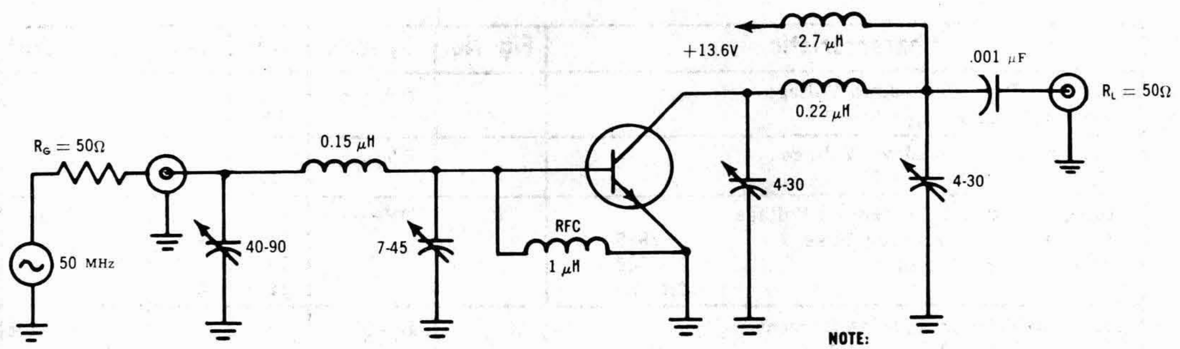

POWER OUTPUT versus POWER INPUT

FIGURE 1 — POWER OUTPUT AND POWER GAIN CIRCUIT



+13.6V
2.7 μH
.001 μF
0.22 μH
R_L = 50Ω
R_G = 50Ω
0.15 μH
4-30
4-30
40-90
7-45
RFC
1 μH
50 MHz

NOTE:
GROUND POINT must be kept as close as possible to the transistor emitter lead.
Transistor must be mounted with heat sink.

2N2955 (GERMANIUM)
2N2956
2N2957

CASE 22
(TO-18)

PNP germanium epitaxial mesa transistors for high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS (T

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector-Emitter Voltage 2N2955 2N2956 2N2957	V_{CEO}	25 20 18	Vdc
Collector Current	I_C	100	mAdc
Junction Temperature	T_J	100	°C
Storage Temperature	T_{stg}	-65 to +100	°C
Total Device Dissipation at 25°C Case Temperature (Derate 4 mW/°C above 25°C)	P_D	300	mW
Total Device Dissipation at 25°C Ambient Temperature (Derate 2 mW/°C above 25°C)	P_D	150	mW

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	40	60	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	3.5	5	---	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, Emitter-Base Termination - Open) 2N2955 2N2956 2N2957	8	BV_{CEO}	25 20 18	35 28 25	--- --- ---	Vdc
Collector-Emitter Reverse Current (V_{CE} = 25 Vdc, V_{EB} = 0.5 Vdc)		I_{CEX}	---	---	10	μAdc
Base Leakage Current (V_{CE} = 25 Vdc, V_{EB} = 0.5 Vdc)	9	I_{BL}	---	---	10	μAdc

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Fig. No.	Symbol	Min	Typ	Max	Unit
On Characteristics							
Forward Current Transfer Ratio			h_{FE}				---
(I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N2955	1		20	43	---	
	2N2956	2		30	64	---	
	2N2957	3		60	105	---	
(I_C = 50 mAdc, V_{CE} = 1 Vdc)	2N2955			20	43	60	
	2N2956			40	76	120	
	2N2957			100	130	---	
(I_C = 100 mAdc, V_{CE} = 1 Vdc)	2N2956			30	69	---	
	2N2957			60	115	---	
Collector-Emitter Saturation Voltage			$V_{CE(sat)}$				Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)	2N2955	5		---	0.12	0.20	
	2N2956	6		---	0.12	0.18	
	2N2957	7		---	0.09	0.15	
(I_C = 50 mAdc, I_B = 5 mAdc)	2N2955			---	0.20	0.30	
	2N2956			---	0.16	0.25	
	2N2957			---	0.13	0.20	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N2956			---	0.23	0.34	
	2N2957			---	0.18	0.26	
Base-Emitter Voltage		4	V_{BE}				Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)	2N2955			---	0.38	0.50	
	2N2956			---	0.37	0.47	
	2N2957			---	0.36	0.44	
(I_C = 50 mAdc, I_B = 5 mAdc)	2N2955			---	0.51	0.65	
	2N2956			---	0.48	0.60	
	2N2957			---	0.45	0.55	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N2956			---	0.56	0.70	
	2N2957			---	0.52	0.65	
Transient Characteristics							
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)		10	C_{ob}	---	2.5	4	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 1 MHz)		10	C_{ib}	---	3.3	---	pF
Small Signal Forward Current Transfer Ratio (V_{CE} = 5 Vdc, I_C = 10 mAdc, f = 100 MHz)	2N2955		$\|h_{fe}\|$	2	3.5	---	---
	2N2956			2.5	3.75	---	
	2N2957			3	4.0	---	
Delay Time (V_{CC} = 12 Vdc, I_{CS} = 50 mAdc, I_{B1} = 5 mAdc, V_{BE} (Off) = 2.2 Vdc)		12	t_d	---	7	15	ns
Rise Time (same conditions as t_d)	2N2955	12, 13	t_r	---	25	40	ns
	2N2956			---	18	30	
	2N2957			---	15	25	
Storage Time (V_{CC} = 12 Vdc, I_{CS} = 50 mAdc, I_{B1} = 5 mAdc, I_{B2} = 5 mAdc)	2N2955	12,16	t_s	---	28	40	ns
	2N2956			---	37	55	
	2N2957			---	42	60	
Fall Time (same conditions as t_s)	2N2955	12, 15	t_f	---	25	40	ns
	2N2956			---	18	35	
	2N2957			---	18	35	
Total Control Charge (I_C = 10 mAdc, I_B = 1 mAdc)	2N2955	17	Q_T	---	84	---	pc
	2N2956			---	88	---	
	2N2957			---	88	---	
Active Region Time Constant (I_C = 10 mAdc)		14	τ_A	---	2.9	---	ns

FIGURE 1 — CURRENT GAIN CHARACTERISTICS

2N2955

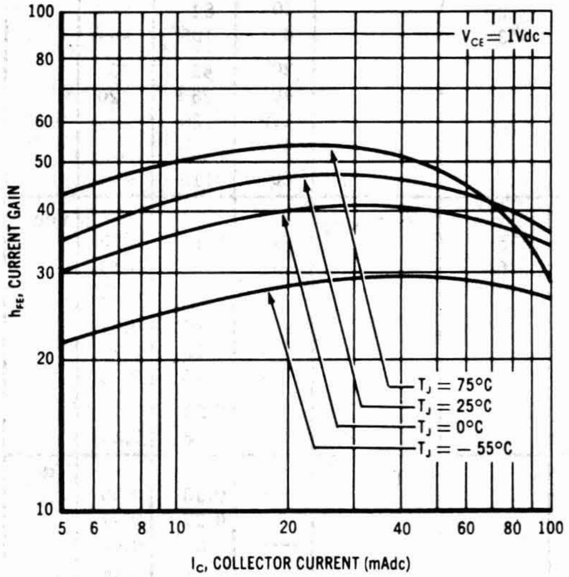


FIGURE 2 — CURRENT GAIN CHARACTERISTICS

2N2956

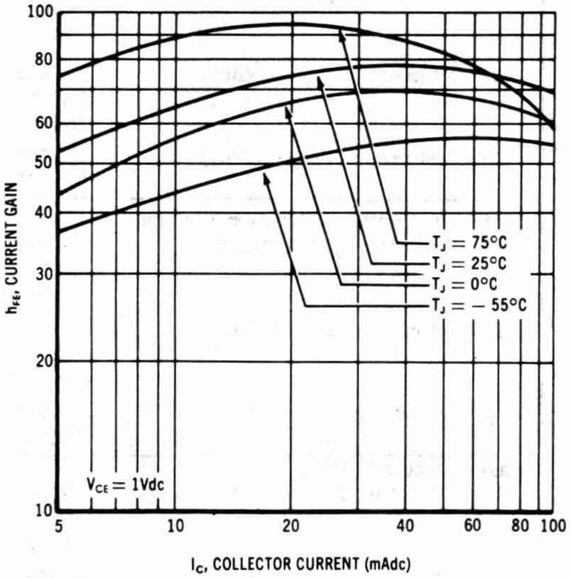


FIGURE 3 — CURRENT GAIN CHARACTERISTICS

2N2957

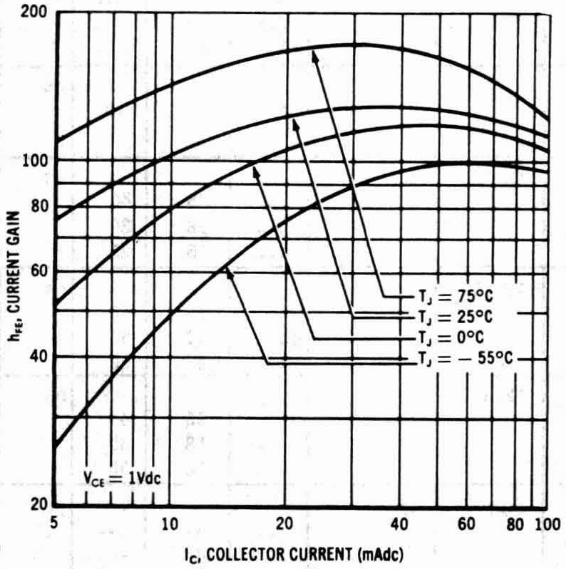
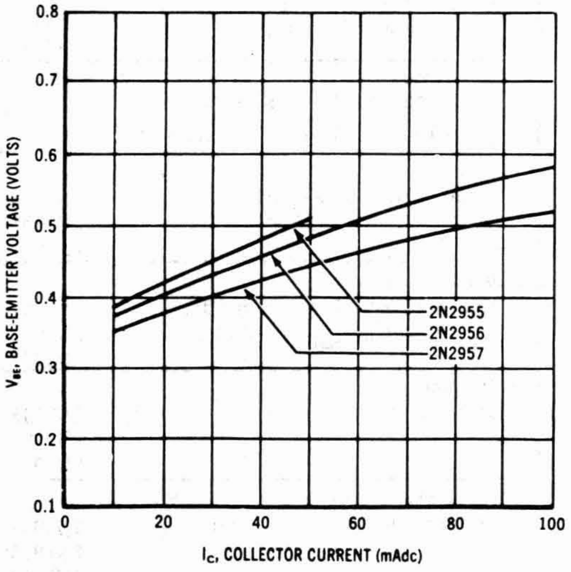


FIGURE 4 — BASE EMITTER VOLTAGE versus COLLECTOR CURRENT



COLLECTOR-EMITTER SATURATION VOLTAGE versus BASE CURRENT

FIGURE 5 —2N2955

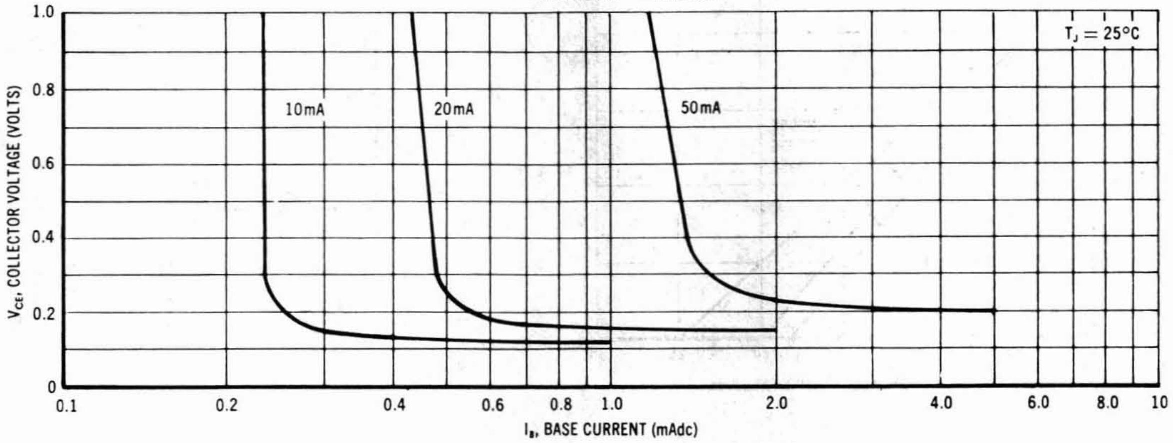


FIGURE 6 —2N2956

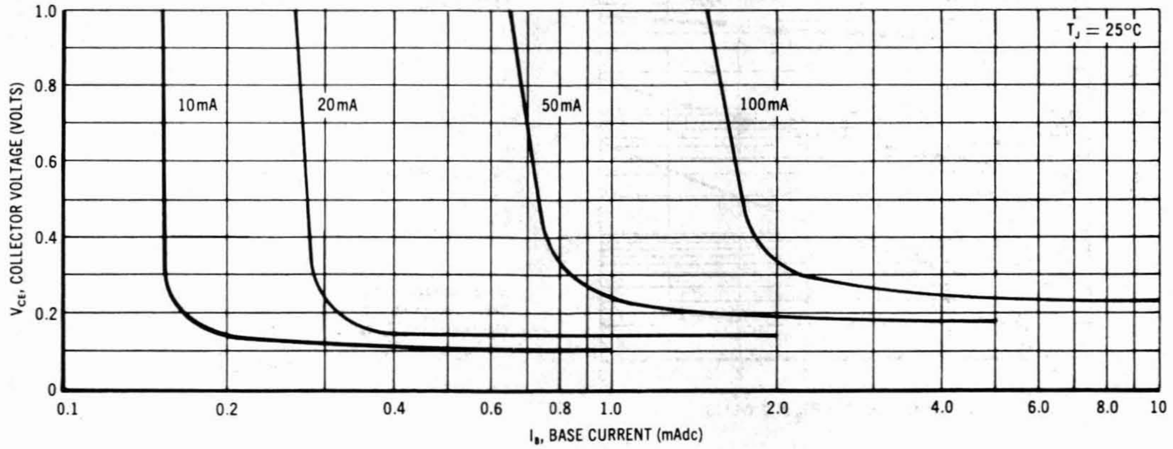


FIGURE 7 —2N2957

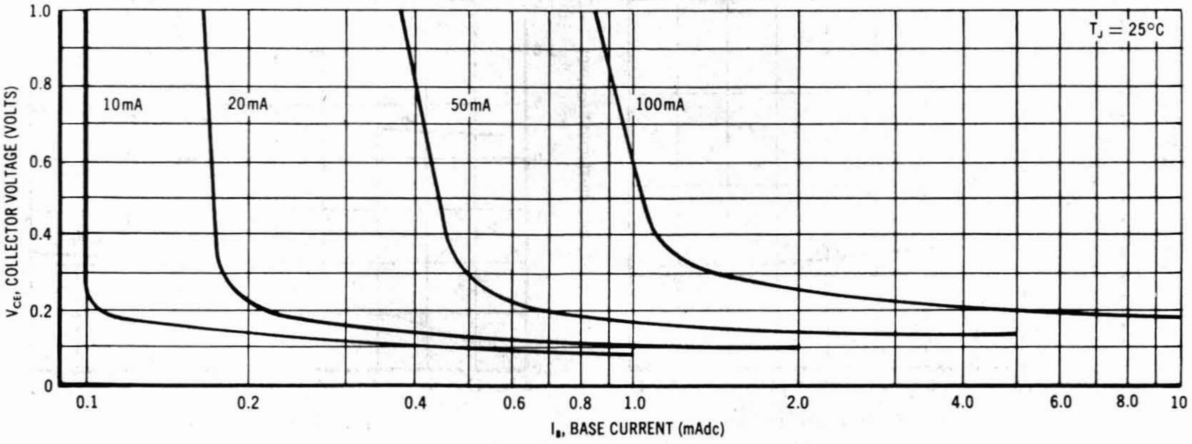
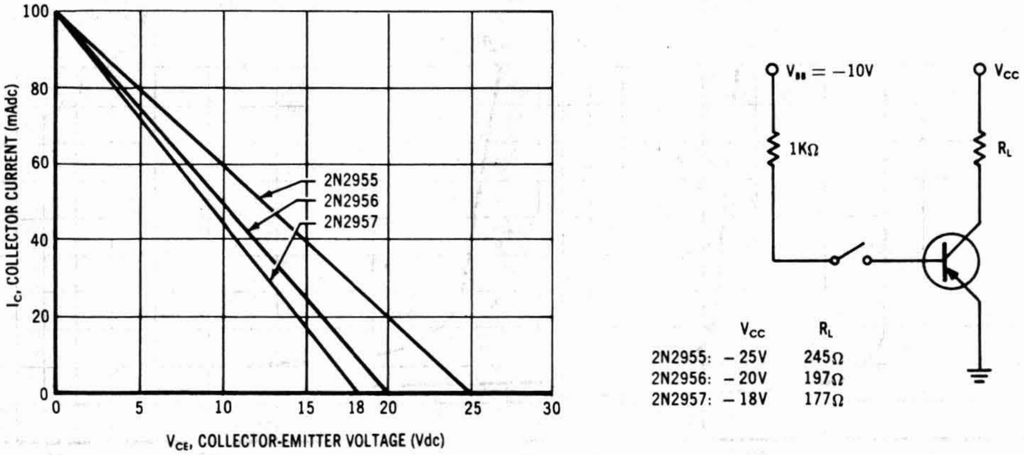
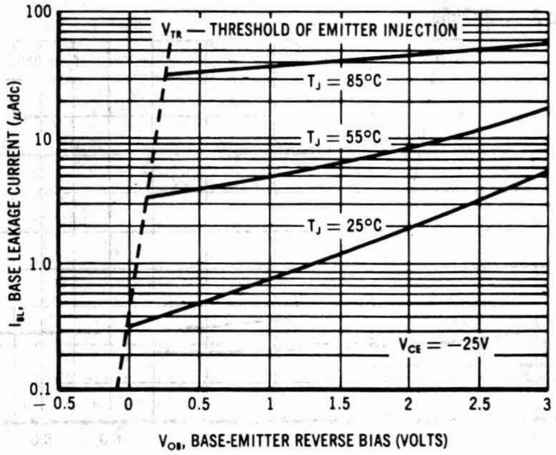


FIGURE 8 — OPEN BASE LOAD LINE RATING & TEST CIRCUIT

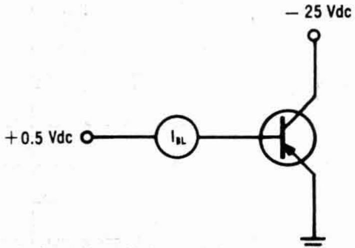


	V_{CC}	R_L
2N2955:	− 25V	245Ω
2N2956:	− 20V	197Ω
2N2957:	− 18V	177Ω

FIGURE 9 — COMMON EMITTER DC LEAKAGE CHARACTERISTICS



BASE LEAKAGE CURRENT TEST CIRCUIT



Base Leakage Current. I_{BL} is defined as base leakage current with both junctions reverse biased. I_C is always less than I_{BL} for $V_{OB} > V_T$. (V_{OB} is off condition base bias, V_T is base voltage at threshold of condition.)

FIGURE 10 — JUNCTION CAPACITANCE versus REVERSE BIAS

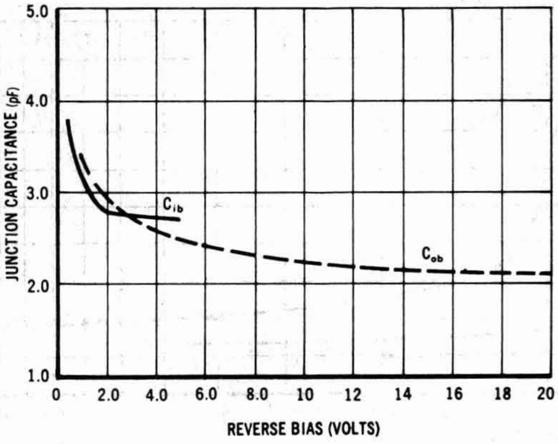


FIGURE 11 — TEMPERATURE COEFFICIENTS

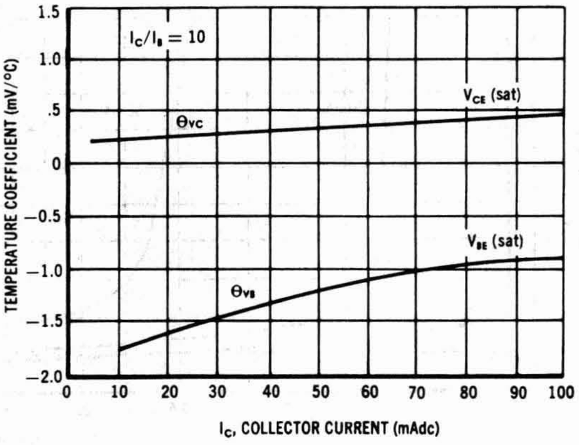


FIGURE 12 — SWITCHING TIME TEST CIRCUIT

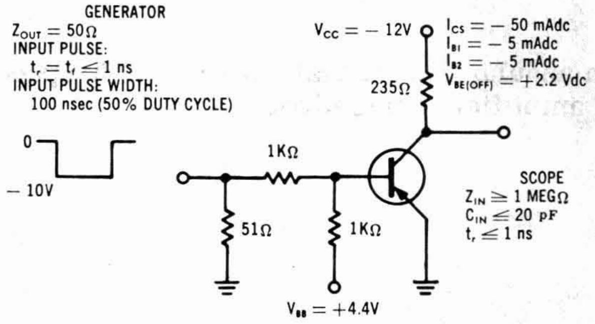

GENERATOR
$Z_{OUT} = 50\Omega$
INPUT PULSE:
$t_r = t_f \leq 1$ ns
INPUT PULSE WIDTH:
100 nsec (50% DUTY CYCLE)
0
− 10V
1KΩ
51Ω
1KΩ
$V_{BB} = +4.4V$
$V_{CC} = -12V$
235Ω
$I_{CS} = -50$ mAdc
$I_{B1} = -5$ mAdc
$I_{B2} = -5$ mAdc
$V_{BE(OFF)} = +2.2$ Vdc
SCOPE
$Z_{IN} \geq 1$ MEGΩ
$C_{IN} \leq 20$ pF
$t_r \leq 1$ ns

FIGURE 13 — RISE TIME FACTOR

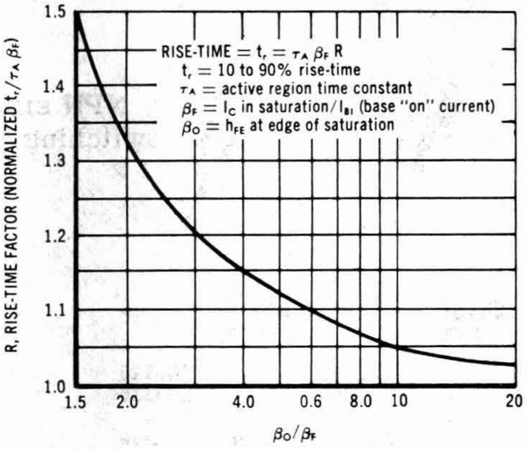


FIGURE 14 — ACTIVE REGION TIME CONSTANT

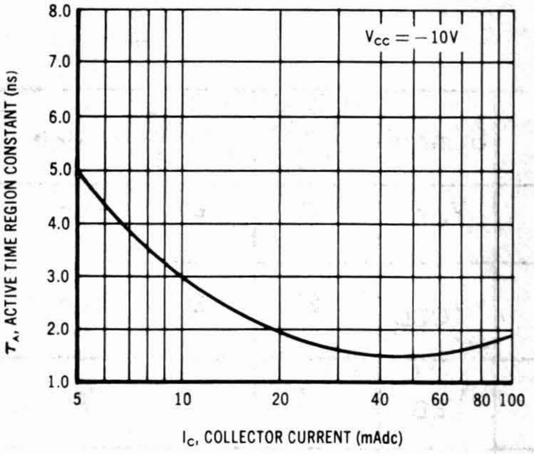


FIGURE 15 — FALL TIME FACTOR

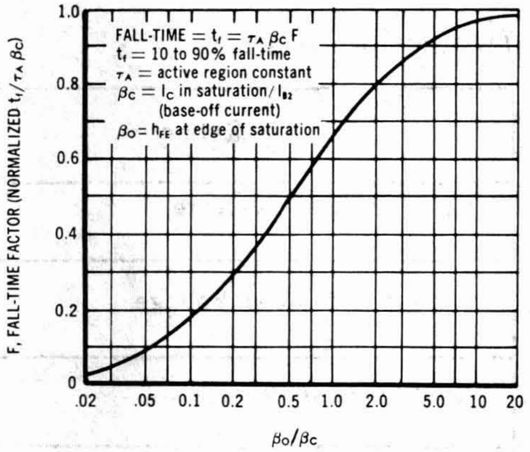


FIGURE 16 — STORAGE TIME

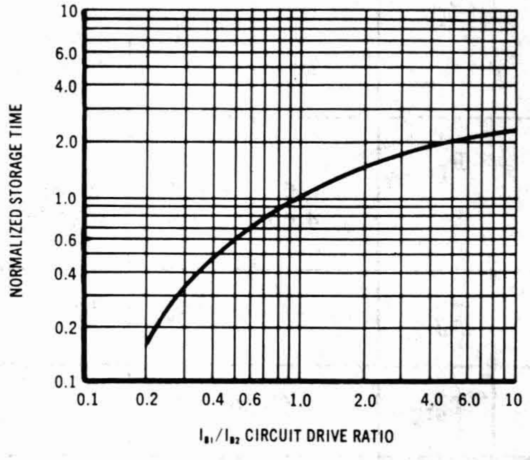
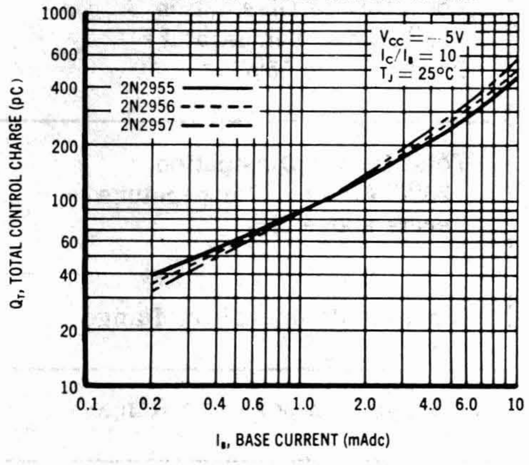
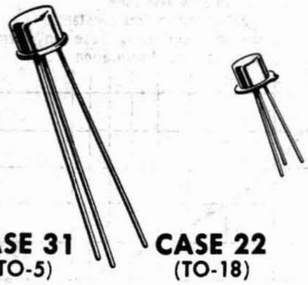


FIGURE 17 — TOTAL CONTROL CHARGE



2N2958 (SILICON)
2N2959
2N3115
2N3116

NPN silicon annular Star transistors for high-speed switching and amplifier applications.



Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N2958 2N2959 (TO-5)	2N3115 2N3116 (TO-18)	Unit
Collector-Base Voltage	V_{CB}	60	60	Vdc
Collector-Emitter Voltage	V_{CEO}	20	20	Vdc
Emitter-Base Voltage	V_{EB}	5	5	Vdc
Collector-Current	I_C	600	600	mAdc
Total Device Dissipation 25°C Case Temperature Derate above 25°C	P_D	3 20	1.8 12	Watts mW/°C
Total Device Dissipation 25°C Ambient Temperature Derate above 25°C	P_D	0.6 4.00	0.4 2.67	Watts mW/°C
Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

ELECTRICAL CHARACTERISTICS $T_A = 25°C$ unless otherwise noted

Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	--- ---	0.025 15	μ Adc
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)	I_{CEX}	---	.050	μ Adc
Base Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)	I_{BL}	---	.050	μ Adc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	---	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, pulsed, I_B = 0)	BV_{CEO}*	20	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5	---	Vdc
Collector Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE\,(sat)}$*	---	0.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE\,(sat)}$*	---	1.3	Vdc
DC Forward Current Transfer Ratio (I_C = 150 mAdc, 2N2958, 2N3115 V_{CE} = 10 Vdc) 2N2959, 2N3116	h_{FE}	40 100	120 300	---
Common-Base Open Circuit Output Capacitance (V_{CB} = 10 V, I_E = 0, f = 100 kHz)	C_{ob}	---	8	pF
Delay Time (V_{CC} = 30 V, I_{CS} = 150 mA, I_{B1} = 15 mA)	t_d	---	20	ns
Rise Time (V_{CC} = 30 V, I_{CS} = 150 mA, I_{B1} = 15 mA)	t_r	---	75	ns
Storage Time (V_{CC} = 6 V, I_{CS} = 150 mA, I_{B1} = 15 mA, I_{B2} = 15 mA)	t_s	---	300	ns
Fall Time (V_{CC} = 6 V, I_{CS} = 150 mA, I_{B1} = 15 mA, I_{B2} = 15 mA)	t_f	---	200	ns
Current Gain-Bandwidth Product (I_C = 20 mA, V_{CE} = 20 V, f = 100 MHz)	f_T	250	---	MHz

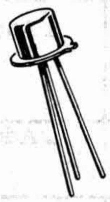
*PULSE TEST: Pulse width ≤ 300 μs, duty cycle ≤ 2%

2N2972 thru 2N2979

For Specifications, See 2N2913 Data.

2N3009 (SILICON)
2N3013
2N3014

NPN silicon epitaxial switching transistors designed for high-speed, medium-power saturated switching applications



Collector connected to case

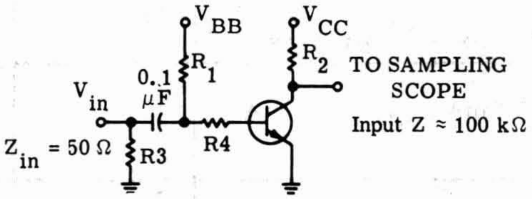
CASE 27
(TO-52)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage* 2N3009, 2N3013 2N3014	V_{CEO}*	 15 20	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage 2N3009 2N3013, 2N3014	V_{EB}	 4.0 5.0	Vdc
Collector Current — Continuous (10 μs pulse) Peak	I_C	200 500	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ T_C = 25°C @ T_C = 100°C Derate above 25°C	P_D	1.20 0.68 6.85	Watts Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

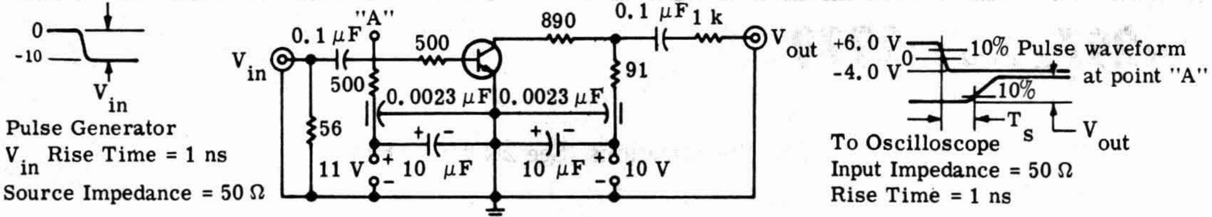
* Applicable from 0.01 mA to 10 mA (Pulsed)

FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT


V_{BB}
V_{CC}
R_1
R_2
TO SAMPLING SCOPE
0.1 μF
V_{in}
Input Z ≈ 100 kΩ
Z_{in} = 50 Ω
R3
R4

		SWITCHING TEST CIRCUIT VALUES							INPUT PULSE		
Type	Test	V_{in}	V_{BB}	V_{CC}	R_1	R_2	R_3	R_4	t_r	t_f	Pulse Width
2N3009 2N3013	t_{on} & t_{off}	(volts)			(ohms)				(nanoseconds)		
		11	-5.0	15	300	50	75	170	<1.0	<1.0	>100
2N3014	t_{on}	7.0	GND	2.0	100	62	100	2.0 k	<1.0	-	>200
	t_{off}	-13	7.0	2.0							

FIGURE 2 — CHARGE STORAGE TIME CONSTANT TEST CIRCUIT


0
-10
V_{in}
Pulse Generator
V_{in} Rise Time = 1 ns
Source Impedance = 50 Ω
V_{in}
"A"
0.1 μF
500
500
56
890
0.1 μF
1 k
V_{out}
91
0.0023 μF
0.0023 μF
11 V
10 μF
10 μF
10 V
+6.0 V
0
-4.0 V
10% Pulse waveform at point "A"
10%
T_s
V_{out}
To Oscilloscope
Input Impedance = 50 Ω
Rise Time = 1 ns

V_{in} Rise Time less than 1 ns PW = 300 ns Duty Cycle = 2%

2N3009, 2N3013, 2N3014 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage*	$BV_{CEO(sus)}$*			Vdc
(I_C = 10 mAdc, I_B = 0) 2N3009, 2N3013		15	-	
2N3014		20	-	
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage	BV_{EBO}			Vdc
(I_E = 100 μAdc, I_C = 0) 2N3009		4.0	-	
2N3013, 2N3014		5.0	-	
Collector-Cutoff Current	I_{CES}			μAdc
(V_{CE} = 20 Vdc, V_{BE} = 0) 2N3009		-	0.5	
(V_{CE} = 20 Vdc, V_{BE} = 0, T_A = +85°C) 2N3009		-	15	
(V_{CE} = 20 Vdc, V_{BE} = 0) 2N3013, 2N3014		-	0.3	
(V_{CE} = 20 Vdc, V_{BE} = 0, T_A = +125°C) 2N3013, 2N3014		-	40	
Base Current	I_B			μAdc
(V_{CE} = 20 Vdc, V_{BE} = 0) 2N3009		-	0.5	
2N3013, 2N3014		-	0.3	
ON CHARACTERISTICS				
DC Current Gain*	h_{FE}*			
(I_C = 30 mAdc, V_{CE} = 0.4 Vdc) All Types		30	120	
(I_C = 10 mAdc, V_{CE} = 0.4 Vdc) 2N3014		25	-	
(I_C = 100 mAdc, V_{CE} = 0.5 Vdc) 2N3009, 2N3013		25	-	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc) 2N3014		25	-	
(I_C = 300 mAdc, V_{CE} = 1.0 Vdc) 2N3009, 2N3013		15	-	
(I_C = 30 mAdc, V_{CE} = 0.4 Vdc, T_A = -55°C) 2N3013, 2N3014		12	-	
Collector-Emitter Saturation Voltage*	$V_{CE(sat)}$*			Vdc
(I_C = 30 mAdc, I_B = 3.0 mAdc) All Types		-	0.18	
(I_C = 100 mAdc, I_B = 10 mAdc) 2N3009, 2N3013		-	0.28	
(I_C = 100 mAdc, I_B = 10 mAdc) 2N3014		-	0.35	
(I_C = 300 mAdc, I_B = 30 mAdc) 2N3009, 2N3013		-	0.50	
(I_C = 10 mAdc, I_B = 1.0 mAdc) 2N3014		-	0.18	
(I_C = 30 mAdc, I_B = 3.0 mAdc, T_A = +85°C) 2N3009		-	0.30	
(I_C = 30 mAdc, I_B = 3.0 mAdc, T_A = +125°C) 2N3013, 2N3014		-	0.25	
Base-Emitter Saturation Voltage*	$V_{BE(sat)}$*			Vdc
(I_C = 30 mAdc, I_B = 3.0 mAdc) All Types		0.75	0.95	
(I_C = 100 mAdc, I_B = 10 mAdc) All Types		-	1.20	
(I_C = 300 mAdc, I_B = 30 mAdc) 2N3009, 2N3013		-	1.70	
(I_C = 10 mAdc, I_B = 1.0 mAdc) 2N3014		0.70	0.80	
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 30 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	350	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	5.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	8.0	pF
Turn-On Time (Figure 1)	t_{on}			ns
($V_{EB(off)}$ = 5.0 V, V_{CC} = 15 V, I_C = 300 mAdc, I_{B1} ≈ 30 mAdc) 2N3009, 2N3013		-	15	
($V_{EB(off)}$ = 0, V_{CC} = 2.0 V, I_C = 30 mAdc, I_{B1} ≈ 3.0 mAdc) 2N3014		-	16	
Turn-Off Time (Figure 1)	t_{off}			ns
(V_{CC} = 15 V, I_C = 300 mAdc, I_{B1} ≈ I_{B2} ≈ 30 mAdc) 2N3009, 2N3013		-	25	
(V_{CC} = 2.0 V, I_C = 30 mAdc, I_{B1} ≈ I_{B2} ≈ 3.0 mAdc) 2N3014		-	25	
Charge-Storage Time (Figure 2) (I_C ≈ I_{B1} ≈ I_{B2} ≈ 10 mAdc)	t_s	-	18	ns

* Pulse Test: Pulse Width = 300 μs; Duty Cycle ≤ 2%.

2N3010 (SILICON)

CASE 22
(TO-18)

NPN silicon low-power transistor primarily designed for high-speed, saturated switching applications.

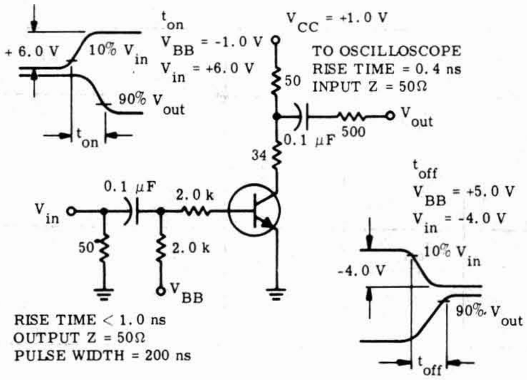
Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage*	V_{CEO}*	6.0	Vdc
Collector-Emitter Voltage	V_{CES}	11	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current — Continuous	I_C	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.30 1.71	Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

* Applicable from 0.01 mAdc to 10 mAdc (Pulsed).

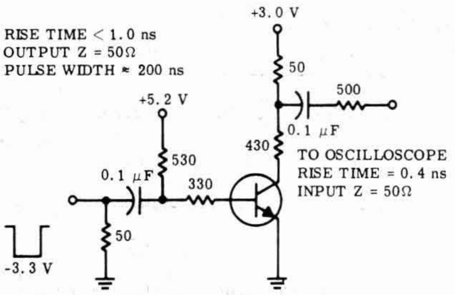
FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT



t on
V BB = -1.0 V
V in = +6.0 V
V CC = +1.0 V
+ 6.0 V
10% V in
90% V out
t on
TO OSCILLOSCOPE
RISE TIME = 0.4 ns
INPUT Z = 50Ω
50
0.1 μF
500
V out
34
0.1 μF
2.0 k
V in
50
2.0 k
V BB
t off
V BB = +5.0 V
V in = -4.0 V
10% V in
-4.0 V
90% V out
t off

RISE TIME < 1.0 ns
OUTPUT Z = 50Ω
PULSE WIDTH = 200 ns

FIGURE 2 — CHARGE-STORAGE TIME TEST CIRCUIT



+3.0 V
50
500
0.1 μF
430
+5.2 V
530
0.1 μF
330
50
-3.3 V
TO OSCILLOSCOPE
RISE TIME = 0.4 ns
INPUT Z = 50Ω

RISE TIME < 1.0 ns
OUTPUT Z = 50Ω
PULSE WIDTH ≈ 200 ns

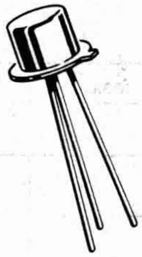
2N3010 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	6.0	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 μAdc, V_{BE} = 0)	BV_{CES}	11	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	15	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4.0	-	Vdc
Collector Cutoff Current	I_{CES}			μAdc
(V_{CE} = 11 Vdc, V_{BE} = 0)		-	10	
(V_{CE} = 5.0 Vdc, V_{BE} = 0)		-	0.1	
(V_{CE} = 5.0 Vdc, V_{BE} = 0, T_A = +85°C)		-	5.0	
Base Cutoff Current (V_{CE} = 11 Vdc, $V_{EB(off)}$ = 0)	I_{BL}	-	10	μAdc
ON CHARACTERISTICS				
DC Current Gain*	h_{FE}*			-
(I_C = 1.0 mAdc, V_{CE} = 0.4 Vdc)		15	-	
(I_C = 10 mAdc, V_{CE} = 0.4 Vdc)		25	125	
(I_C = 30 mAdc, V_{CE} = 0.4 Vdc)		15	-	
Collector-Emitter Saturation Voltage*	$V_{CE(sat)}$*			Vdc
(I_C = 1.0 mAdc, I_B = 0.1 mAdc)		-	0.25	
(I_C = 10 mAdc, I_B = 1.0 mAdc)		-	0.25	
(I_C = 30 mAdc, I_B = 3.0 mAdc)		-	0.38	
(I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = 85°C)		-	0.4	
Base-Emitter Saturation Voltage*	$V_{BE(sat)}$*			Vdc
(I_C = 1.0 mAdc, I_B = 0.1 mAdc)		0.68	0.85	
(I_C = 10 mAdc, I_B = 1.0 mAdc)		0.75	0.95	
(I_C = 30 mAdc, I_B = 3.0 mAdc)		-	1.3	
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 4.0 Vdc, f = 100 MHz)	f_T	600	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	3.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	2.0	pF
Turn-On Time (Figure 1) (V_{CC} = 1.0 Vdc, $V_{BE(off)}$ = 1.0 Vdc, I_C = 10 mAdc, $I_{B1} \approx$ 2.0 mAdc)	t_{on}	-	12	ns
Turn-Off Time (Figure 1) (V_{CC} = 1.0 Vdc, $I_C \approx$ 10 mAdc, $I_{B1} \approx I_{B2} \approx$ 1.0 mAdc)	t_{off}	-	12	ns
Charge Storage Time (Figure 2) ($I_C = I_{B1} \approx I_{B2}$ = 5.0 mAdc)	t_s	-	6.0	ns

* Pulse Test: Pulse Length = 300 μs; Duty Cycle ≤ 2.0%.

2N3011 (SILICON)



NPN silicon low-power transistor primarily designed for high-speed, saturated switching applications.

Collector connected to case

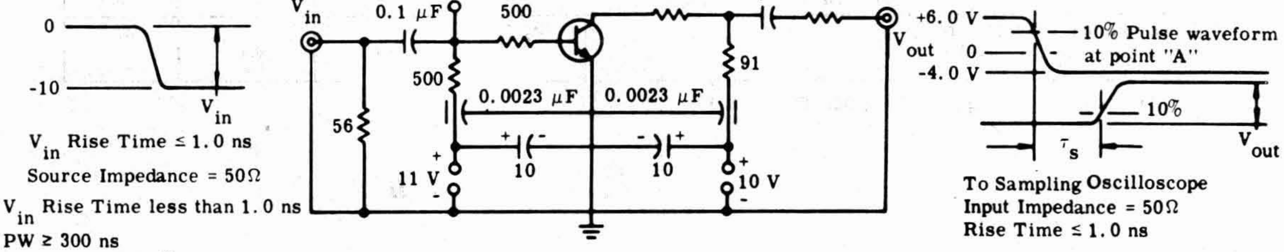
CASE 22
(TO-18)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage*	V_{CEO}*	12	Vdc
Collector-Emitter Voltage	V_{CES}	30	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector-Current-Continuous	I_C	200	mAdc
Peak (10 μs Pulse)		500	
Total Device Dissipation @ T_A=25°C	P_D	0.36	Watt
Derate above 25°C		2.06	mW/°C
Total Device Dissipation @ T_C=25°C	P_D	1.20	Watt
T_C=100°C		0.68	
Derate above 25°C		6.85	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

* Applicable from 0.01 mA to 10 mA (Pulsed)

FIGURE 1 — CHARGE-STORAGE TIME TEST CIRCUIT


0
-10
V_{in}
V_{in}
0.1 μF
"A"
500
500
56
0.0023 μF
0.0023 μF
+
11 V
-
10
10
+
10 V
-
890
0.1 μF
1.0 k
91
V_{out}
+6.0 V
0
-4.0 V
10% Pulse waveform at point "A"
10%
τ_s
V_{out}

V_{in} Rise Time ≤ 1.0 ns
Source Impedance = 50Ω

V_{in} Rise Time less than 1.0 ns
PW ≥ 300 ns
Duty Cycle ≤ 2.0%

To Sampling Oscilloscope
Input Impedance = 50Ω
Rise Time ≤ 1.0 ns

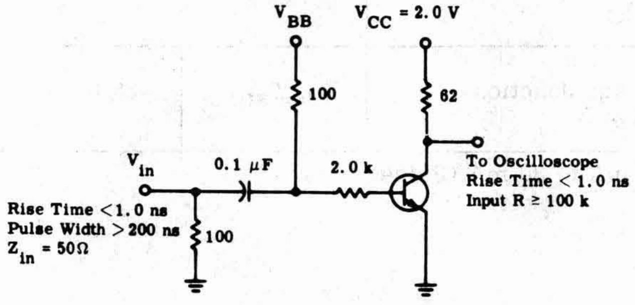
2N3011 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	12	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 µAdc, V_{BE} = 0)	BV_{CES}	30	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	BV_{CBO}	30	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 µAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0) (V_{CE} = 20 Vdc, V_{BE} = 0, T_A = +85°C)	I_{CES}	- -	0.4 10	µAdc
Base Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0)	I_{BL}	-	0.4	µAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 0.35 Vdc) (I_C = 30 mAdc, V_{CE} = 0.4 Vdc) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}*	30 25 12	120 - -	-
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 30 mAdc, I_B = 3.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc) (I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = +85°C)	$V_{CE(sat)}$*	- - - -	0.20 0.25 0.50 0.30	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 30 mAdc, I_B = 3.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{BE(sat)}$*	0.72 - -	0.87 1.15 1.60	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	400	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	4.0	pF
Turn-On Time (Figure 2) (V_{CC} = 2.0 Vdc, $V_{EB(off)}$ = 0, I_C ≈ 30 mAdc, I_{B1} ≈ 3.0 mAdc)	t_{on}	-	15	ns
Turn-Off Time (Figure 2) (V_{CC} = 2.0 Vdc, I_C = 30 mAdc, I_{B1} ≈ $-I_{B2}$ ≈ 3.0 mAdc)	t_{off}	-	20	ns
Charge Storage Time (Figure 1) (I_C = I_{B1} ≈ $-I_{B2}$ ≈ 10 mAdc)	t_s	-	13	ns

* Pulse Test: Pulse Length = 300 µs, Duty Cycle ≤ 2.0%.

FIGURE 2 – TURN-ON AND TURN-OFF TIME TEST CIRCUIT



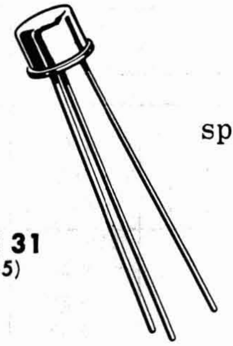
T_{on}: V_{BB} Grounded
V_{in} = 7.0 V

T_{off}: V_{BB} = 7.0 V
V_{in} = -13 V

2N3013
2N3014

For Specifications, See 2N3009 Data.

2N3015 (SILICON)



CASE 31
(TO-5)

Collector connected to case

NPN silicon annular transistor designed for high-speed, medium-power saturated switching applications.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage*	V_{CEO}*	30	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	800 4.6	mW mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	3.0 17.2	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to + 200	°C

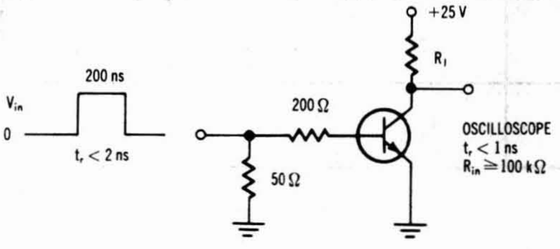
*Applicable from 1.0 mA to 30 mA (Pulsed)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 30 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	30	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5	—	Vdc
Collector-Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0)	I_{CES}	—	0.2	μAdc
Collector-Cutoff Current (V_{CB} = 30 Vdc, I_E = 0, T_A = 125°C)	I_{CBO}	—	200	μAdc
Base Leakage Current (V_{CE} = 30 Vdc, V_{BE} = 0)	I_{BL}	—	0.2	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 150 mAdc, V_{CE} = 10 Vdc) (I_C = 300 mAdc, V_{CE} = 0.7 Vdc)	h_{FE}*	 30 10	 120 —	—
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{CE(sat)}$*	 — —	 0.4 1.0	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{BE(sat)}$*	 — —	 1.2 1.6	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	8.0	pF
Turn-On Time (Figure 1) (V_{CC} = 25 Vdc, $I_C \approx$ 300 mAdc, $I_{B1} \approx$ 30 mAdc) (V_{CC} = 25 Vdc, $I_C \approx$ 500 mAdc, $I_{B1} \approx$ 50 mAdc)	t_{on}	 — —	 40 40	ns
Turn-Off Time (Figure 2) (V_{CC} = 25 Vdc, $I_C \approx$ 300 mAdc, $I_{B1} \approx I_{B2}$ = 30 mAdc) (V_{CC} = 25 Vdc, $I_C \approx$ 500 mAdc, $I_{B1} \approx I_{B2}$ = 50 mAdc)	t_{off}	 — —	 60 60	ns

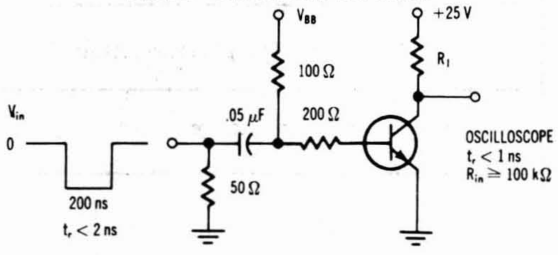
*Pulse Test: Pulse Width = 300 μs; Duty Cycle ≤ 2%

FIGURE 1 — TURN-ON TIME TEST CIRCUIT



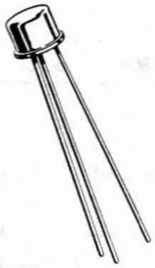
I_C mA	V_{in} Volts	R_1 ohms
300	7	80
500	11	48

FIGURE 2 — TURN-OFF TIME TEST CIRCUIT



I_C mA	V_{in} Volts	V_{BB} Volts	R_1 ohms
300	−13	10	80
500	−21	16	48

2N3019 (SILICON)
2N3020



CASE 31
(TO-5)

Collector connected to case

NPN silicon annular transistors designed for high-current, high-frequency amplifier applications.

MAXIMUM RATINGS

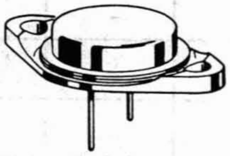
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	80	Vdc
Collector-Base Voltage	V_{CB}	140	Vdc
Emitter-Base Voltage	V_{EB}	7	Vdc
Collector Current	I_C	1	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.8 4.6	W mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	5 28.6	W mW/°C
Operating Junction Temperature Range	T_J	-65 to +200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 30 mAdc, I_B = 0)	BV_{CEO}*	80	–	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	140	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	7	–	Vdc
Collector Cutoff Current (V_{CB} = 90 Vdc, I_E = 0) (V_{CB} = 90 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 – –	 0.010 10	μAdc
Emitter Cutoff Current (V_{BE} = 5 Vdc, I_C = 0)	I_{EBO}	–	0.010	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) 2N3019 2N3020 (I_C = 10 mAc, V_{CE} = 10 Vdc) 2N3019 2N3020 (I_C = 150 mAdc, V_{CE} = 10 Vdc) 2N3019 2N3020 (I_C = 150 mAdc, V_{CE} = 10 Vdc, T_C = -55°C) 2N3019 (I_C = 500 mAdc, V_{CE} = 10 Vdc) 2N3019 2N3020 (I_C = 1 Adc, V_{CE} = 10 Vdc) Both Types	h_{FE}*	 50 30 90 40 100 40 40 50 30 15	 – 100 – 120 300 120 – – 100 –	–
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{CE(sat)}$*	 – –	 0.2 0.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$*	–	1.1	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz) 2N3019 2N3020	f_T	 100 80	–	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	–	12	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1 MHz)	C_{ib}	–	60	pF
Small-Signal Current Gain (I_C = 1mAdc, V_{CE} = 5 Vdc, f = 1 kHz) 2N3019 2N3020	h_{fe}	 80 30	 400 200	–
Collector-Base Time Constant (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 4 MHz)	$r_b'C_c$	–	400	ps
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, f = 1 kHz, R_S = 1 kohm) 2N3019	NF	–	4	dB

*Pulse Test: Pulse Width ≤ 300 μs, duty cycle ≤ 1%

2N3021 thru 2N3026 (SILICON)



CASE 1
(TO-3)

PNP silicon power transistors for Class C power amplifiers, high-current core switching and high-speed switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3021 2N3024	2N3022 2N3025	2N3023 2N3026	Unit
Collector-Base Voltage	V_{CB}	30	45	60	Volts
Collector-Emitter Voltage	V_{CEO}	30	45	60	Volts
Emitter-Base Voltage	V_{EB}	4.0			Volts
Collector Current	I_C	3.0			Amp
Base Current	I_B	0.5			Amp
Power Dissipation	P_D	25			Watts
Junction Operating Temperature Range	T_J	-65 to +175			°C

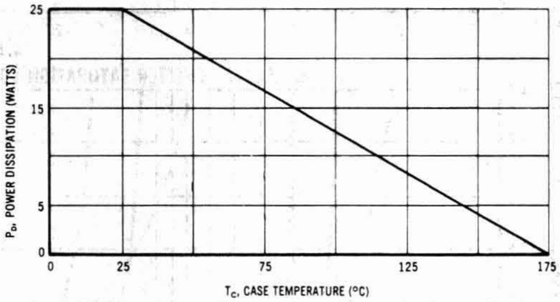
ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise specified)

Characteristics		Symbol	Min	Max	Unit
Emitter-Base Cutoff Current (V_{BE} = 4 Vdc)		I_{EBO}	—	1.0	mAdc
Collector-Emitter Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 25 Vdc, V_{BE} = 2 Vdc)	2N3021, 2N3024		—	0.2	
(V_{CE} = 40 Vdc, V_{BE} = 2 Vdc)	2N3022, 2N3025		—	0.2	
(V_{CE} = 54 Vdc, V_{BE} = 2 Vdc)	2N3023, 2N3026		—	0.2	
(V_{CE} = 15 Vdc, V_{BE} = 2 Vdc, T_C = 150°C)	2N3021, 2N3024		—	2.0	
(V_{CE} = 25 Vdc, V_{BE} = 2 Vdc, T_C = 150°C)	2N3022, 2N3025		—	2.0	
(V_{CE} = 35 Vdc, V_{BE} = 2 Vdc, T_C = 150°C)	2N3023, 2N3026		—	2.0	
Collector-Emitter Breakdown Voltage*		BV_{CEO}*			Vdc
(I_C = 100 mAdc, I_B = 0)	2N3021, 2N3024		30	—	
(I_C = 50 mAdc, I_B = 0)	2N3022, 2N3025		45	—	
(I_C = 20 mAdc, I_B = 0)	2N3023, 2N3026		60	—	
DC Current Gain		h_{FE}			—
(I_C = 1.0 Adc, V_{CE} = 2 Vdc)	2N3021, 2N3022, 2N3023		20	60	
	2N3024, 2N3025, 2N3026		50	180	
Collector-Emitter Saturation Voltage		$V_{CE\,(sat)}$			Vdc
(I_C = 3 Adc, I_B = 0.3 Adc)	2N3021, 2N3022, 2N3023		—	1.5	
	2N3024, 2N3025, 2N3026		—	1.0	
Base-Emitter Saturation Voltage (I_C = 3 Adc, I_B = 0.3 Adc)		$V_{BE\,(sat)}$	—	1.5	Vdc
Small Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 15 Vdc, f = 30 MHz)		h_{fe}	2.0	—	—
Switching Times (I_C = 1 Adc, I_{B1} = I_{B2} = 100 mAdc)		$t_d + t_r$ t_s t_f	— — —	100 325 75	ns

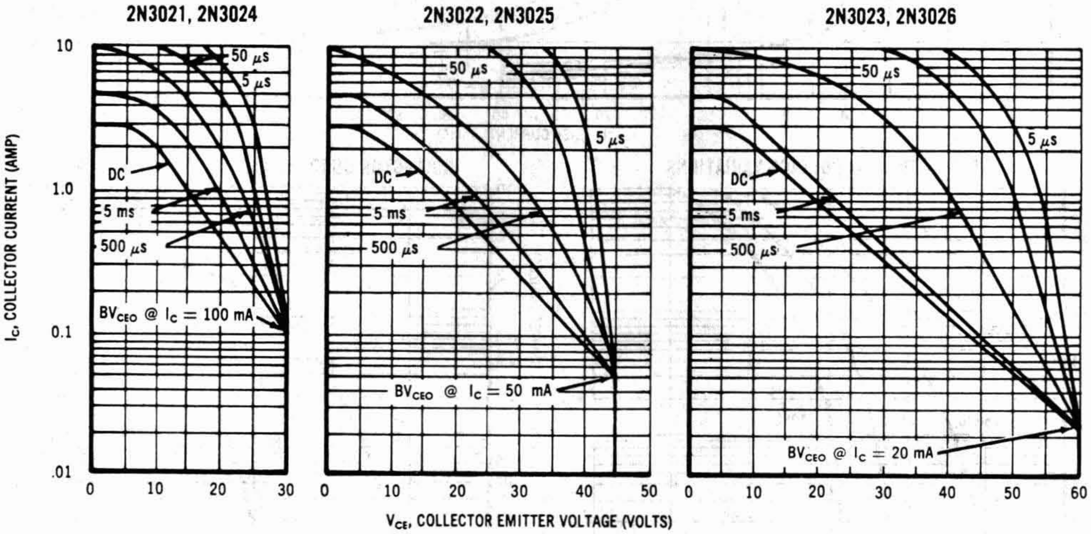
*Perform tests using sweep method to prevent heating.

POWER-TEMPERATURE DERATING CURVE

THESE TRANSISTORS ARE ALSO SUBJECT TO SAFE AREA CURVES AS INDICATED BOTH LIMITS ARE APPLICABLE AND MUST BE OBSERVED



SAFE OPERATING AREAS


2N3021, 2N3024

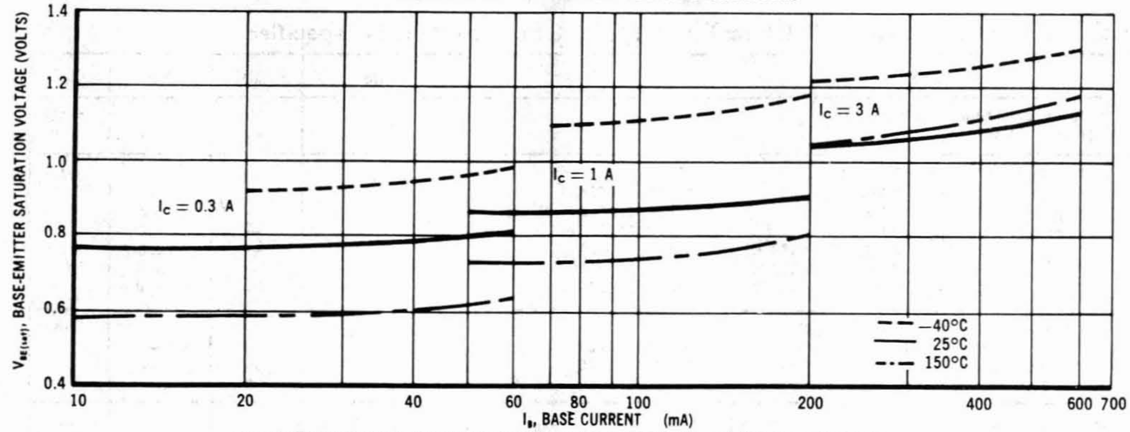
2N3022, 2N3025

2N3023, 2N3026

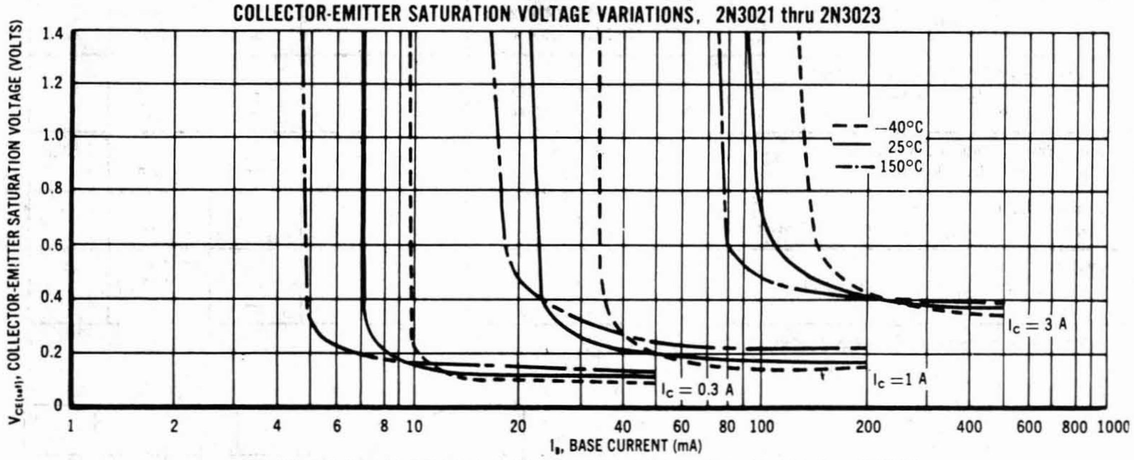
The Safe Operating Area Curves indicate I_C - V_{CE} limits below which the devices will not go into secondary breakdown. As the safe operating areas shown are independent of temperature and duty cycle, these curves can be used as long as the average power derating curve is also taken into consideration to insure operation below the maximum junction temperature.

2N3021 thru 2N3026 (continued)

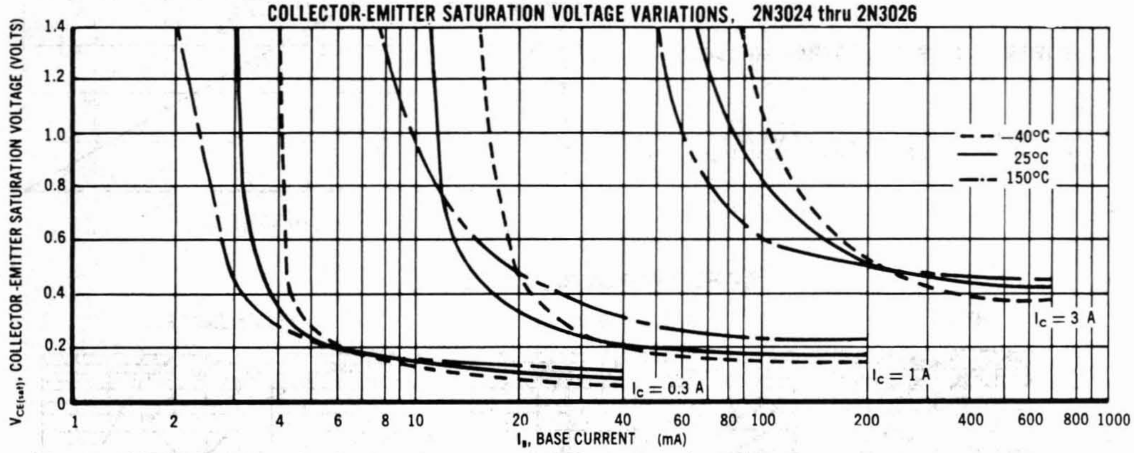
BASE-EMITTER SATURATION VOLTAGE VARIATIONS



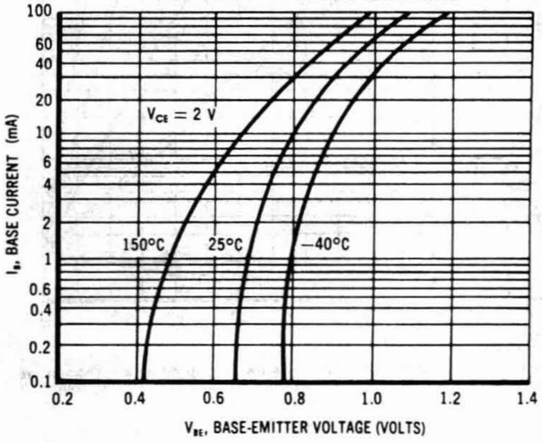
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS, 2N3021 thru 2N3023



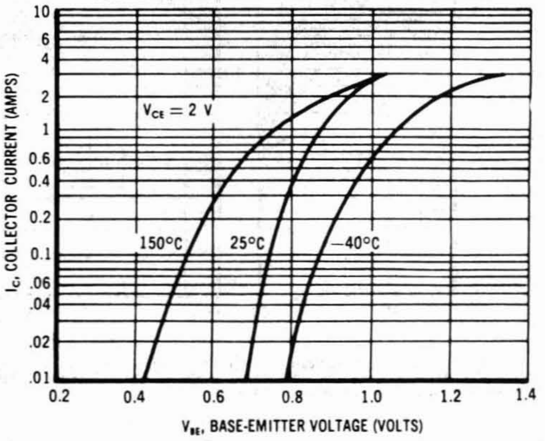
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS, 2N3024 thru 2N3026



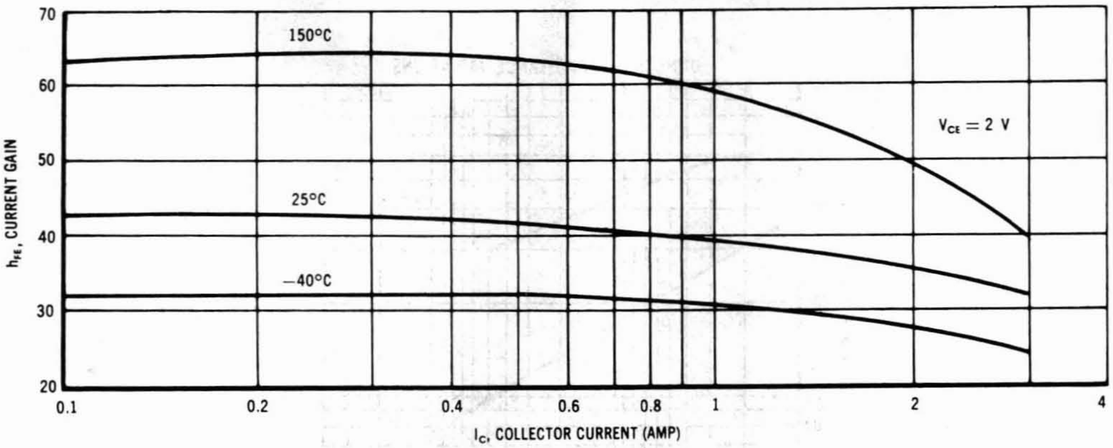
BASE CURRENT — VOLTAGE VARIATIONS



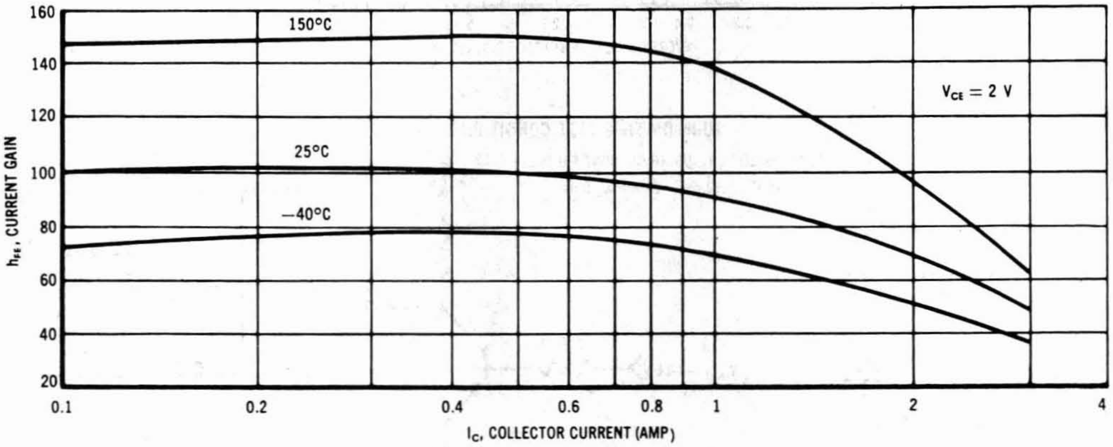
COLLECTOR CURRENT vs BASE-EMITTER VOLTAGE



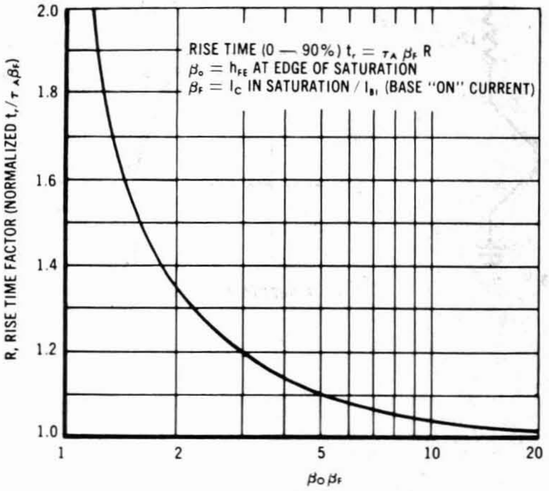
CURRENT GAIN VARIATIONS, 2N3021 thru 2N3023



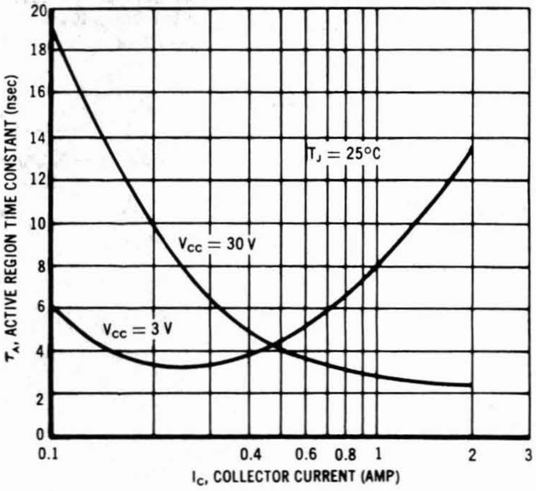
CURRENT GAIN VARIATIONS, 2N3024 thru 2N3026



RISE TIME FACTOR



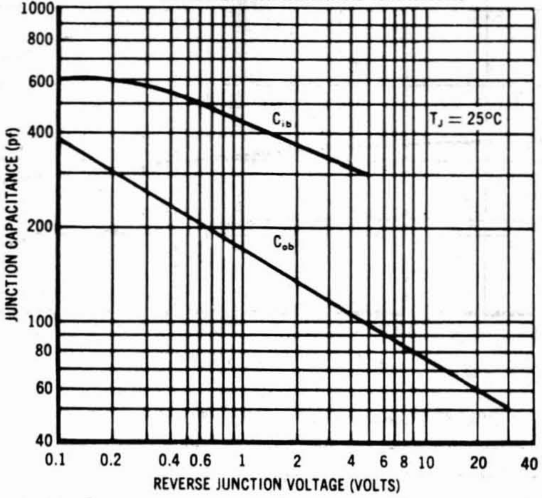
ACTIVE REGION TIME CONSTANT



SWITCHING TIME EQUATIONS

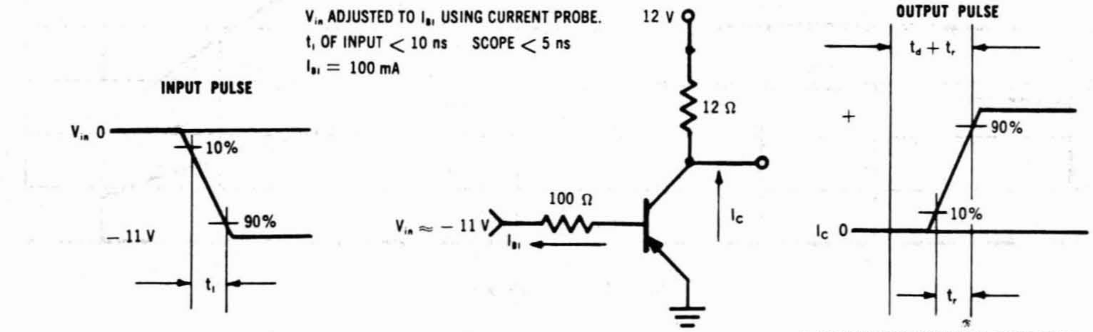
Using charge control theory and data given with this transistor, switching times for a wide variety of conditions can be readily computed.

JUNCTION CAPACITANCE VARIATIONS



TURN-ON TIME TEST CONDITIONS

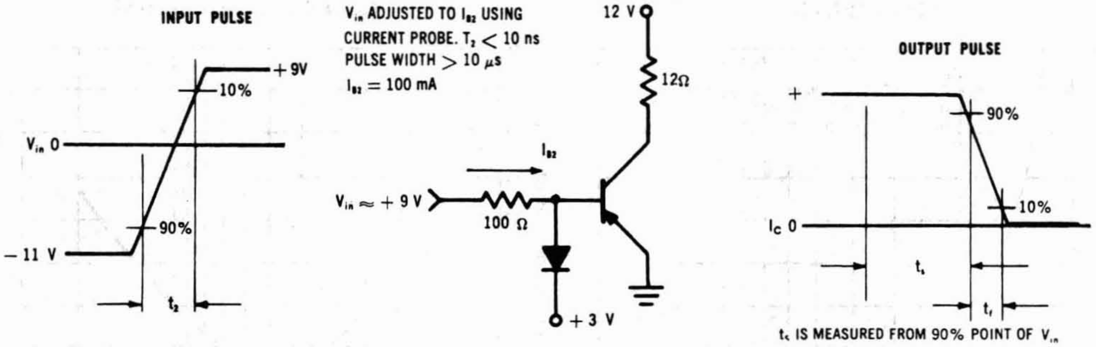
V_{in} ADJUSTED TO I_{B1} USING CURRENT PROBE.
t_r OF INPUT < 10 ns SCOPE < 5 ns
$I_{B1} = 100$ mA


INPUT PULSE
V_{in} 0
10%
90%
− 11 V
t_r
12 V
12 Ω
100 Ω
$V_{in} \approx -11$ V
I_{B1}
I_C
OUTPUT PULSE
$t_d + t_r$
+
90%
10%
I_C 0
t_r

t_d IS MEASURED FROM 10% POINT OF V_{in}

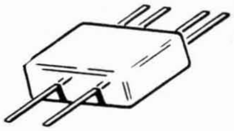
TURN-OFF TIME TEST CONDITIONS

V_{in} ADJUSTED TO I_{B2} USING
CURRENT PROBE. $T_2 < 10$ ns
PULSE WIDTH $> 10\ \mu$s
$I_{B2} = 100$ mA


INPUT PULSE
+ 9V
10%
V_{in} 0
90%
− 11 V
t_2
12 V
12Ω
I_{B2}
$V_{in} \approx +9$ V
100 Ω
+ 3 V
OUTPUT PULSE
+
90%
10%
I_C 0
t_s
t_f

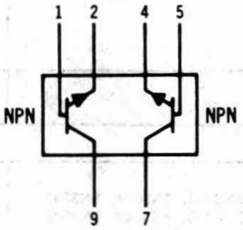
t_s IS MEASURED FROM 90% POINT OF V_{in}

2N3043 thru 2N3048 (SILICON)



CASE 33
(TO-89)

Dual NPN silicon annular transistors designed for low-level, low-noise differential amplifier applications. Can be used in complementary circuits with 2N3049, 2N3050, for metal can see 2N2639-2N2644 series.



Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	45		Vdc
Collector-Base Voltage	V_{CB}	45		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	30		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	250 1.43	350 2.0	mW mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	700 4.0	1400 8.0	mW mW/°C

2N3043 thru 2N3048 (continued)

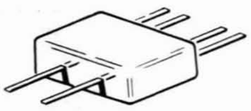
ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)		$BV_{CEO(sus)}$*	45	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0)		I_{CBO}	—	0.010	μAdc
(V_{CB} = 45 Vdc, I_E = 0, T_A = +150°C)			—	10	
Emitter-Base Cutoff Current (V_{EB} = 4 Vdc, I_C = 0)		I_{EBO}	—	0.010	μAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 10 μAdc, V_{CE} = 5 Vdc)	2N3043, 2N3044, 2N3045	h_{FE}*	100	300	—
	2N3046, 2N3047, 2N3048		50	200	
(I_C = 1 mAdc, V_{CE} = 5 Vdc)	2N3043, 2N3044, 2N3045		130	—	
	2N3046, 2N3047, 2N3048		65	—	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc)		$V_{CE(sat)}$	—	1.0	Vdc
Base-Emitter On Voltage (I_C = 10 mAdc, V_{CE} = 5 Vdc)		$V_{BE(on)}$	0.6	0.8	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 20 MHz)		f_T	30	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)		C_{ob}	—	8	pF
Input Impedance (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	2N3043, 2N3044, 2N3045	h_{ie}	3.2k	19k	Ohms
	2N3046, 2N3047, 2N3048		1.6k	13k	
Small-Signal Current Gain (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	2N3043, 2N3044, 2N3045	h_{fe}	130	600	—
	2N3046, 2N3047, 2N3048		65	400	
Output Admittance (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	2N3043, 2N3044, 2N3045	h_{oe}	—	100	μmhos
	2N3046, 2N3047, 2N3048		—	70	
Noise Figure (I_C = 10 μAdc, V_{CE} = 5 Vdc, R_S = 10k ohms, Bandwidth = 10 Hz to 15.7 kHz)		NF	—	5	dB
MATCHING CHARACTERISTICS					
DC Current Gain Ratio** (I_C = 10 μAdc, V_{CE} = 5 Vdc)	2N3043, 2N3046	h_{FE1}/h_{FE2}**	0.9	1.0	—
	2N3044, 2N3047		0.8	1.0	
Base Voltage Differential (I_C = 10 μAdc, V_{CE} = 5 Vdc)	2N3043, 2N3046	$\lvert V_{BE1} - V_{BE2}\rvert$	—	5	mVdc
	2N3044, 2N3047		—	10	
Base Voltage Differential Temperature Gradient (I_C = 10 μAdc, V_{CE} = 5 Vdc, T_A = -55 to +125°C)	2N3043, 2N3046	$\frac{\Delta(V_{BE1} - V_{BE2})}{\Delta T_A}$	—	10	μV/°C
	2N3044, 2N3047		—	20	

*Pulse Test: Pulse Width ≦ 300 μs; Duty Cycle ≦ 2%

**The lowest h_{FE} reading is taken as h_{FE1} for this test.

2N3049 (SILICON)
2N3050

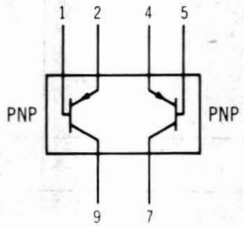


CASE 33

(TO-89)

Dual PNP silicon annular transistors designed for low-level, low-noise differential amplifier applications. Can be used in complementary circuits with 2N3043 thru 2N3048 series.

All Leads Electrically Isolated From Case



Pin Connections, Bottom View

MAXIMUM RATINGS (each side) ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	20		Vdc
Collector-Base Voltage	V_{CB}	25		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	100		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	250 1.43	350 2.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	700 4.0	1400 8.0	mW mW/°C

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	20	—	Vdc
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 25 Vdc, I_E = 0)		—	0.010	
(V_{CB} = 25 Vdc, I_E = 0, T_A = +150°C)		—	10	
Emitter-Base Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)	I_{EBO}	—	0.010	μAdc
ON CHARACTERISTICS				
DC Current Gain*	h_{FE}*			—
(I_C = 10 μAdc, V_{CE} = 5 Vdc)		20	120	
(I_C = 100 μAdc, V_{CE} = 5 Vdc)		30	120	
(I_C = 1 mAdc, V_{CE} = 5 Vdc)		30	120	
(I_C = 10 mAdc, V_{CE} = 5 Vdc)		30	120	
(I_C = 10 mAdc, V_{CE} = 1 Vdc)		20	—	
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$	—	0.2	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	0.7	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 20 MHz)	f_T	60	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	8	pF
Input Impedance (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	h_{ie}	750k	4500k	Ohms
Small-Signal Current Gain (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	h_{fe}	30	130	—
Output Admittance (I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	h_{oe}	—	50	μmhos
Noise Figure (I_C = 100 μAdc, V_{CE} = 5 Vdc, R_S = 1k ohm, Bandwidth = 10 Hz to 15.7 kHz)	NF	—	6	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 100 μAdc, V_{CE} = 5 Vdc) 2N3049 2N3050	h_{FE1}/h_{FE2}**	0.9 0.8	1.0 1.0	—
Base Voltage Differential (I_C = 100 μAdc, V_{CE} = 5 Vdc) 2N3049 2N3050	$\lvert V_{BE1} - V_{BE2}\rvert$	— —	5 10	mVdc
Base Voltage Differential Temperature Gradient (I_C = 100 μAdc, V_{CE} = 5 Vdc, T_A = -55 to +125°C) 2N3049 2N3050	$\frac{\Delta(V_{BE1} - V_{BE2})}{\Delta T_A}$	— —	10 20	μV/°C

*Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2%

**The lowest h_{FE} reading is taken as h_{FE1} for this test.

2N3053 (SILICON)

CASE 31
(TO-5)

NPN silicon annular transistor designed for medium-current switching and amplifier applications.

MAXIMUM RATINGS

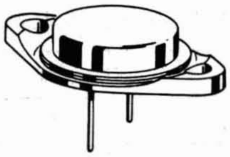
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current-Continuous	I_C	700	mAdc
Total Device Dissipation @ $T_C = 25^\circ C$ Derate above $25^\circ C$	P_D	5 28.6	Watts $mW/^\circ C$
Operating Junction Temperature Range	T_J	200	$^\circ C$
Storage Temperature Range	T_{stg}	-65 to +200	$^\circ C$

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 100\ \mu Adc$, $I_E = 0$)	BV_{CEO}	40	—	Vdc
Collector-Emitter Breakdown Voltage ($I_C = 100$ mAdc, $R_{BE} = 10$ ohms)	BV_{CER}	50	—	Vdc
Collector-Base Breakdown Voltage ($I_C = 100\ \mu Adc$, $I_E = 0$)	BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu Adc$, $I_C = 0$)	BV_{EBO}	5	—	Vdc
Collector Cutoff Current ($V_{CE} = 60$ Vdc, $V_{EB(off)} = 1.5$ Vdc)	I_{CEX}	—	0.25	μAdc
Base Cutoff Current ($V_{CE} = 60$ Vdc, $V_{EB(off)} = 1.5$ Vdc)	I_{BL}	—	0.25	μAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 150$ mAdc, $V_{CE} = 2.5$ Vdc) ($I_C = 150$ mAdc, $V_{CE} = 10$ Vdc)*	h_{FE}	25 50	— 250	—
Collector-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{CE(sat)}$	—	1.4	Vdc
Base-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{BE(sat)}$	—	1.7	Vdc
Base-Emitter On Voltage ($I_C = 150$ mAdc, $V_{CE} = 2.5$ Vdc)	$V_{BE(on)}$	—	1.7	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc, $f = 20$ MHz)	f_T	100	—	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, $f = 140$ kHz)	C_{ob}	—	15	pF
Input Capacitance ($V_{BE} = 0.5$ Vdc, $I_C = 0$, $f = 140$ kHz)	C_{ib}	—	80	pF

*Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2%

2N3055 (SILICON)



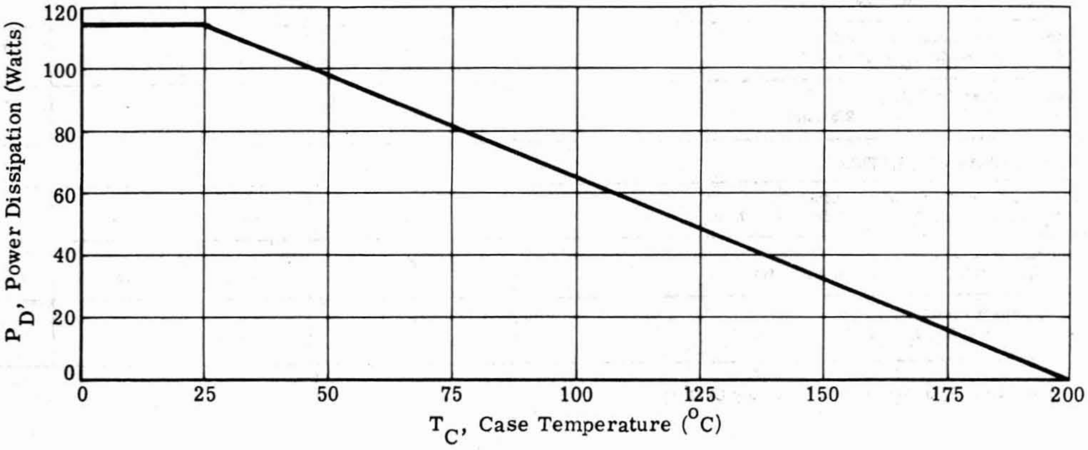
CASE 11
(TO-3)

NPN silicon power transistor designed for switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	100	Vdc
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Emitter Voltage	V_{CER}	70	Vdc
Emitter-Base Voltage	V_{EB}	7.0	Vdc
Collector Current (Continuous)	I_C	15	Adc
Base Current (Continuous)	I_B	7.0	Adc
Power Dissipation	P_D	117	Watts
Thermal Resistance, Junction to Case	θ_{JC}	1.5	°C/W
Junction Operating Temperature Range	T_J	-65 to +200	°C

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Emitter-Base Cutoff Current (V_{EB} = 7 Vdc)	I_{EBO}	-	5.0	mAdc
Collector Cutoff Current (V_{CB} = 100 Vdc, V_{BE} = 1.5 Vdc) (V_{CE} = 100 Vdc, V_{BE} = 1.5 Vdc, T_C = 150°C)	I_{CEX}	- -	5.0 30.0	mAdc
Collector-Emitter Sustaining Voltage* (I_C = 200 mAdc, I_B = 0)	$V_{CEO(sus)}$	60	-	Vdc
DC Current Gain (I_C = 4.0 Adc, V_{CE} = 4 Vdc) (I_C = 10.0 Adc, V_{CE} = 4 Vdc)	h_{FE}	20 5.0	70 -	-
Collector-Emitter Saturation Voltage (I_C = 4.0 Adc, I_B = 0.4 Adc) (I_C = 10.0 Adc, I_B = 3.3 Adc)	$V_{CE(sat)}$	- -	1.1 8.0	Vdc
Collector-Emitter Voltage* (I_C = 200 mAdc, R_{BE} = 100)	V_{CER}	70	-	Vdc
Base-Emitter Voltage (I_C = 4.0 Adc, V_{CE} = 4 Adc)	V_{BE}	-	1.8	Vdc
Small Signal Current Gain (V_{CE} = 4.0 Vdc, I_C = 1.0 Adc, f = 1 kHz) (V_{CE} = 4.0 Vdc, I_C = 1.0 Adc)	h_{fe} $f_{\alpha e}$	15 20	- -	kHz
Collector-Emitter Current (V_{CE} = 30 Vdc, I_B = 0)	I_{CEO}	-	0.7	mAdc

*Use sweep test to prevent overheating.

2N3114 (SILICON)

CASE 31
(TO-5)

Collector connected to case

NPN silicon annular transistor designed for high-voltage, low-power video amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	150	Vdc
Collector-Emitter Voltage*	V_{CEO}	150*	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ T_A = 25°C Derating Factor Above 25°C	P_D	0.8 4.57	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derating Factor Above 25°C	P_D	5 28.6	Watts mW/°C
Operating Junction Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

*Between 0 and 30 mA.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	150	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 30 mAdc, I_B = 0)	BV_{CEO}*	150	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5	—	Vdc
Collector Saturation Voltage* (I_C = 50 mAdc, I_B = 5 mAdc)	$V_{CE(sat)}$*	—	1	Vdc
Base-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5 mAdc)	$V_{BE(sat)}$*	—	0.9	Vdc
DC Current Gain*	h_{FE}*			—
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)		15	—	
(I_C = 30 mAdc, V_{CE} = 10 Vdc)		30	120	
(I_C = 30 mAdc, V_{CE} = 10 Vdc, T_A = -55°C)		12	—	
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 100 Vdc, I_E = 0)		—	0.010	
(V_{CB} = 100 Vdc, I_E = 0, T_A = 150°C)		—	10	
Emitter Cutoff Current (V_{EB} = 4 Vdc, I_C = 0)	I_{EBO}	—	0.10	μAdc
Small Signal Current Gain (V_{CE} = 10 Vdc, I_C = 30 mAdc, f = 20 MHz)	$\|h_{fe}\|$	2.0	—	—
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	9	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	—	80	pF
Small Signal Current Gain (I_C = 1.0 mA, V_{CE} = 5 V, f = 1 kHz)	h_{fe}	25	—	—
Real Part of Input Impedance (I_C = 10 mA, V_{CE} = 10 V, f = 100 MHz)	Re(h_{ie})	—	30	ohms

*PW ≤ 300 μsec, Duty Cycle ≤ 1%

2N3115 (SILICON)
2N3116

For Specifications, See 2N2958 Data.

JAN 2N3127 (GERMANIUM)

2N3127

CASE 20
(TO-72)

Active Elements Isolated From Case

PNP germanium mesa transistor designed for industrial and commercial VHF/UHF amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Emitter Voltage	V_{CES}	25	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	0.75	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	100 1.33	mW $mW/^oC$
Operating & Storage Junction Temperature	T_J, T_{stg}	-65 to + 100	^oC

JAN 2N3127 (continued)

TABLE I – GROUP A INSPECTION (T_A = 25°C unless otherwise noted) (LTPD applies to JAN 2N3127 only)

Examination or Test	MIL-STD-750 Method	Symbol	Limits Min	Limits Max	Unit	LTPD
SUBGROUP 1						
Visual and Mechanical Examination	2071	—	—	—	—	10
SUBGROUP 2						
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	3001 Condition D	BV_{CBO}	25	—	Vdc	5
Collector-Emitter Breakdown Voltage (I_C = 2 mAdc, I_B = 0)	3011 Condition D	BV_{CEO}	20	—	Vdc	
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	3011 Condition C	BV_{CES}	25	—	Vdc	
Collector-Base Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	—	3	μAdc	
Emitter-Base Cutoff Current (V_{BE} = 0.75 Vdc, I_C = 0)	3061 Condition D	I_{EBO}	—	100	μAdc	
DC Current Gain (I_C = 3 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}	20	100	—	
Base-Emitter Saturation Voltage (I_C = 5 mAdc, I_B = 1 mAdc)	3066 Condition A	$V_{BE(sat)}$	—	0.6	Vdc	
Collector-Emitter Saturation Voltage (I_C = 5 mAdc, I_B = 1 mAdc)	3071	$V_{CE(sat)}$	—	0.3	Vdc	
SUBGROUP 3						
Small-Signal Current Gain (I_C = 3 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	3206	h_{fe}	20	125	—	10
Current-Gain — Bandwidth Product (I_C = 2 mAdc, V_{CE} = 6 Vdc, f = 100 MHz)	3261	f_T	400	—	MHz	
Collector - Base Capacitance* (V_{CB} = 10 Vdc, I_E = 0, $f \geq 0.1 \leq 1.0$ MHz)	3236	C_{cb}*	—	1.2	pF	
SUBGROUP 4						
Collector-Base Cutoff Current (V_{CB} = 10 Vdc, I_E = 0, T_A = 85°C)	3036 Condition D	I_{CBO}	—	50	μAdc	10
DC Current Gain ‡ (I_C = 3 mAdc, V_{CE} = 10 Vdc, T_A = -55 $^{+0}_{-3}$ °C)	3076	h_{FE} ‡	7	—	—	
SUBGROUP 5						
Power Gain (Figure 1) (I_C = 3 mAdc, V_{CE} = 10 Vdc, R_S = 50 ohms, f = 200 MHz)	3256	G_{pe}	17	25	dB	15
Noise Figure (Figure 1) (I_C = 3 mAdc, V_{CE} = 10 Vdc, R_S = 50 ohms, f = 200 MHz).	3246	NF	—	5	dB	

STANDARD UNIT ONLY

Collector-Base Time Constant (Figure 2) (I_C = 3 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)	$r'_b C_c$	1	12	ps	—

* Measured in a guarded circuit, such that the can capacitance is not included.

‡ Applies to JAN unit only.

JAN 2N3127 (continued)

TABLE II – GROUP B INSPECTION – JAN 2N3127 only (T_A = 25°C unless otherwise noted)

Examination or Test	MIL-STD-750 Method	Symbol	Limits		Unit	LTPD
			Min	Max		
SUBGROUP 1						
Physical Dimensions	2066	—	—	—	—	20
SUBGROUP 2						
Solderability (Omit aging)	2026	—	—	—	—	15
Temperature Cycling $(T_{high} = 100^{+3}_{-0}\ ^{\circ}C)$	1051 Condition B	—	—	—	—	
Thermal Shock (Glass Strain)	1056 Condition A	—	—	—	—	
Seal (Leak Rate)**	** Condition C, Procedure IIIa. Condition B for Gross Leaks	—	—	10^{-7}	atm cc/s	
Moisture Resistance	1021	—	—	—	—	
End-Point Tests: (Subgroups 2, 3)						
Collector-Base Cutoff Current (V_{CB} = 10 Vdc)	3036 Condition D	I_{CBO}	—	3	μAdc	
DC Current Gain (I_C = 3 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}	20	100	—	
SUBGROUP 3						
Shock (Non-operating; 1500 G; 5 blows of 0.5 ms each in Orientations X_1, Y_1, Y_2, and Z_1) (total = 20 blows)	2016	—	—	—	—	15
Vibration Fatigue (Non-operating; 20G)	2046	—	—	—	—	
Vibration, Variable Frequency	2056	—	—	—	—	
Constant Acceleration (Centrifugal) (20,000G, Orientations X_1, Y_1, Y_2, and Z_1)	2006	—	—	—	—	
End-Point Tests: Same as Subgroup 2						
SUBGROUP 4						
Lead Fatigue	2036 Condition E	—	—	—	—	15
SUBGROUP 5						
High-Temperature Life (Non-operating) (T_{stg} = 100°C)	1031	—	—	—	—	λ = 15
End-Point Tests: (Subgroups 5, 6)						
Collector-Base Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	—	6	μAdc	
DC Current Gain (I_C = 3 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}	17	125	—	
SUBGROUP 6						
Steady State Operation Life (I_C = 10 mAdc, V_{CB} = 10 Vdc)	1026	—	—	—	—	λ = 15
End-Point Tests: Same as Subgroup 5						

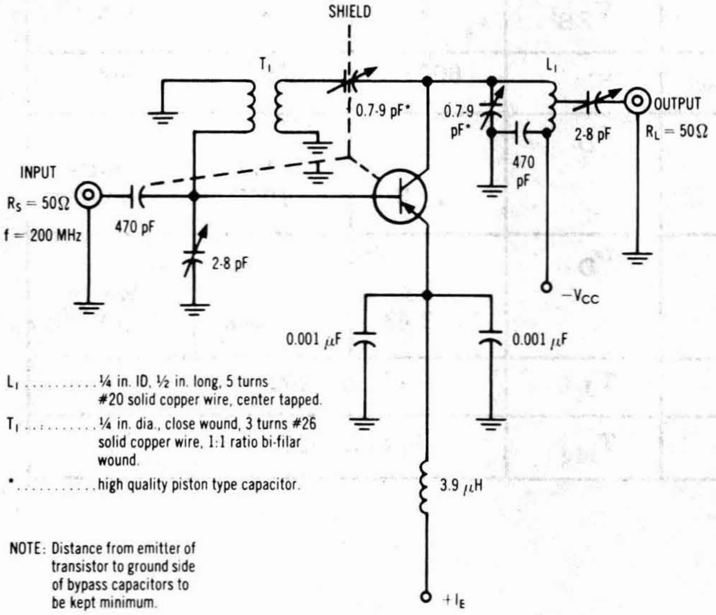
**Per Method 112 of MIL-STD-202

TABLE III – GROUP C INSPECTION‡ – JAN 2N3127 only (T_A = 25°C unless otherwise noted)

Examination or Test	MIL-STD-750 Method	Symbol	Limits		Unit	LTPD
			Min	Max		
SUBGROUP 1						
Collector-Base Time Constant (Figure 2) (I_C = 3 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)		$r_b'C_c$	—	12	ps	20
Salt Atmosphere (Corrosion)	1041	—	—	—	—	
End-Point Tests:						
Collector-Base Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	3036 Condition D	I_{CBO}	-	3	μAdc	
DC Current Gain (I_C = 3 mAdc, V_{CE} = 10 Vdc)	3076	h_{FE}	20	100	—	
SUBGROUP 2						
Output Conductance (I_C = 2 mAdc, V_{CE} = 6 Vdc, f = 30 MHz)	3216	$Re(h_{oe})$	1.0	3.5	mmhos	10
Input Conductance (I_C = 2 mAdc, V_{CE} = 6 Vdc, f = 30 MHz)	3221	$Re(y_{ie})$	1.25	5.0	mmhos	

‡ Group C tests shall be performed on the initial lot and every six months thereafter.

FIGURE 1 – TEST CIRCUIT FOR POWER GAIN AND NOISE FIGURE


SHIELD
T₁
L₁
0.7-9 pF*
0.7-9 pF*
470 pF
2-8 pF
OUTPUT
R_L = 50Ω
INPUT
R_S = 50Ω
f = 200 MHz
470 pF
2-8 pF
−V_CC
0.001 μF
0.001 μF
3.9 μH
+I_E

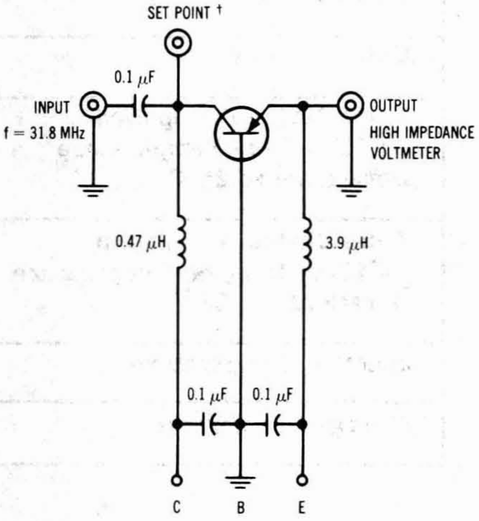
L₁ .... ¼ in. ID, ½ in. long, 5 turns #20 solid copper wire, center tapped.

T₁ .... ¼ in. dia., close wound, 3 turns #26 solid copper wire, 1:1 ratio bi-filar wound.

* .... high quality piston type capacitor.

NOTE: Distance from emitter of transistor to ground side of bypass capacitors to be kept minimum.

FIGURE 2 – TEST CIRCUIT FOR COLLECTOR-BASE TIME CONSTANT


SET POINT †
0.1 μF
INPUT
f = 31.8 MHz
OUTPUT
HIGH IMPEDANCE VOLTMETER
0.47 μH
3.9 μH
0.1 μF
0.1 μF
C
B
E

† NOTE: E_{in} = 0.5 V measured at set point.
$r_b'C_c = E_{out}$ (in mV) × 10

2N3133 thru 2N3136 (SILICON)

CASE 31
(TO-5)

CASE 22
(TO-18)

PNP silicon annular Star transistors for high-speed switching and DC to UHF amplifier applications.

2N3133
2N3134

2N3135
2N3136

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N3133 2N3134 (TO-5)	2N3135 2N3136 (TO-18)	Unit
Collector-Base Voltage	V_{CB}	50	50	Vdc
Collector-Emitter Voltage	V_{CEO}	35	35	Vdc
Emitter-Base Voltage	V_{EB}	4	4	Vdc
Collector Current	I_C	600	600	mA
Total Device Dissipation @25°C Case Temperature Derate Above 25°C	P_D	3 17.3	1.8 10.3	Watts mW/°C
Total Device Dissipation @25°C Ambient Temperature Derate Above 25°C	P_D	0.6 3.43	0.4 2.28	Watts mW/°C
Junction Temperature	T_J	-65 to +200		°C
Storage Temperature	T_{stg}	-65 to +200		°C

SWITCHING CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Typ	Max	Unit
Turn-On Time (V_{CC} = 30 V, I_{CS} = 150 mA, I_{B1} = 15 mA)	t_{on}	26	75	ns
Turn-Off Time (V_{CC} = 6V, I_{CS} = 150 mA, I_{B1} = I_{B2} = 15 mA)	t_{off}	70	150	ns

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current	I_{CBO}			µAdc
(V_{CB} = 30 Vdc, I_E = 0)		---	0.05	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C)		---	30	
Collector Cutoff Current (V_{CE} = 30 V, V_{BE} = 0.5 V)	I_{CEX}	---	0.1	µAdc
Base Cutoff Current (V_{CE} = 30 V, V_{BE} = 0.5 V)	I_{BL}	---	0.1	µAdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	BV_{CBO}	50	---	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	35	---	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)	BV_{EBO}	4	---	Vdc
Collector Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE\,(sat)}$*	---	0.6	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE\,(sat)}$*	---	1.5	Vdc
DC Forward Current Transfer Ratio	h_{FE}			---
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc) 2N3133, 2N3135		25	---	
2N3134, 2N3136		50	---	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)* 2N3133, 2N3135		40	120	
2N3134, 2N3136		100	300	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	---	10	pF
Input Capacitance (V_{BE} = 2 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	---	40	pF
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	200	---	MHz

*Pulse Test: Pulse Width ≤ 300 µs, duty cycle ≤ 2%

2N3137 (SILICON)
MM1803

CASE 31
(TO-5)

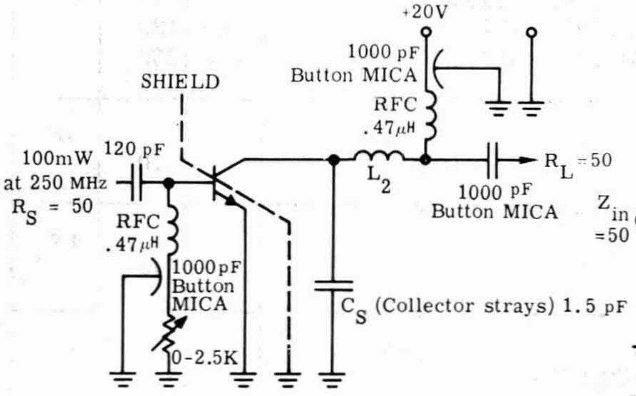
NPN silicon annular transistors for large signal VHF and UHF applications.

Collector connected to case

MAXIMUM RATINGS

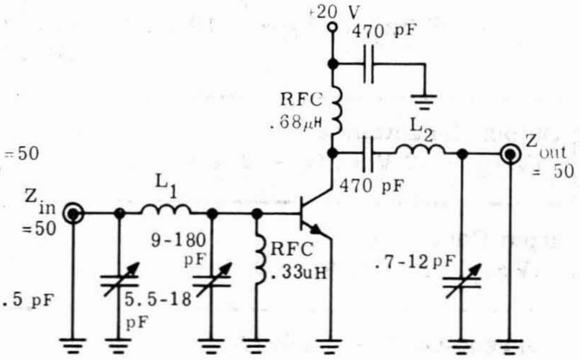
Rating	Symbol	2N3137	MM1803	Units
Collector-Base Voltage	V_{CB}	40	50	Vdc
Collector-Emitter Voltage	V_{CEO}	20	25	Vdc
Emitter-Base Voltage	V_{EB}	4	5	Vdc
Collector Current (Continuous)	I_C	150	150	mAdc
Power Dissipation @25° C Case Temperature @25° C Ambient Temperature	P_D	2.0 0.8		Watts
Operating Junction Temperature Storage Temperature Range	T_J, T_{stg}	-65 to +200		°C
Thermal Resistance Junction to Case	θ_{JC}	87.5		°C/ Watt
Thermal Resistance Junction to Ambient	θ_{JA}	153		°C/ Watt

250 MHz POWER GAIN TEST CIRCUIT (2N3137)


+20V
1000 pF
Button MICA
SHIELD
RFC
.47μH
100mW
at 250 MHz
R_S = 50
120 pF
L_2
R_L = 50
1000 pF
Button MICA
RFC
.47μH
1000pF
Button
MICA
C_S (Collector strays) 1.5 pF
0-2.5K

L_2 = .075 μH (5.5 turns #16ga. ID = 3/16" length 1/2")

250 MHz POWER GAIN TEST CIRCUIT (MM1803)


+20 V
470 pF
RFC
.68μH
L_2
Z_{out} = 50
470 pF
L_1
Z_{in} =50
9-180 pF
RFC
.33uH
.7-12 pF
5.5-18 pF

L_1 = 3/4 turn No. 14 tinned wire 3/8" ID
L_2 = 4 turns No. 18 tinned wire 1/4" ID 7/16" long

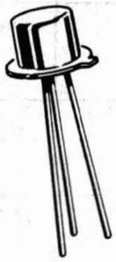
2N3137, MM1803 (Continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise specified)

Characteristic	Symbol	Min	Typical	Max	Unit
Collector-Base Breakdown Voltage $I_C = 0.1$mAdc, $I_E = 0$ 2N3137 MM1803	V_{CBO}	40 50			Vdc
Collector-Emitter Open Base Sus. Voltage $I_C = 15$mAdc, $I_B = 0$ 2N3137 MM1803	$V_{CEO(sus)}$	20 25			Vdc
Collector Cutoff Current $V_{CB} = 20$Vdc, $I_E = 0$, $T_C = +150^\circ$C	I_{CBO}			50	μAdc
Collector Cutoff Current $V_{CB} = 20$Vdc, $I_E = 0$	I_{CBO}			.05	μAdc
Emitter-Base Breakdown Voltage $I_E = 100\mu$A, $I_C = 0$ 2N3137 MM1803	V_{EBO}	4 5			Vdc
DC Current Gain $V_{CE} = 5$Vdc, $I_C = 50$mAdc 2N3137 MM1803	h_{FE}	20 40		120 160	
Collector-Emitter Saturation Voltage $I_C = 50$mAdc, $I_E = 5$mAdc	$V_{CE(sat)}$			0.3	Vdc
Small Signal Current Gain $V_{CE} = 10$Vdc, $I_C = 50$mAdc, f = 100 MHz	$\lvert h_{fe} \rvert$	5.0			
Common-base Output Capacitance $V_{CB} = 10$Vdc, $I_C = 0$, f = 100 kHz	C_{ob}			3.5	pF
Power Output	P_{out}	400	600		mWatts
Power Gain $P_{in} = 100$mw, f = 250 MHz 2N3137	G_e	6.0	7.7		dB
Efficiency $V_{CE} = 20$Vdc	η	40	65		%
Power Output	P_{out}	560	700		mWatts
Power Gain $P_{in} = 100$mw, f = 250 MHz MM1803	G_e	7.5	8.5		db
Efficiency $V_{CE} = 20$V	η	45	60		%

*Pulse Width ≈ 300 μs, Duty cycle = 1%

2N3210 (SILICON)



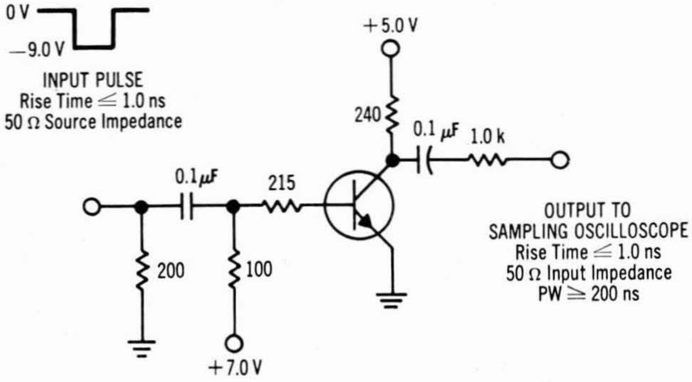
CASE 22
(TO-18)

NPN silicon high frequency switching transistor is designed for high speed, saturated switching applications for industrial service.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage Applicable from 0 to 500 mAdc	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.2 6.9	Watts mW/°C
Storage Temperature Range	T_{stg}	-65 to + 200	°C

FIGURE 1 — STORAGE TIME TEST CIRCUIT



0 V
−9.0 V
INPUT PULSE
Rise Time ≤ 1.0 ns
50 Ω Source Impedance
+5.0 V
240
0.1 μF
1.0 k
0.1μF
215
200
100
+7.0 V
OUTPUT TO
SAMPLING OSCILLOSCOPE
Rise Time ≤ 1.0 ns
50 Ω Input Impedance
PW ≥ 200 ns

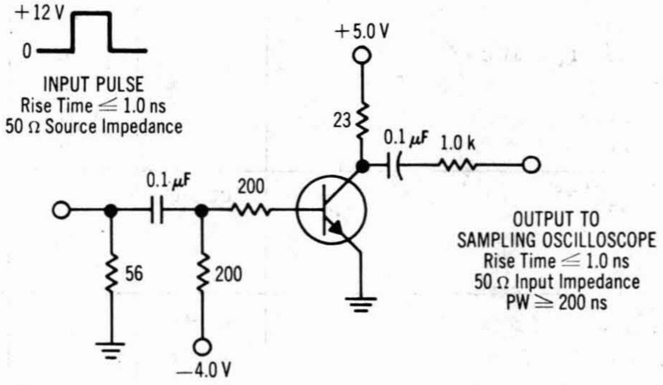
2N3210 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 30 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 2.0 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	I_{CEX}	-	25	nAdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 - -	 0.010 15	μAdc
Emitter Cutoff Current (V_{EB} = 2.0 Vdc, I_C = 0)	I_{EBO}	-	100	nAdc
Base Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	I_{BL}	-	0.025	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}*	30	120	-
Collector-Emitter Saturation Voltage (I_C = 20 mAdc, I_B = 2.0 mAdc, T_A = +125°C) (I_C = 200 mAdc, I_B = 20 mAdc)	$V_{CE(sat)}$	 - -	 0.25 0.75	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 200 mAdc, I_B = 20 mAdc)	$V_{BE(sat)}$	 0.7 -	 0.8 1.5	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain - Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	6.0	pF
Turn-On Time ($V_{BE(off)}$ ≧ 0.2 Vdc, I_C = 200 mAdc, I_{B1} = 40 mAdc) (Figure 2)	t_{on}	-	40	ns
Turn-Off Time (I_C = 200 mAdc, I_{B1} = 40 mAdc, I_{B2} = 20 mAdc) (Figure 2)	t_{off}	-	40	ns
Storage Time ($I_C \approx I_{B1} \approx I_{B2} \approx$ 20 mAdc) (Figure 1)	t_s	-	20	ns

*Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

FIGURE 2 — TURN-ON AND TURN-OFF TEST CIRCUIT


+12 V
0
INPUT PULSE
Rise Time ≦ 1.0 ns
50 Ω Source Impedance
+5.0 V
23
0.1 μF
1.0 k
0.1 μF
200
56
200
−4.0 V
OUTPUT TO
SAMPLING OSCILLOSCOPE
Rise Time ≦ 1.0 ns
50 Ω Input Impedance
PW ≧ 200 ns

2N3211 (SILICON)

CASE 22
(TO-18)

NPN silicon high frequency switching transistor designed for high speed, saturated switching applications for industrial service.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ T_A = 25°C	P_D	0.36	Watt
Derate above 25°C		2.06	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	1.2	Watts
Derate above 25°C		6.9	mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 30 mAdc, I_B = 0)	BV_{CEO}	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	6.0	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3.0 Vdc)	I_{CEX}	-	25	nAdc
Base Cutoff Current	I_{BL}			μAdc
(V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3.0 Vdc)		-	0.025	
(V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3.0 Vdc, T_A = 85°C)		-	10	
ON CHARACTERISTICS				
DC Current Gain*	h_{FE}*			-
(I_C = 100 μAdc, V_{CE} = 1.0 Vdc)		20	-	
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc)		50	-	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)		50	150	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)		20	-	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)		40	-	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)		30	-	
(I_C = 500 mAdc, V_{CE} = 5.0 Vdc)		10	-	
Collector-Emitter Saturation Voltage*	$V_{CE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		-	0.2	
(I_C = 50 mAdc, I_B = 5.0 mAdc)		-	0.3	
(I_C = 100 mAdc, I_B = 10 mAdc)		-	0.4	
Base-Emitter Saturation Voltage*	$V_{BE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		-	0.85	
(I_C = 50 mAdc, I_B = 5.0 mAdc)		-	1.0	
(I_C = 100 mAdc, I_B = 10 mAdc)		-	1.2	

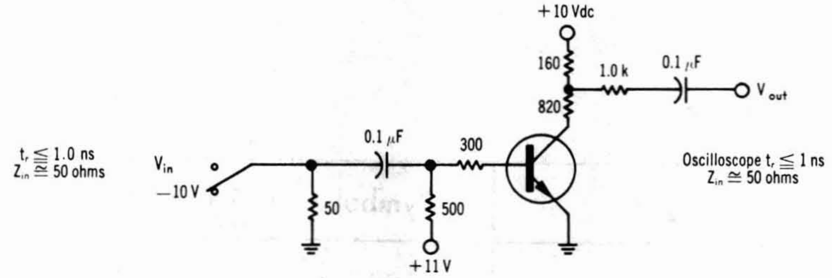
*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N3211 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

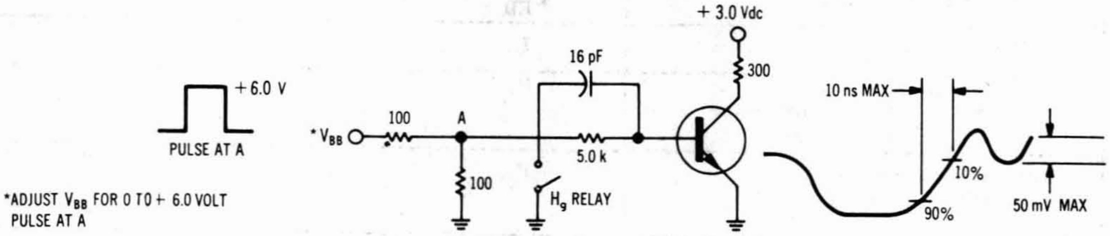
Characteristic	Symbol	Min	Max	Unit
DYNAMIC CHARACTERISTICS				
Current-Gain – Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	350	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	7.0	pF
Charge-Storage Time Constant ($I_C \approx I_{B1} \approx I_{B2} \approx$ 10 mAdc) (Figure 1)	τ_s	-	15	ns
Total Control Charge (I_C = 10 mAdc, I_B = 1.0 mAdc) (Figure 2)	Q_T	-	60	pC
Active Region Time Constant (I_C = 10 mAdc, I_B = 1.0 mAdc) (Figure 3)	τ_A	-	2.5	ns

FIGURE 1 — CHARGE STORAGE TIME CONSTANT TEST CIRCUIT



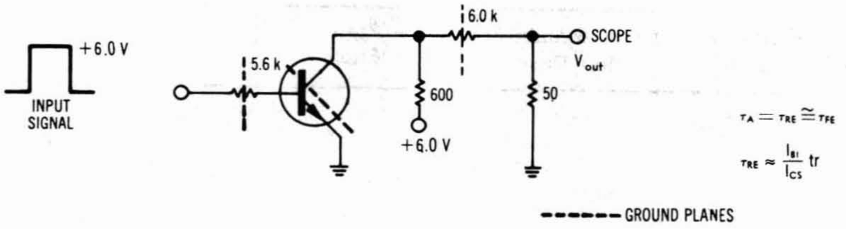
+10 Vdc
160
820
1.0 k
0.1 μF
V out
0.1 μF
300
t_r ≤ 1.0 ns
Z_in ≅ 50 ohms
V_in
−10 V
50
500
+11 V
Oscilloscope t_r ≤ 1 ns
Z_in ≅ 50 ohms

FIGURE 2 — TOTAL CONTROL CHARGE TEST CIRCUIT



+6.0 V
PULSE AT A
*ADJUST V_BB FOR 0 TO + 6.0 VOLT PULSE AT A
*V_BB
100
A
100
16 pF
5.0 k
H_g RELAY
+3.0 Vdc
300
10 ns MAX
10%
90%
50 mV MAX

FIGURE 3 — ACTIVE REGION TIME CONSTANT TEST CIRCUIT



+6.0 V
INPUT SIGNAL
5.6 k
6.0 k
SCOPE
V out
600
+6.0 V
50
τA = τRE ≅ τFE
τRE ≈ (I_B1 / I_CS) tr
GROUND PLANES

NOTES FOR FIGURES 2, 3

INPUT PULSE — TRANSITION TIME TO +6.0 Vdc ≤ 2.0 ns
INPUT PULSE — OPTIONAL GENERATOR OUTPUT IMPEDANCE: ADJUST FOR +6.0 Vdc
SCOPE INPUT CAPACITANCE = 3.0 pF MAX
SCOPE INPUT IMPEDANCE = 10 MEGOHMS
SCOPE RISE TIME ≤ 0.7 ns

2N3227 (SILICON)

For Specifications, See 2N2369 Data.

2N3244 (SILICON)
2N3245

CASE 31
(TO-5)

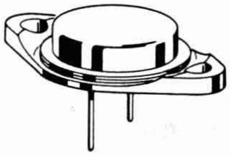
PNP silicon annular transistors for medium-current, high-speed switching and driver applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N 3244	2N 3245	Unit
Collector-Base Voltage	V_{CB}	40	50	Vdc
Collector-Emitter Voltage	V_{CEO}	40	50	Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	1		Adc
Total Device Dissipation @ 25° C Ambient Temperature Derating Factor Above 25°C	P_D	1.0 5.71		Watt mW/°C
Total Device Dissipation @ 25 ° C Case Temperature Derating Factor Above 25°C	P_D	5 28.6		Watts mW/°C
Junction Temperature, Operating	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
Thermal Resistance, Junction to Ambient Thermal Resistance, Junction to Case	θ_{JA} θ_{JC}	0.175 35		°C/mW °C/W

2N3232 (SILICON)
2N3235



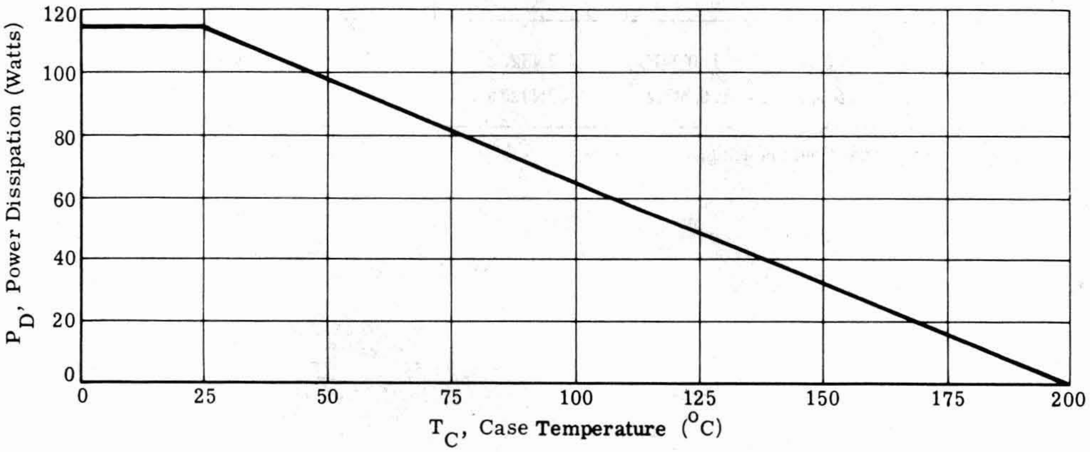
CASE 11
(TO-3)

NPN silicon power transistors designed for switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3232	2N3235	Units
Collector-Base Voltage	V_{CB}	60	55	Vdc
Collector-Emitter Voltage	V_{CEO}	60	55	Vdc
Emitter-Base Voltage	V_{EB}	6.0	7.0	Vdc
Collector Current (Continuous)	I_C	7.5	15	Adc
Base Current (Continuous)	I_B	3.0	7.0	Adc
Power Dissipation	P_D	117		Watts
Thermal Resistance, Junction to Case	θ_{JC}	1.5		°C/W
Junction Operating Temperature Range	T_J	-65 to +200		°C

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = 6.0 Vdc)	2N3232		-	1.0	
(V_{EB} = 7.0 Vdc)	2N3235		-	5.0	
Collector-Emitter Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 60 Vdc, V_{BE} = -1.5 Vdc)	2N3232		-	1.0	
	2N3235		-	1.0	
(V_{CE} = 30 Vdc, V_{BE} = -1.5 Vdc, T_C = 150°C)	2N3232		-	5.0	
	2N3235		-	5.0	
Collector-Emitter Sustaining Voltage*		$V_{CEO(sus)}$*			Vdc
(I_C = 100 mAdc, I_B = 0)	2N3232		60	-	
	2N3235		55	-	
Collector Current		I_{CEO}			mAdc
(V_{CE} = 60 Vdc, I_B = 0)	2N3232		-	10	
(V_{CE} = 55 Vdc, I_B = 0)	2N3235		-	10	
DC Current Gain*		h_{FE}			-
(I_C = 1.5 Adc, V_{CE} = 10 Vdc)	2N3232		18	-	
(I_C = 3.0 Adc, V_{CE} = 10 Vdc)	2N3232		18	55	
(I_C = 2 Adc, V_{CE} = 4 Vdc)	2N3235		20	-	
(I_C = 4 Adc, V_{CE} = 4 Vdc)	2N3235		20	70	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 3.0 Adc, I_B = 0.2 Adc)	2N3232		-	2.5	
(I_C = 4.0 Adc, I_B = 0.4 Adc)	2N3235		-	1.1	
Base-Emitter Voltage*		V_{BE}			Vdc
(I_C = 3.0 Adc, V_{CE} = 10 Vdc)	2N3232		-	3.5	
(I_C = 4.0 Adc, V_{CE} = 4 Vdc)	2N3235		-	1.8	
Small Signal Current Gain		h_{fe}			-
(V_{CE} = 10 Vdc, I_C = 3.0 Adc, f = 1.0 MHz)	2N3232		1.0	-	
(V_{CE} = 4 Vdc, I_C = 4.0 Adc, f = 1.0 MHz)	2N3235		1.0	-	

*Use sweep test to prevent overheating.

2N3244, 2N3245 (Continued)

ELECTRICAL CHARACTERISTICS (at T_A = 25°C unless otherwise specified)

Characteristic			Fig. No.	Symbol	Min	Max	Unit
Collector Cutoff Current	(V_{CB} = 30 Vdc, I_E = 0)			I_{CBO}	—	.050	μAdc
	(V_{CB} = 30 Vdc, I_E = 0, T_A = 100°C)				—	10	
Collector Cutoff Current	(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 3 Vdc)			I_{CEX}	—	50	nAdc
Emitter-Base Leakage Current	(V_{EB} = 3 Vdc, I_C = 0)			I_{EBO}	—	30	nAdc
Base Cutoff Current	(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 3 Vdc)			I_{BL}	—	80	nAdc
Collector-Base Breakdown Voltage	(I_C = 10 μAdc, I_E = 0)	2N3244		BV_{CBO}	40	—	Vdc
		2N3245			50	—	
Collector-Emitter Breakdown Voltage*	(I_C = 10 mAdc, I_B = 0)	2N3244		BV_{CEO}*	40	—	Vdc
		2N3245			50	—	
Emitter-Base Breakdown Voltage	(I_E = 10μ Adc, I_C = 0)			BV_{EBO}	5	—	Vdc
Collector Saturation Voltage*	(I_C = 150 mAdc, I_B = 15 mAdc)	2N3244	2,3	$V_{CE(sat)}$*	—	0.3	Vdc
		2N3245			—	0.35	
	(I_C = 500 mAdc, I_B = 50 mAdc)	2N3244			—	0.5	
		2N3245			—	0.6	
	(I_C = 1 Adc, I_B = 100 mAdc)	2N3244			—	1.0	
		2N3245			—	1.2	
Base-Emitter Saturation Voltage*	(I_C = 150 mAdc, I_B = 15 mAdc)		3	$V_{BE(sat)}$*	—	1.1	Vdc
	(I_C = 500 mAdc, I_B = 50 mAdc)				0.75	1.5	
	(I_C = 1 Adc, I_B = 100 mAdc)				—	2.0	
DC Forward Current Transfer Ratio*	(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)	2N3244	1	h_{FE}*	60	—	—
		2N3245			35	—	
	(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)	2N3244			50	150	
		2N3245			30	90	
	(I_C = 1 Adc, V_{CE} = 5 Vdc)	2N3244			25	—	
		2N3245			20	—	
Output Capacitance	(V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		5	C_{ob}	—	25	pF
Input Capacitance	(V_{OB} = 0.5 Vdc, I_C = 0, f = 100 kHz)		5	C_{ib}	—	100	pF
Current-Gain - Bandwidth Product	(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3244		f_T	175	—	MHz
		2N3245			150	—	
Delay Time	(I_C = 500 mA, I_{B1} = 50 mA V_{OB} = 2 V, V_{CC} = 30 V)		6,8	t_d	—	15	ns
Rise Time		2N3244		t_r	—	35	ns
		2N3245			—	40	
Storage Time	(I_C = 500 mA, V_{CC} = 30 V I_{B1} = I_{B2} = 50 mA)	2N3244	6,9	t_s	—	140	ns
		2N3245				120	
Fall Time				t_f	—	45	ns
Total Control Charge	(I_C = 500 mA, I_B = 50 mA, V_{CC} = 30 V)	2N3244	7,10	Q_T	—	14	nC
		2N3245			—	12	

* Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2%

FIGURE 1 — MINIMUM CURRENT GAIN CHARACTERISTICS

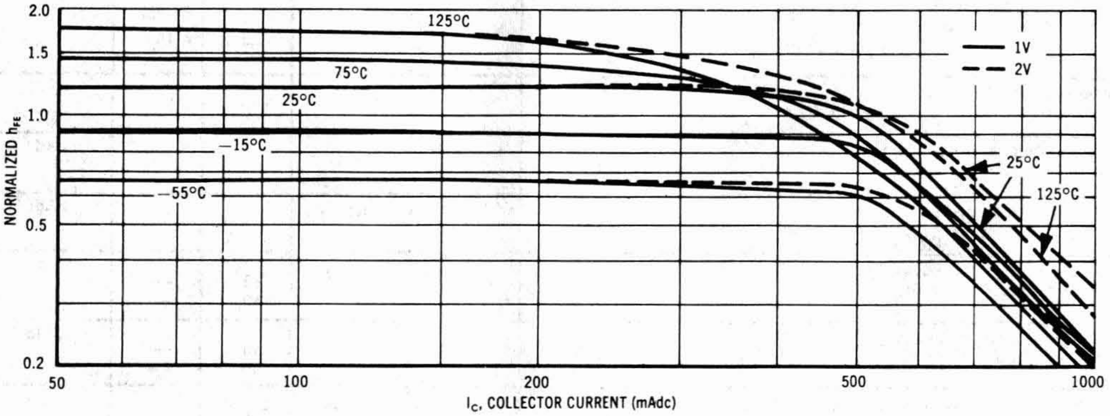


FIGURE 2 — COLLECTOR-EMITTER SATURATION VOLTAGE CHARACTERISTICS

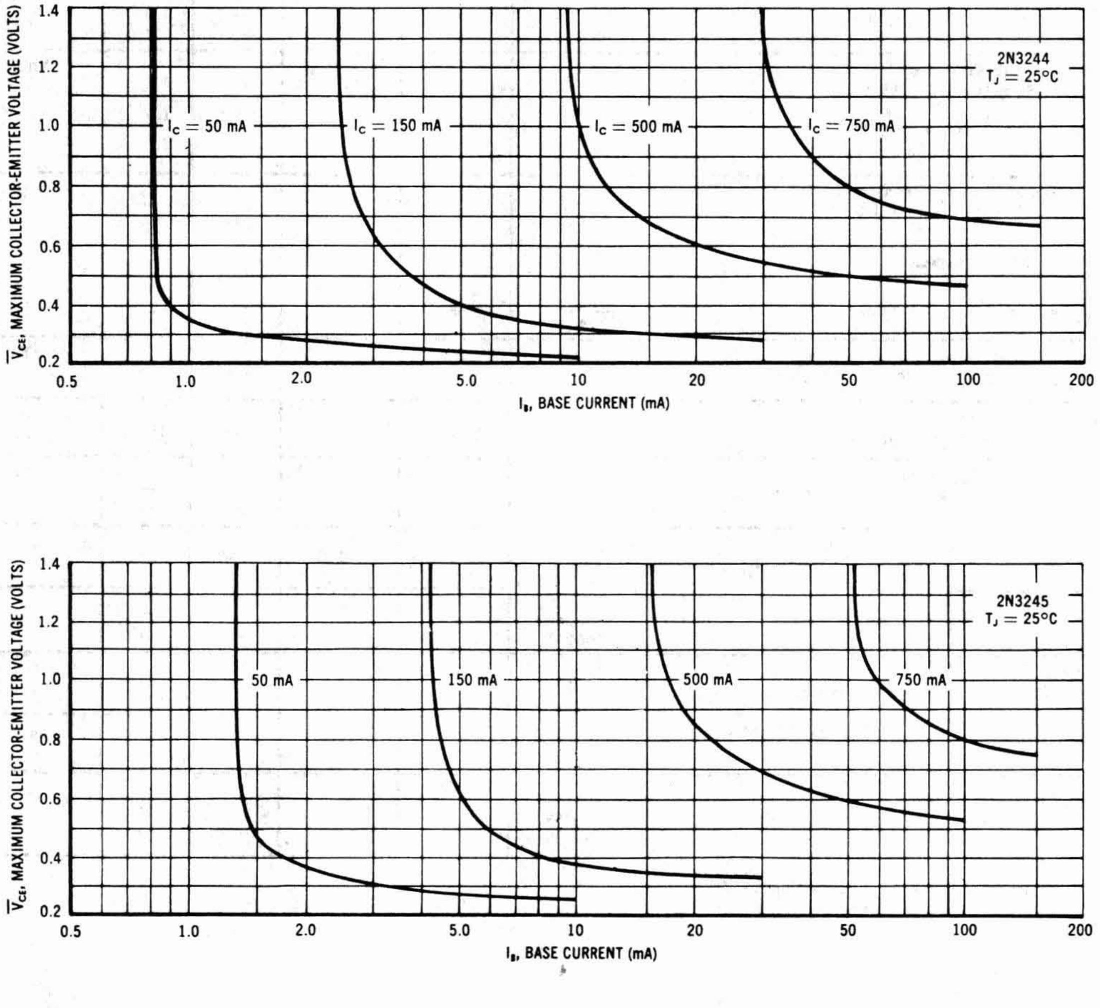


FIGURE 3 — MAXIMUM SATURATION VOLTAGES

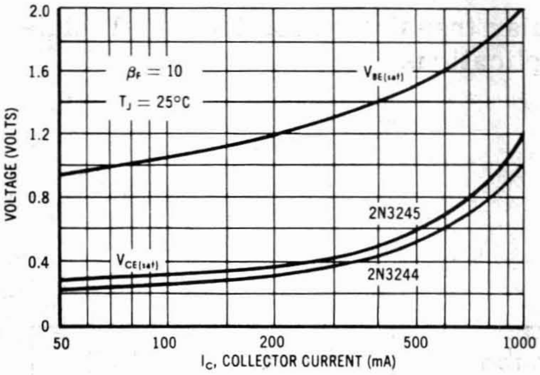


FIGURE 4 — TYPICAL TEMPERATURE COEFFICIENTS

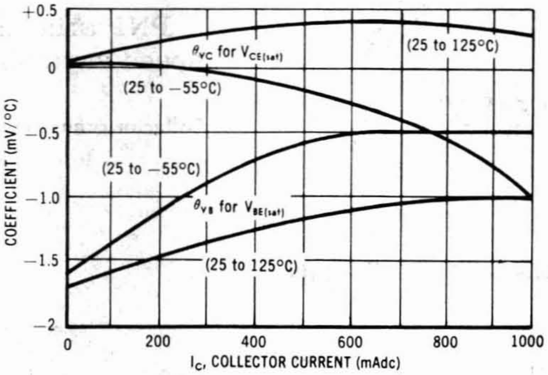


FIGURE 5 — JUNCTION CAPACITANCE

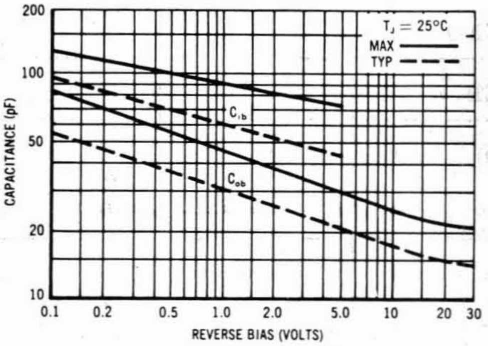


FIGURE 6 — TYPICAL SWITCHING TIMES

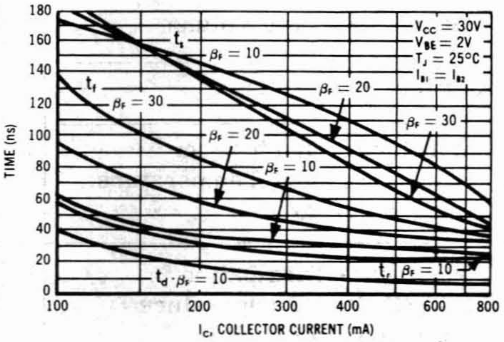


FIGURE 7 — CHARGE DATA

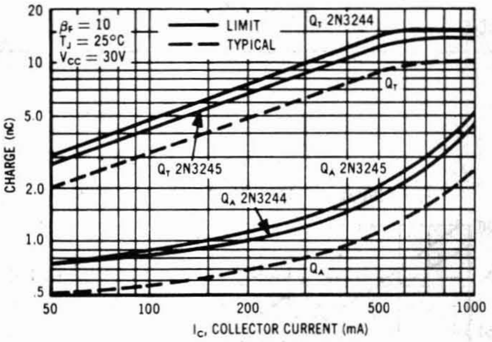
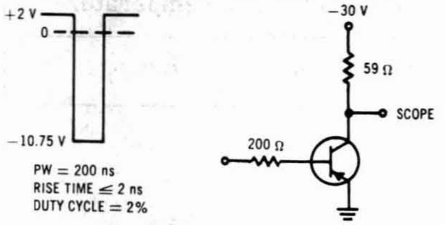
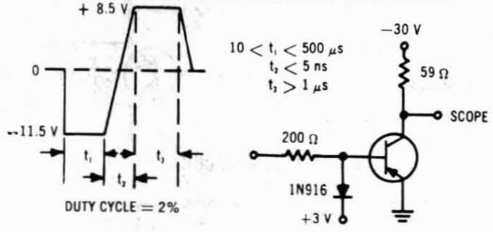


FIGURE 8 — TURN-ON EQUIVALENT TEST CIRCUIT



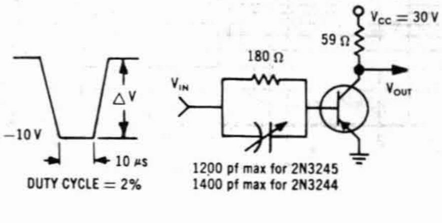
+2 V
0
−10.75 V
PW = 200 ns
RISE TIME ≤ 2 ns
DUTY CYCLE = 2%
−30 V
59 Ω
SCOPE
200 Ω

FIGURE 9 — TURN-OFF EQUIVALENT TEST CIRCUIT



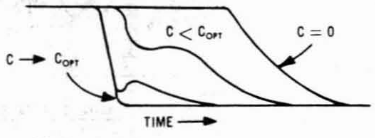
+ 8.5 V
0
−11.5 V
t_1
t_2
t_3
DUTY CYCLE = 2%
$10 < t_1 < 500\ \mu s$
$t_2 < 5$ ns
$t_3 > 1\ \mu s$
−30 V
59 Ω
SCOPE
200 Ω
1N916
+3 V

FIGURE 10 — Q_T TEST CIRCUIT



−10 V
ΔV
10 µs
DUTY CYCLE = 2%
$V_{CC} = 30V$
59 Ω
180 Ω
V_{IN}
V_{OUT}
1200 pf max for 2N3245
1400 pf max for 2N3244

FIGURE 11 — TURN-OFF WAVEFORM



$C < C_{OPT}$
$C = 0$
$C \rightarrow C_{OPT}$
TIME

2N3248 (SILICON)
2N3249

CASE 22
(TO-18)

PNP silicon annular transistors for low-level, high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	15	Vdc
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Total Device Dissipation @ 25°C Ambient Temperature Derate above 25°C	P_D	 0.36 2.06	 Watt mW/°C
Total Device Dissipation @ 25°C Case Temperature Derate above 25°C	P_D	 1.2 6.9	 Watts mW/°C
Operating Junction Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 — t_{on} CIRCUIT

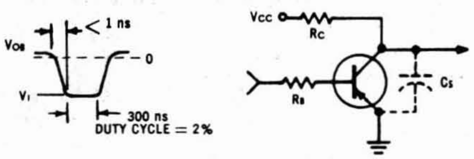
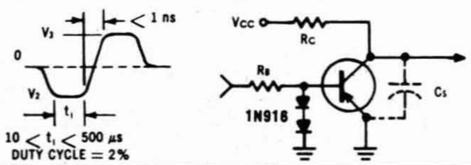

< 1 ns
V_{OB}
0
V_1
300 ns
DUTY CYCLE = 2%
Vcc
Rc
R_B
C_S

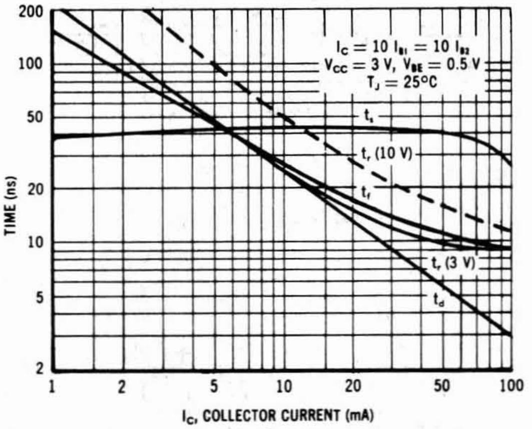
FIGURE 2 — t_{off} CIRCUIT


< 1 ns
V_3
0
V_2
t_1
10 < t_1 < 500 µs
DUTY CYCLE = 2%
Vcc
Rc
R_B
1N916
C_S

I_C mA	V_{CC} volts	R_B ohms	R_C ohms	$C_{S(max)}$* pF	V_{OB} volts	V_1 volts	V_2 volts	V_3 volts
10	3	10 K	285	4	+0.5	−10.6	−10.9	+9.1
100	10	1 K	95	12	+0.5	−10.7	−11.3	+8.7

*Total shunt capacitance of test jig and connectors.

FIGURE 3 — TYPICAL SWITCHING TIMES



Characteristic		Fig.No.	Symbol	Min	Max	Unit
Collector-Cutoff Current			I_{CEX}			μAdc
(V_{CE} = 10 Vdc, $V_{BE(off)}$ = 1 Vdc)				—	.05	
(V_{CE} = 10 Vdc, $V_{BE(off)}$ = 1 Vdc, T_A = 100°C)				—	5	
Base Cutoff Current (V_{CE} = 10 Vdc, $V_{BE(off)}$ = 1 Vdc)			I_{BL}	—	50	nAdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)			BV_{CBO}	15	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)			BV_{CEO}*	12	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)			BV_{EBO}	5	—	Vdc
Collector Saturation Voltage *		7,8	$V_{CE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)				—	0.125	
(I_C = 50 mAdc, I_B = 5 mAdc)				—	0.25	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N3248			—	0.4	
	2N3249			—	0.45	
Base-Emitter Saturation Voltage *		8	$V_{BE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)				0.6	0.9	
(I_C = 50 mAdc, I_B = 5 mAdc)				—	1.1	
(I_C = 100 mAdc, I_B = 10 mAdc)				0.7	1.3	
DC Current Gain*		4	h_{FE}*			—
(I_C = 0.1 mAdc, V_{CE} = 1 Vdc)	2N3248			50	—	
	2N3249			100	—	
(I_C = 1.0 mAdc, V_{CE} = 1 Vdc)	2N3248			50	—	
	2N3249			100	—	
(I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N3248			50	150	
	2N3249			100	300	
(I_C = 50 mAdc, V_{CE} = 1 Vdc)	2N3248			35	—	
	2N3249			75	—	
(I_C = 100 mAdc, V_{CE} = 1 Vdc)	2N3248			25	—	
	2N3249			35	—	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		6	C_{ob}	—	8	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 100 kHz)		6	C_{ib}	—	8	pF
Current-Gain — Bandwidth Product			f_T			MHz
(I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3248			250	—	
	2N3249			300	—	
Total Control Charge (I_C = 10 mA, I_B = 0.25 mA, V_{CC} = 3 V)		5,10	Q_T	—	150	pC
Delay Time	I_C = 100 mA, I_B = 10 mA, $V_{BE(off)}$ = 0.5 V, V_{CC} = 10 V	1,3	t_d	—	5	ns
Rise Time			t_r	—	15	ns
Storage Time	I_C = 100 mA, I_{B1} = I_{B2} = 10 mA, V_{CC} = 10 V	2,3	t_s	—	60	ns
Fall Time			t_f	—	20	ns
Turn-On Time	I_C = 10 mA, I_{B1} = 1 mA, $V_{BE(off)}$ = 0.5 V, V_{CC} = 3 V	1,3	t_{on}	—	90	ns
Turn-Off Time	I_C = 10 mA, I_{B1} = I_{B2} = 1 mA, V_{CC} = 3 V	2,3	t_{off}	—	100	ns

*Pulse Test: PW = 300 μs, Duty Cycle ≤ 2%

FIGURE 4 — MINIMUM CURRENT GAIN CHARACTERISTICS

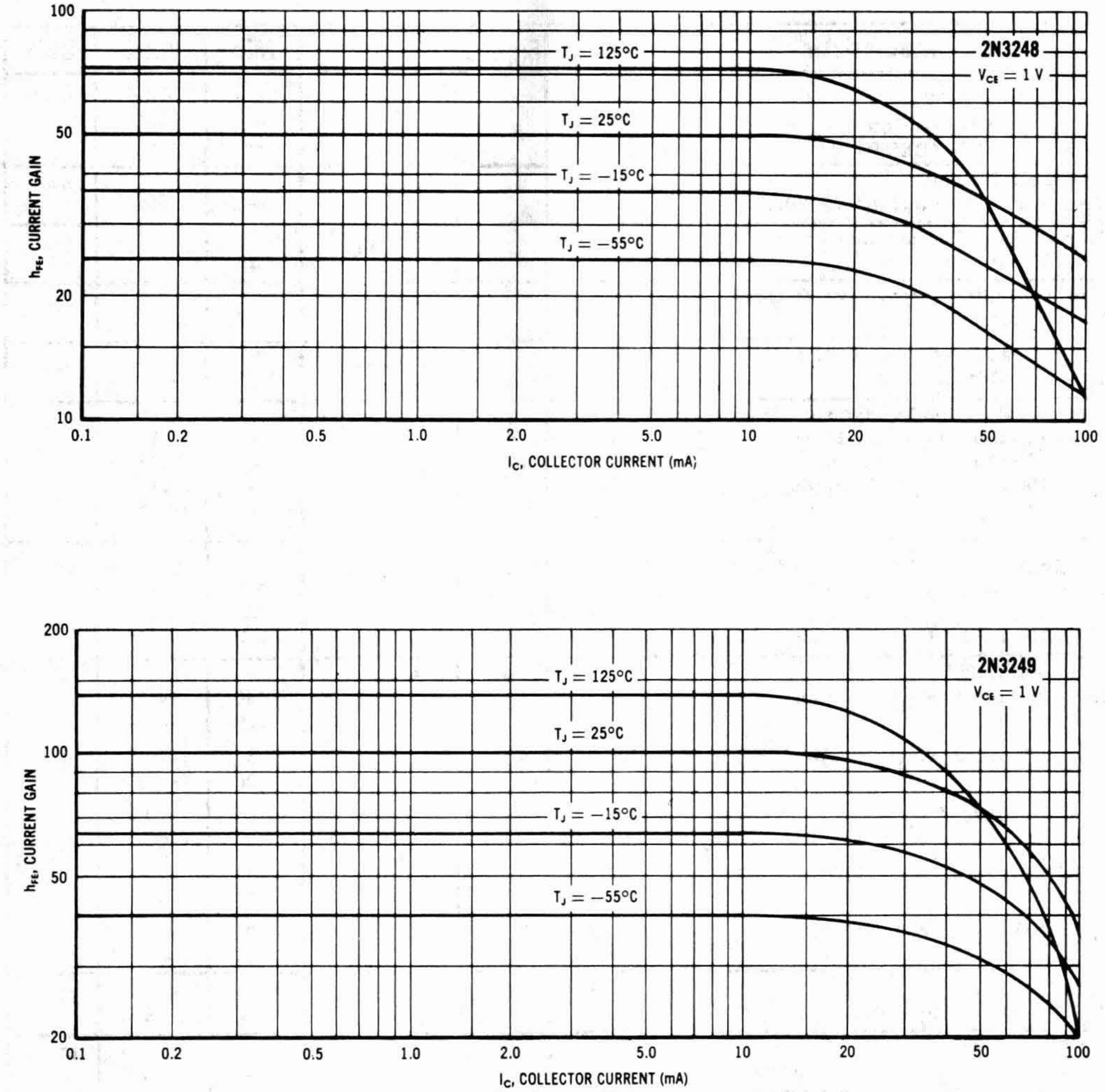


FIGURE 5 — MAXIMUM CHARGE DATA

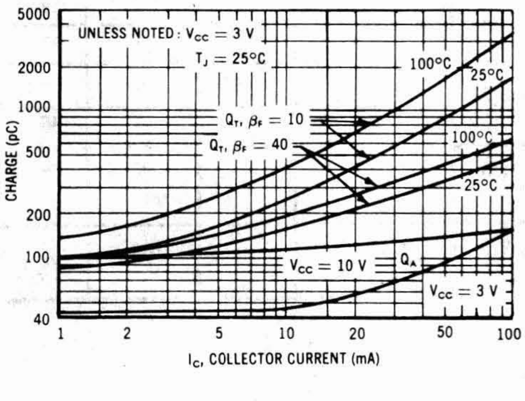


FIGURE 6 — JUNCTION CAPACITANCE

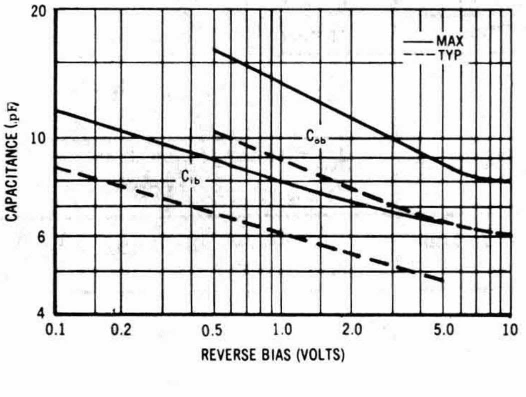


FIGURE 7 COLLECTOR SATURATION VOLTAGE CHARACTERISTICS

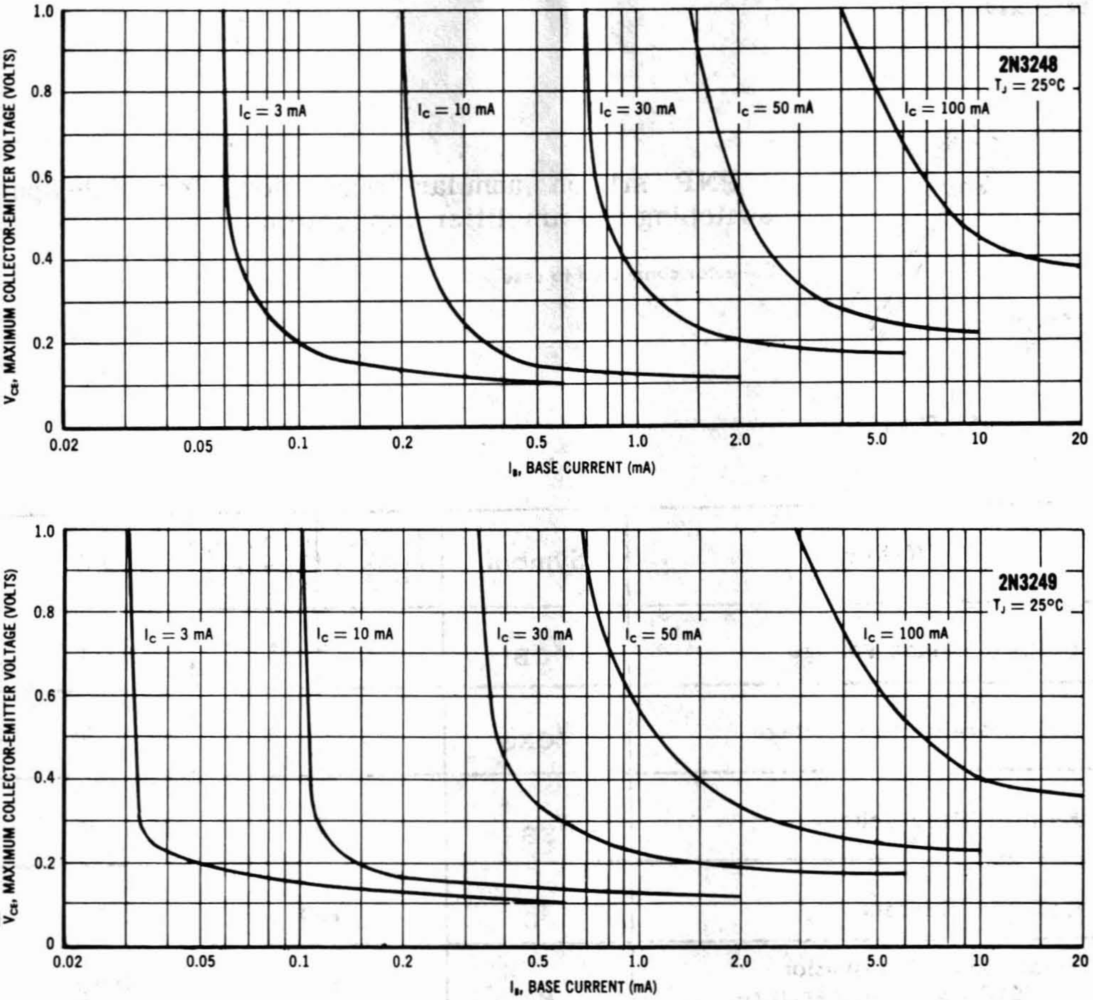


FIGURE 8 – SATURATION VOLTAGE LIMITS

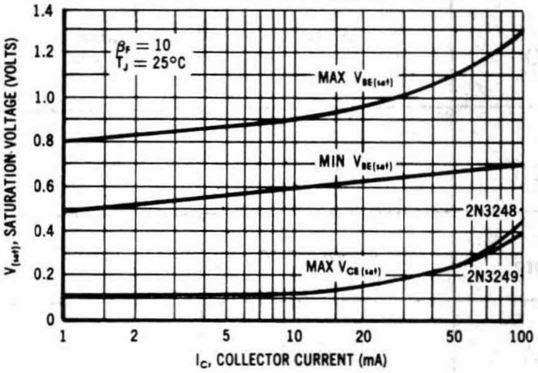
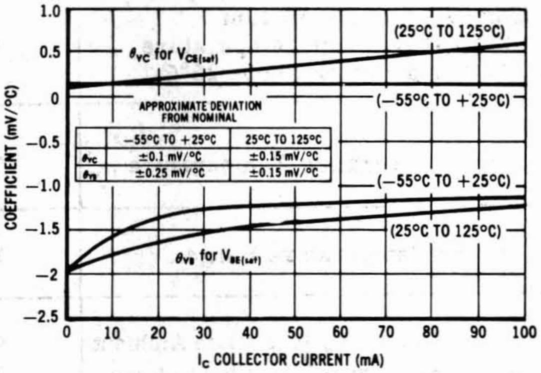


FIGURE 9 – TYPICAL TEMPERATURE COEFFICIENTS



APPROXIMATE DEVIATION FROM NOMINAL

	−55°C TO +25°C	25°C TO 125°C
θ_{VC}	±0.1 mV/°C	±0.15 mV/°C
θ_{VB}	±0.25 mV/°C	±0.15 mV/°C

FIGURE 10 – Q_T TEST CIRCUIT

VALUES REFER TO $I_C = 10$ mA TEST POINT

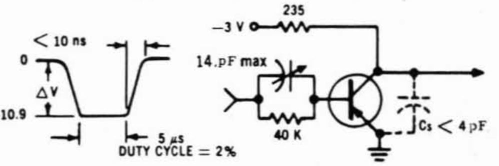
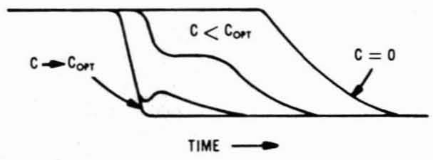
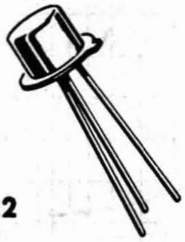

< 10 ns
0
ΔV
-10.9
5 μs
DUTY CYCLE = 2%
−3 V
235
14 pF max
40 K
$C_S < 4$ pF

FIGURE 11 – TURN-OFF WAVE FORM


$C < C_{OPT}$
$C \rightarrow C_{OPT}$
C = 0
TIME

2N3250, A (SILICON)
2N3251, A



CASE 22
(TO-18)

PNP silicon annular transistors for high-speed switching and amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N3250 2N3251	2N3250A 2N3251A	Unit
Collector-Base Voltage	V_{CB}	50	60	Vdc
Collector-Emitter Voltage	V_{CEO}	40	60	Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	200		mAdc
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	1.2 6.9		Watts mW/°C
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	0.36 2.06		Watts mW/°C
Junction Operating Temperature	T_J	200		°C
Storage Temperature Range	T_{stg}	−65 to +200		°C
Thermal Resistance, Junction to Ambient Thermal Resistance, Junction to Case	θ_{JA} θ_{JC}	0.49 0.15		°C/mW °C/mW

2N3250, A, 2N3251, A (Continued)

ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CE} = 40 Vdc, $V_{BE(off)}$ = 3 Vdc)		I_{CEX}	--	20	nAdc
Base Cutoff Current (V_{CE} = 40 Vdc, $V_{BE(off)}$ = 3 Vdc)		I_{BL}	--	50	nAdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc)	2N3250, 2N3251 2N3250A, 2N3251A	BV_{CBO}	50 60	--	Vdc
Collector-Emitter Breakdown Voltage * (I_C = 10 mAdc)	2N3250, 2N3251 2N3250A, 2N3251A	BV_{CEO} *	40 60	--	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc)		BV_{EBO}	5	--	Vdc
Collector Saturation Voltage * (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc)		$V_{CE(sat)}$ *	-- --	0.25 0.5	Vdc
Base-Emitter Saturation Voltage * (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc)		$V_{BE(sat)}$ *	0.6 --	0.9 1.2	Vdc
DC Forward Current Transfer Ratio * (I_C = 0.1 mAdc, V_{CE} = 1 Vdc)	2N3250, 2N3250A 2N3251, 2N3251A	h_{FE} *	40 80	-- --	--
(I_C = 1 mAdc, V_{CE} = 1 Vdc)	2N3250, 2N3250A 2N3251, 2N3251A		45 90	-- --	
(I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N3250, 2N3250A 2N3251, 2N3251A		50 100	150 300	
(I_C = 50 mAdc, V_{CE} = 1 Vdc)	2N3250, 2N3250A 2N3251, 2N3251A		15 30	-- --	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	--	6	pF
Input Capacitance (V_{CB} = 1 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	--	8	pF
Current-Gain - Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N3250, 2N3250A 2N3251, 2N3251A	f_T	250 300	-- --	MHz

SMALL SIGNAL CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Small Signal Current Gain (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3250, 2N3250A 2N3251, 2N3251A	h_{fe}	50 100	200 400	--
Voltage Feedback Ratio (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3250, 2N3250A 2N3251, 2N3251A	h_{re}	-- --	10 20	$X10^{-4}$
Input Impedance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3250, 2N3250A 2N3251, 2N3251A	h_{ie}	1 2	6 12	kohms
Output Admittance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	2N3250, 2N3250A 2N3251, 2N3251A	h_{oe}	4 10	40 60	µ mhos
Collector-Base Time Constant (I_C = 10 mA, V_{CE} = 20 V)		$r'_b C_C$	--	250	ps
Noise Figure (I_C = 100 µA, V_{CE} = 5 V, R_S = 1 kΩ, f = 100 Hz)		NF	--	6	dB

*Pulse Test: PW = 300 µs, Duty Cycle = 2%

SWITCHING CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic			Symbol	Max	Unit
Delay Time	(V_{CC} = 3 Vdc, V_{BE} = 0.5 Vdc I_C = 10 mAdc, I_{B1} = 1 mA)		t_d	35	ns
Rise Time			t_r	35	ns
Storage Time	(I_{B1} = I_{B2} = 1 mAdc V_{CC} = 3V)	2N3250, 2N3250A 2N3251, 2N3251A	t_s	175 200	ns
Fall Time			t_f	50	ns

SWITCHING TIME CHARACTERISTICS

FIGURE 1 — DELAY AND RISE TIME

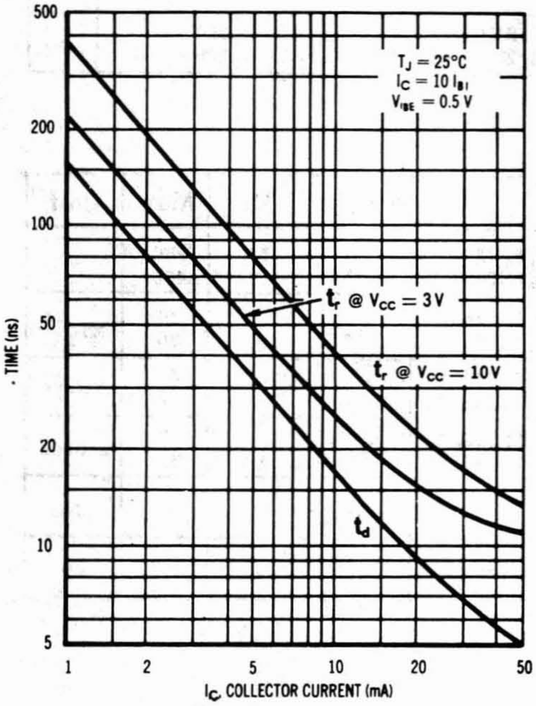
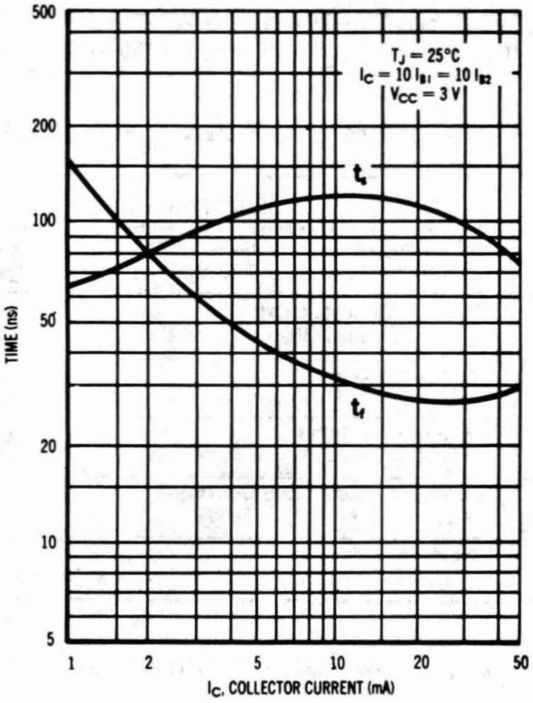


FIGURE 2 — STORAGE AND FALL TIME



AUDIO SMALL SIGNAL CHARACTERISTICS
NOISE FIGURE VARIATIONS
($V_{CE} = 6V$, $T_A = 25°C$)

FIGURE 3 — FREQUENCY

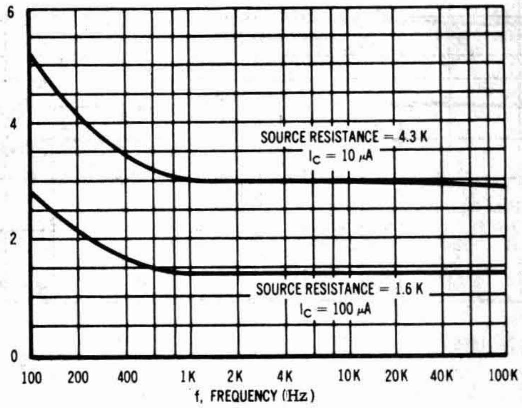
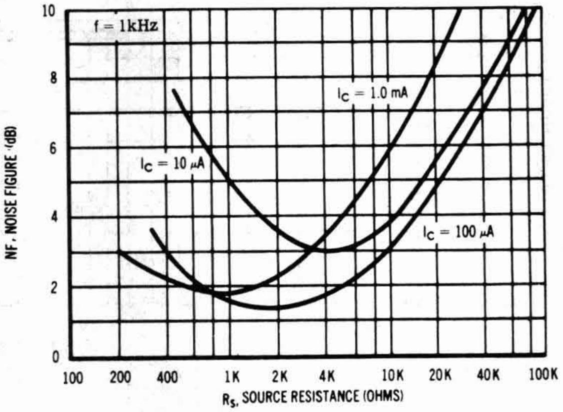


FIGURE 4 — SOURCE RESISTANCE



h PARAMETERS
$V_{CE} = 10$ V, f = 1 kHz, $T_A = 25°C$

FIGURE 5 — CURRENT GAIN

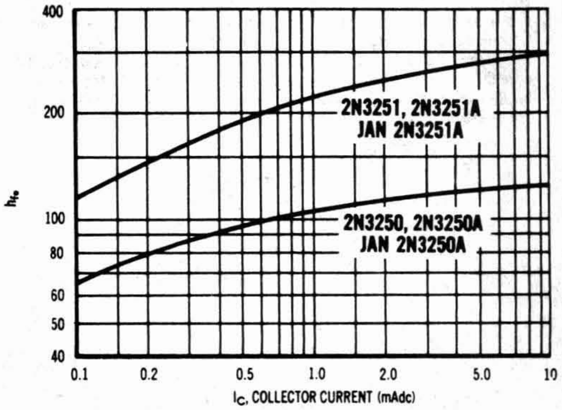


FIGURE 6 — OUTPUT ADMITTANCE

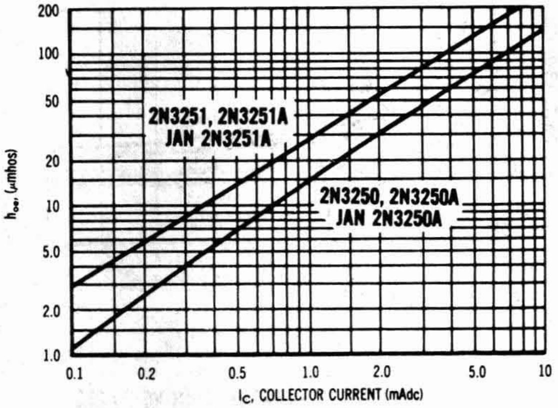


FIGURE 7 — VOLTAGE FEEDBACK RATIO

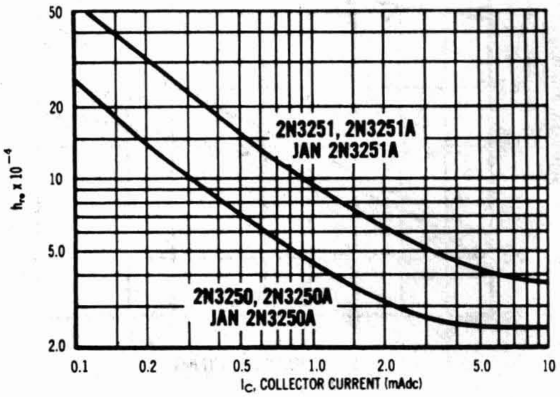


FIGURE 8 — INPUT IMPEDANCE

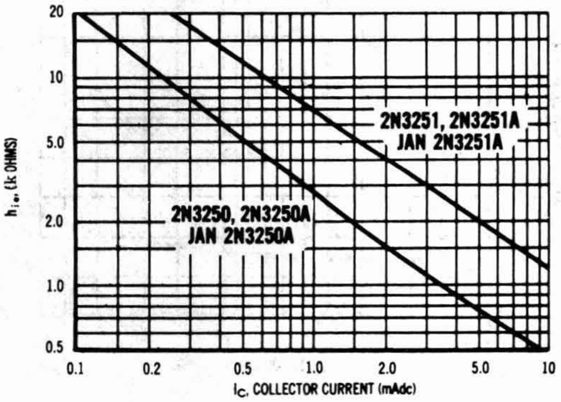


FIGURE 9 — NORMALIZED CURRENT GAIN CHARACTERISTICS

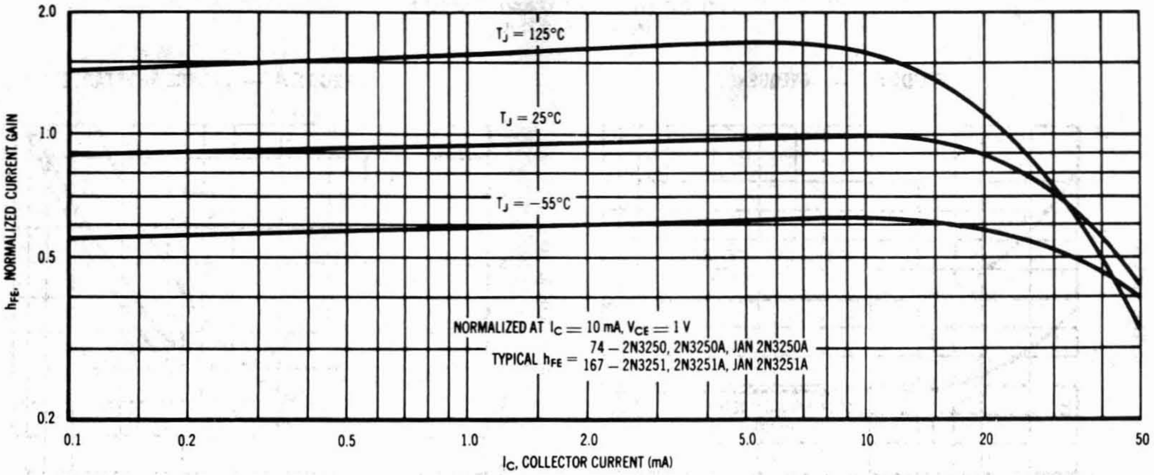
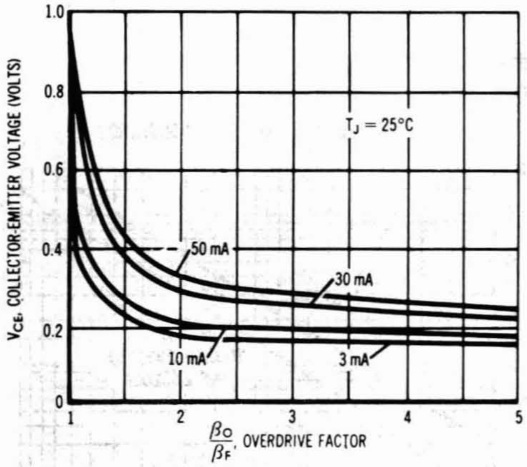


FIGURE 10 — COLLECTOR SATURATION REGION



This graph shows the effect of base current on collector current. β_O is the current gain of the transistor at 1 volt, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit. EXAMPLE: For type 2N3251, estimate a base current (I_{BF}) to insure saturation at a temperature of 25°C and a collector current of 10 mA.

Observe that at $I_C = 10$ mA an overdrive factor of at least 2.5 is required to drive the transistor well into the saturation region. From Figure 9, it is seen that h_{FE} @ 1 volt is typically 167 (guaranteed limits from the Table of Characteristics can be used for "worst-case" design) . . .

$$\frac{\beta_O}{\beta_F} = \frac{h_{FE} \text{ @ 1 Volt}}{I_C/I_{BF}} \qquad 2.5 = \frac{167}{10\,\text{mA}/I_{BF}} \qquad I_{BF} \approxeq 6.68\,\text{mA typ}$$

FIGURE 11 — SATURATION VOLTAGES

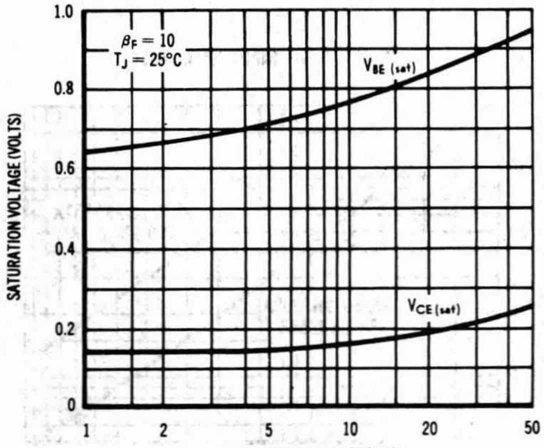


FIGURE 12 — TEMPERATURE COEFFICIENTS

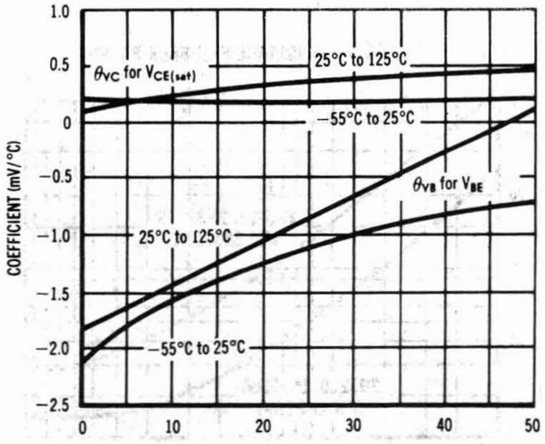


FIGURE 13 — f_T AND $r_b'C_C$ versus I_C

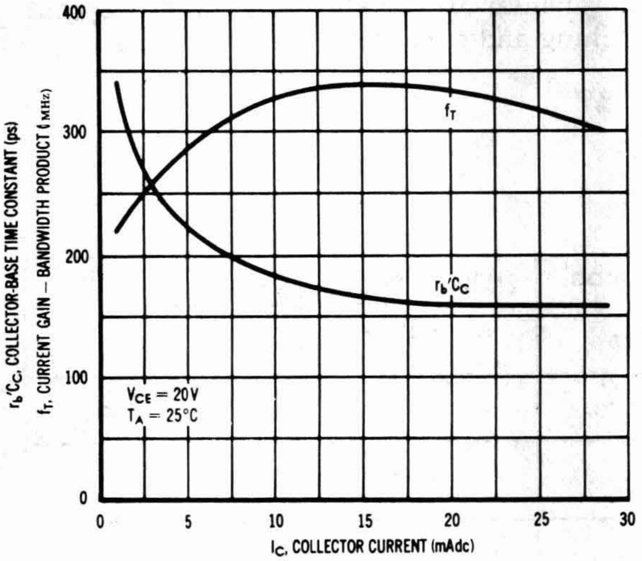


FIGURE 14 — 30 MC EQUIVALENT CIRCUIT

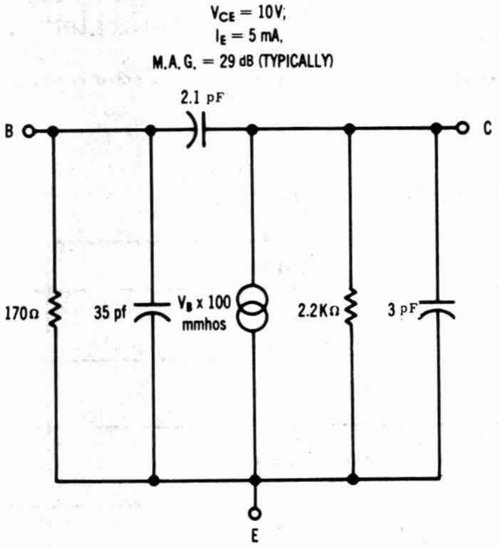

$V_{CE} = 10V$;
$I_E = 5\,mA$,
M.A.G. = 29 dB (TYPICALLY)
2.1 pF
B
C
E
170Ω
35 pf
V_B x 100 mmhos
2.2KΩ
3 pF

FIGURE 15 — JUNCTION CAPACITANCE

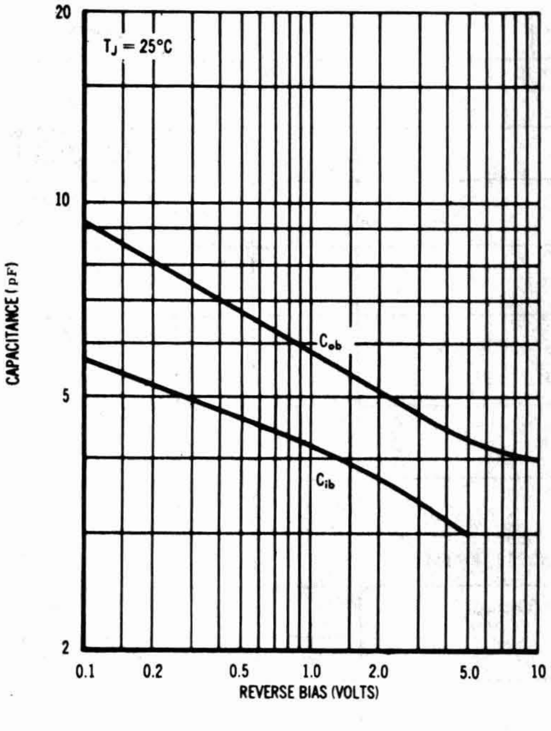
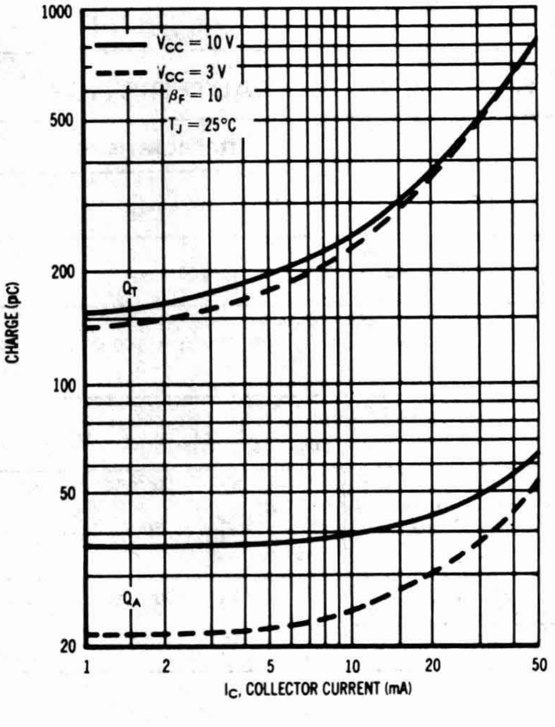


FIGURE 16 — CHARGE DATA



2N3252, 2N3253 (SILICON)
2N3444

CASE 31
(TO-5)

NPN silicon annular transistors for high-current saturated switching and core driver applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N3252	2N3253	2N3444	Unit
Collector-Base Voltage	V_{CB}	60	75	80	Vdc
Collector-Emitter Voltage	V_{CEO}	30	40	50	Vdc
Emitter-Base Voltage	V_{EB}	← 5 →			Vdc
Total Device Dissipation 25°C Case Temperature Derate above 25°C	P_D	← 5 → ← 28.6 →			Watts mW/°C
Total Device Dissipation 25°C Ambient Temperature Derate above 25°C	P_D	← 1.0 → ← 5.71 →			Watt mW/°C
Junction Operating Temperature Range	T_J	← -65 to +200 →			°C
Storage Temperature Range	T_{stg}	← -65 to +200 →			°C
Thermal Resistance:	θ_{JC} θ_{JA}	35 0.175			°C/W °C/mW

SWITCHING CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	12	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	80	pF
Current Gain-Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3252 2N3253, 2N3444	f_T	200 175	— —	MHz
Total Control Charge (I_C = 500 mAdc, I_{B1} = 50 mAdc, V_{CC} = 30 V)		Q_T	—	5	nC
Delay Time	I_C = 500 mAdc, I_{B1} = 50 mAdc	t_d	—	15	ns
Rise Time	V_{CC} = 30 V, V_{BE} = 2 V 2N3252 2N3253, 2N3444	t_r	— —	30 35	ns
Storage Time	I_C = 500 mAdc, I_{B1} = I_{B2} = 50 mAdc	t_s	—	40	ns
Fall Time	V_{CC} = 30 V	t_f	—	30	ns

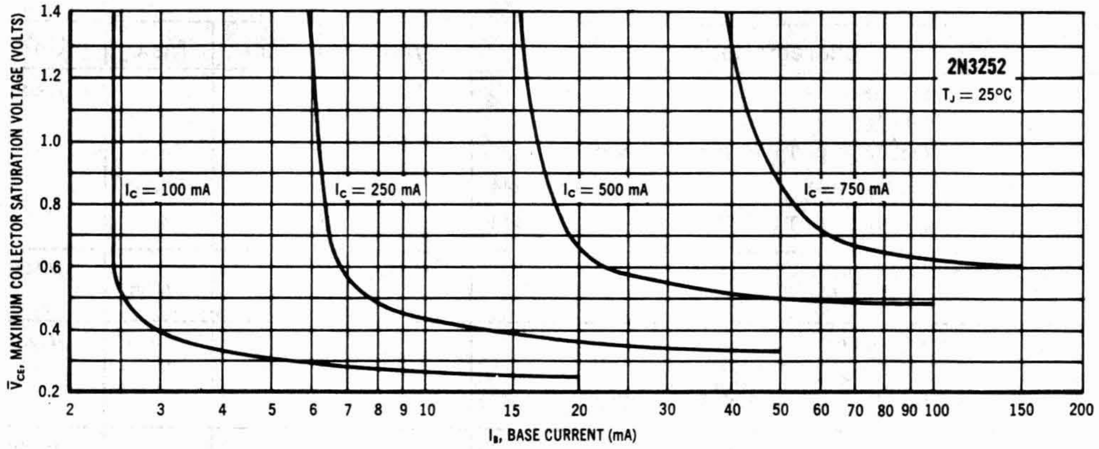
ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

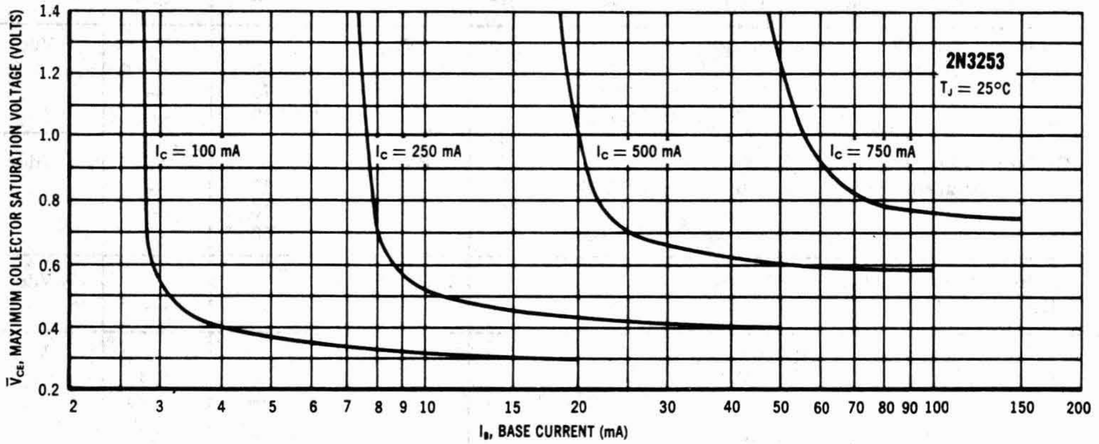
Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 40 Vdc, I_E = 0) 2N3252		—	0.50	
(V_{CB} = 40 Vdc, I_E = 0, T_A = 100°C) 2N3252			75.0	
(V_{CB} = 60 Vdc, I_E = 0) 2N3253, 2N3444			0.50	
(V_{CB} = 60 Vdc, I_E = 0, T_A = 100°C) 2N3253, 2N3444			75.0	
Emitter Cutoff Current	I_{EBO}			μAdc
(V_{BF} = 4 Vdc, I_C = 0)		—	0.05	
Collector Cutoff Current	I_{CEX}			μAdc
(V_{CE} = 40 Vdc, $V_{EB(off)}$ = 4 Vdc) 2N3252		—	0.5	
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 4 Vdc) 2N3253, 2N3444,		—	0.5	
Base Cutoff Current	I_{BL}			μAdc
(V_{CE} = 40 Vdc, $V_{EB(off)}$ = 4 Vdc) 2N3252		—	0.50	
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 4 Vdc) 2N3253, 2N3444		—	0.50	
Collector-Base Breakdown Voltage	BV_{CBO}			Vdc
(I_C = 10 μAdc, I_E = 0) 2N3252		60	—	
2N3253		75	—	
2N3444		80	—	
Collector-Emitter Breakdown Voltage *	BV_{CEO}*			Vdc
(I_C = 10 mAdc, pulsed, I_B = 0) 2N3252		30	—	
2N3253		40	—	
2N3444		50	—	
Emitter-Base Breakdown Voltage	BV_{EBO}			Vdc
(I_E = 10 μAdc, I_C = 0)		5	—	
Collector Saturation Voltage *	$V_{CE\,(sat)}$*			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc) 2N3252		—	0.3	
2N3253, 2N3444		—	0.35	
(I_C = 500 mAdc, I_B = 50 mAdc) 2N3252		—	0.5	
2N3253, 2N3444		—	0.60	
(I_C = 1.0 Adc, I_B = 100 mAdc) 2N3252		—	1.0	
2N3253, 2N3444		—	1.2	
Base-Emitter Saturation Voltage *	$V_{BE\,(sat)}$*			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		—	1.0	
(I_C = 500 mAdc, I_B = 50 mAdc)		0.7	1.3	
(I_C = 1.0 Adc, I_B = 100 mAdc)		—	1.8	
DC Forward Current Transfer Ratio *	h_{FE}*			—
(I_C = 150 mAdc, V_{CE} = 1 Vdc) 2N3252		30	—	
2N3253		25	—	
2N3444		20	—	
(I_C = 500 mAdc, V_{CE} = 1 Vdc) 2N3252		30	90	
2N3253		25	75	
2N3444		20	60	
(I_C = 1 Adc, V_{CE} = 5 Vdc) 2N3252		25	—	
2N3253		20	—	
2N3444		15	—	

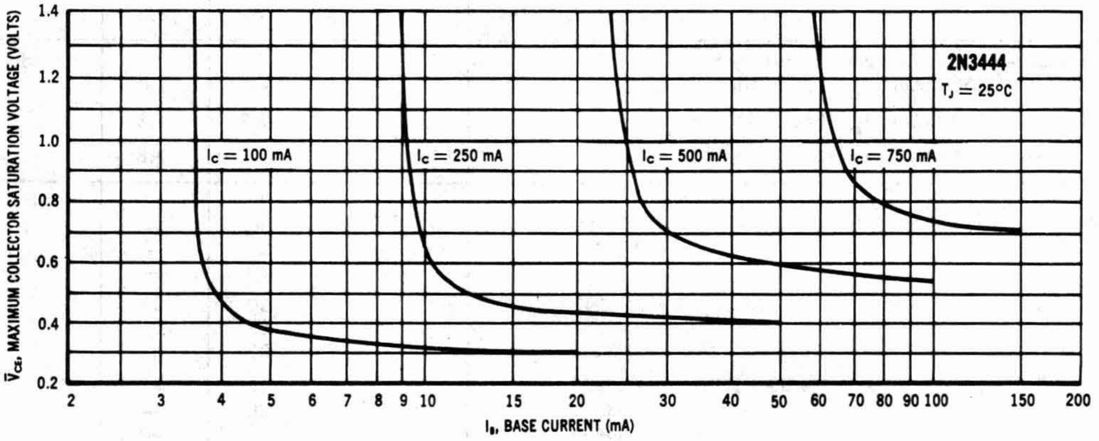
* Pulse Test: Pulse width = 300 μs, duty cycle = 2%

2N3252, 2N3253, 2N3444 (continued)

COLLECTOR SATURATION VOLTAGE CHARACTERISTICS

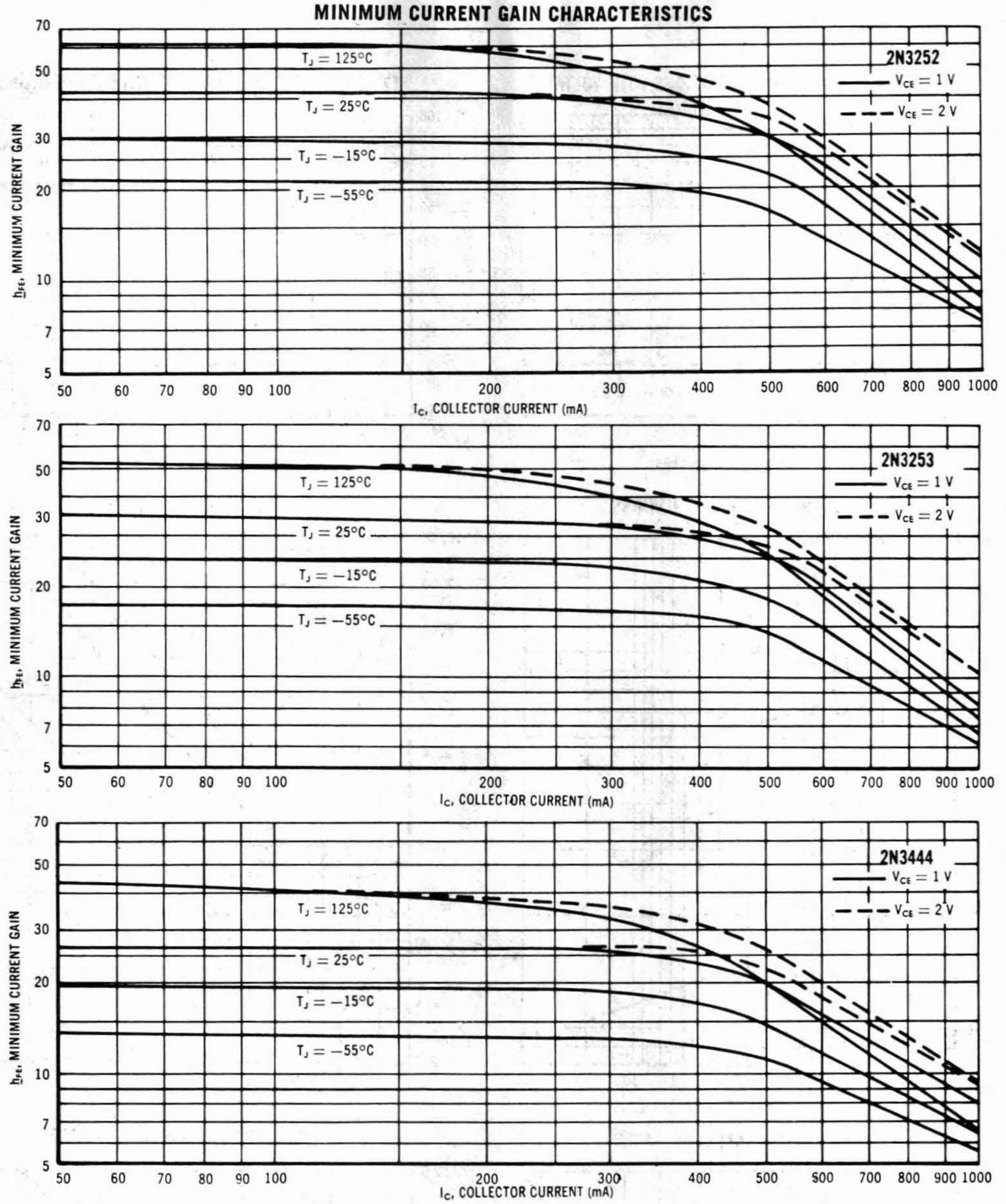




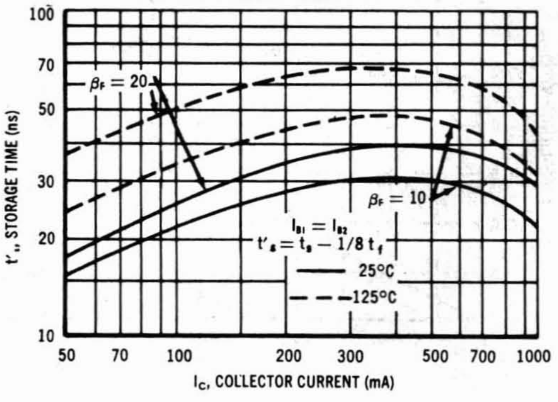


2N3252, 2N3253, 2N3444 (continued)

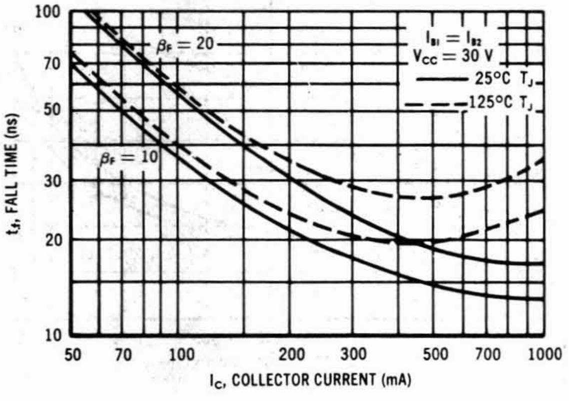
MINIMUM CURRENT GAIN CHARACTERISTICS



TYPICAL STORAGE TIME VARIATIONS

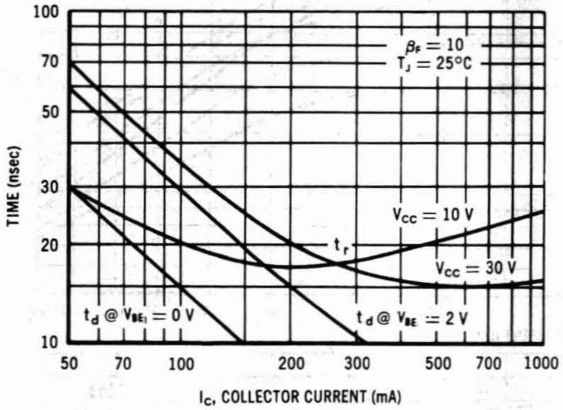


TYPICAL FALL TIME VARIATIONS

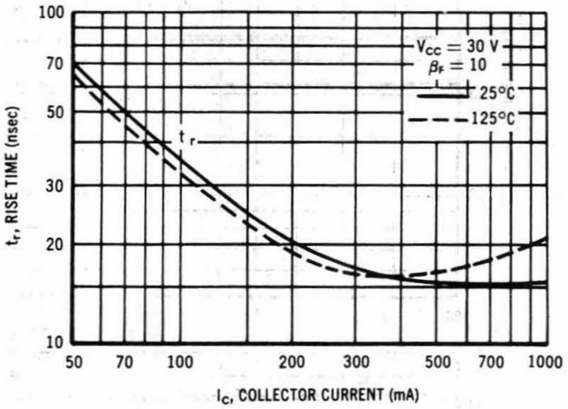


2N3252, 2N3253, 2N3444 (continued)

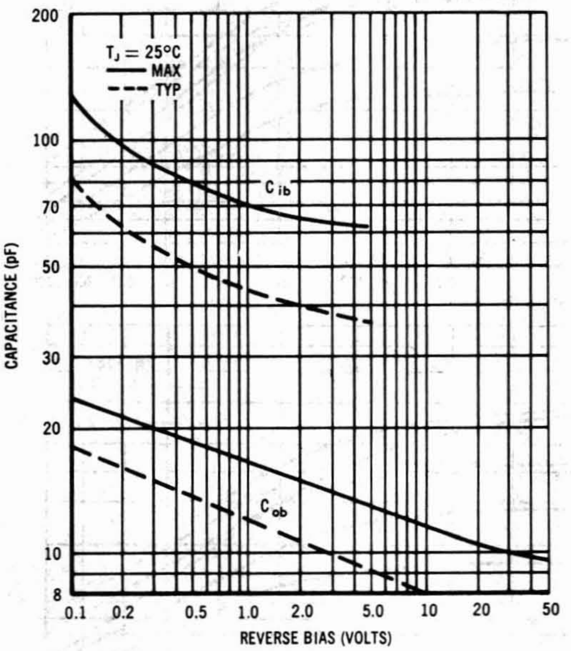
TYPICAL TURN-ON TIME VARIATIONS WITH VOLTAGE



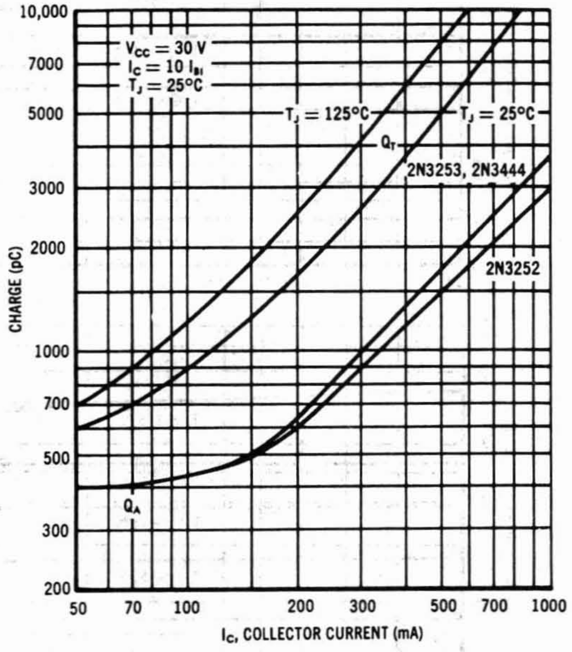
TYPICAL RISE TIME VARIATIONS WITH TEMPERATURE



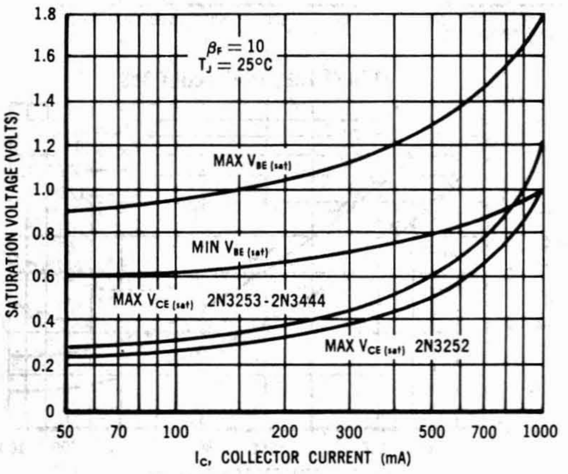
JUNCTION CAPACITANCE VARIATIONS



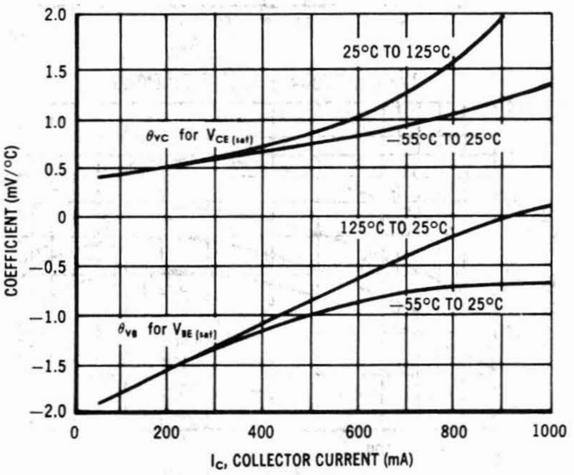
MAXIMUM CHARGE DATA



LIMITS OF SATURATION VOLTAGES



TYPICAL TEMPERATURE COEFFICIENTS



2N3279 thru 2N3282 (GERMANIUM)

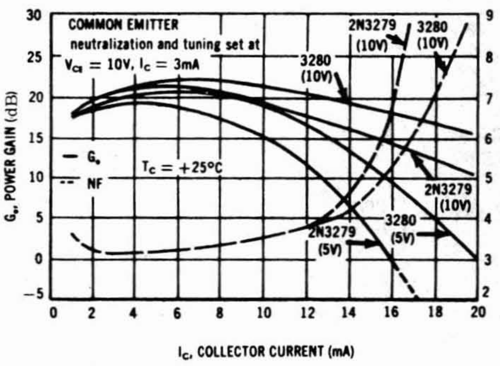
CASE 20
(TO-72)

PNP germanium epitaxial mesa transistors for high-gain, low-noise amplifier, oscillator, mixer and frequency multiplier applications.

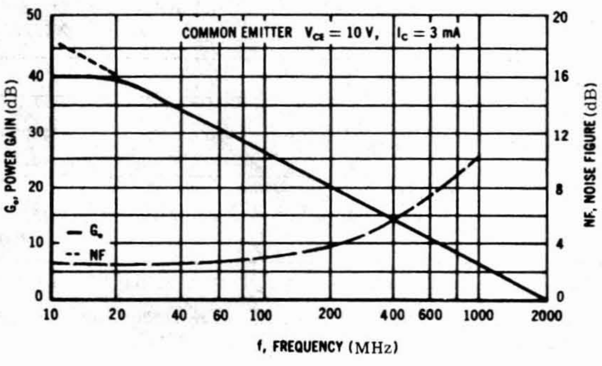
MAXIMUM RATINGS

Rating	Symbol	2N3279 2N3280	2N3281 2N3282	Unit
Collector-Emitter Voltage	V_{CEO}	20	15	Vdc
Collector-Emitter Voltage	V_{CES}	30		Vdc
Collector-Base Voltage	V_{CB}	30		Vdc
Emitter-Base Voltage	V_{EB}	1.0	0.5	
Collector Current	I_C	50		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	100 1.33		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100		°C

POWER GAIN AND NOISE FIGURE versus COLLECTOR CURRENT
200 MHz



NEUTRALIZED POWER GAIN AND NOISE FIGURE versus FREQUENCY



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 2.0 mAdc, I_B = 0)	2N3279, 2N3280	BV_{CEO}	20	-	-	Vdc
	2N3281, 2N3282		15	-	-	
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)		BV_{CES}	30	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	30	-	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	All Types	I_{CBO}	-	1.0	5.0	μAdc
(V_{CB} = 10 Vdc, I_E = 0, T_A = +55°C)	2N3279, 2N3280		-	-	50	
Emitter Cutoff Current (V_{BE} = 0.5 Vdc, I_C = 0)	2N3281, 2N3282	I_{EBO}	-	-	100	μAdc
(V_{BE} = 0.75 Vdc, I_C = 0)	2N3279, 2N3280		-	-	100	
ON CHARACTERISTICS						
DC Current Gain (I_C = 3.0 mAdc, V_{CE} = 10 Vdc)	2N3279, 2N3280	h_{FE}	10	-	70	-
	2N3281, 2N3282		10	-	100	
Collector-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 1.0 mAdc)	2N3279, 2N3280	$V_{CE(sat)}$	-	-	0.3	Vdc
	2N3281, 2N3282		-	-	0.5	
Base-Emitter Saturation Voltage (I_C = 5.0 mAdc, I_B = 1.0 mAdc)	2N3279, 2N3280	$V_{BE(sat)}$	-	-	1.0	Vdc
	2N3281, 2N3282		-	-	1.5	
DYNAMIC CHARACTERISTICS						
Current-Gain–Bandwidth Product (I_C = 3.0 mAdc, V_{CE} = 10 Vdc)	2N3279, 2N3280	f_T	400	500	800	MHz
	2N3281, 2N3282		300	400	800	
Maximum Frequency of Oscillation (I_C = 3.0 mAdc, V_{CE} = 10 Vdc)		f_{max}	-	2000	-	MHz
Output Capacitance* (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	2N3279	C_{ob}*	-	0.9	1.0	pF
	2N3280 thru 2N3282		-	1.0	1.2	
Small-Signal Current Gain (I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3279, 2N3280	h_{fe}	10	-	100	-
	2N3281, 2N3282		10	-	150	
Collector-Base Time Constant (I_E = 3.0 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)	2N3279, 2N3280	$r_b'C_c$	3.0	5.0	10	ps
	2N3281, 2N3282		3.0	5.0	15	
Noise Figure (I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 200 MHz)	2N3279, 2N3280	NF	-	2.9	3.5	dB
	2N3281, 2N3282		-	4.0	5.0	
FUNCTIONAL TESTS						
Power Gain (I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 200 MHz)	2N3279, 2N3280	G_{pe}	17	-	23	dB
	2N3281, 2N3282		16	-	23	
Power Gain (AGC)** (I_C = 20 mAdc, V_{CE} = 5.0 Vdc, f = 200 MHz)	2N3279, 2N3281	G_{pe}(AGC)**	-	-	0	dB
	2N3280, 2N3282		-	0	-	

*C_{ob} is measured in a guarded circuit such that the can capacitance is not included.

**AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = 10 Vdc and I_C = 3.0 mAdc operation.

2N3283 thru 2N3286 (GERMANIUM)

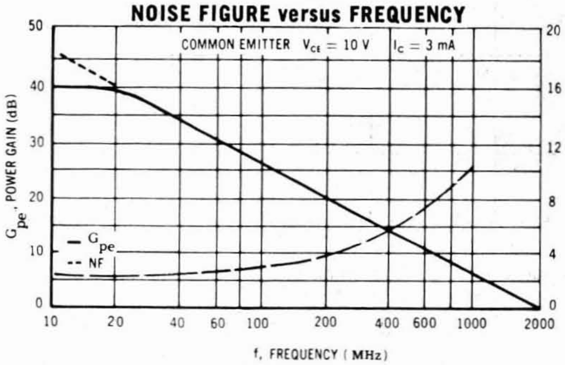
CASE 20
(TO-72)

PNP germanium epitaxial mesa transistors for TV and FM, RF and IF amplifier, oscillator and general purpose high-gain, low-noise amplifier applications.

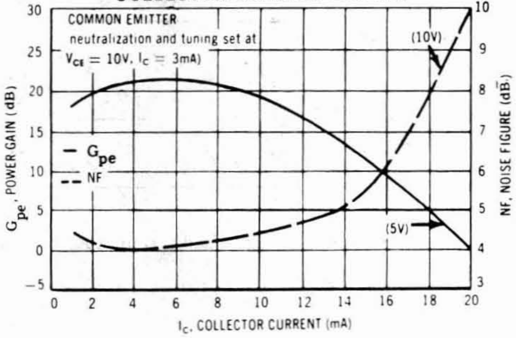
MAXIMUM RATINGS

Rating	Symbol	2N3283 2N3284	2N3285 2N3286	Unit
Collector-Emitter Voltage	V_{CES}	25	20	Vdc
Collector-Base Voltage	V_{CB}	25	20	Vdc
Emitter-Base Voltage	V_{EB}	0.5		Vdc
Collector Current	I_C	50		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	100 1.33		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100		°C

NEUTRALIZED POWER GAIN AND NOISE FIGURE versus FREQUENCY



POWER GAIN AND NOISE FIGURE versus COLLECTOR CURRENT 200 MHZ



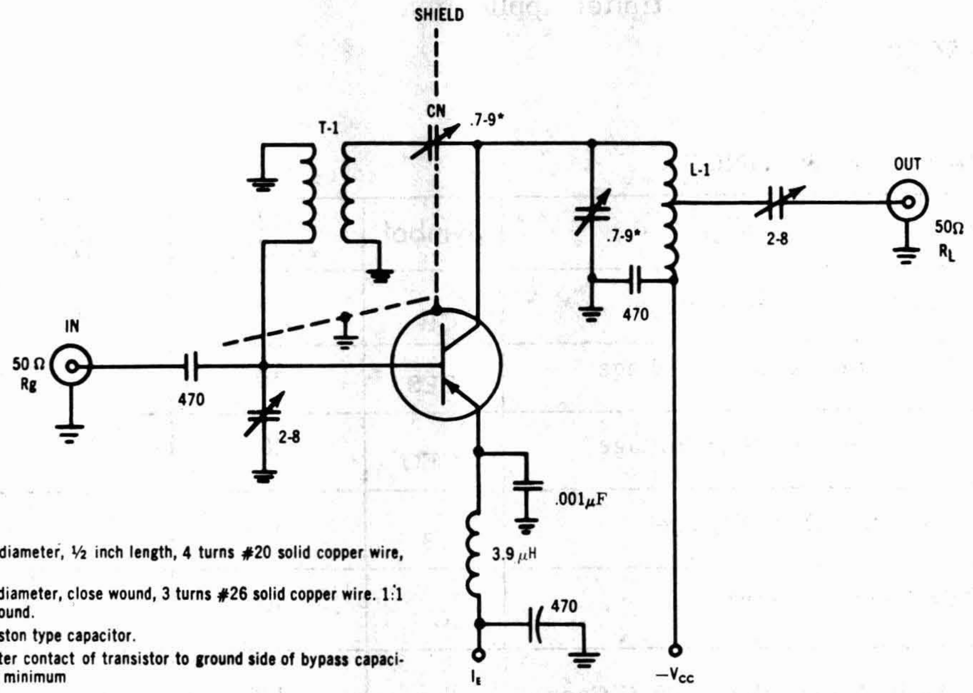
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0) 2N3283, 2N3284 2N3285, 2N3286	BV_{CES}	25 20	30 25	- -	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	2.0	10	μAdc
Emitter Cutoff Current (V_{BE} = 0.5 Vdc, I_C = 0)	I_{EBO}	-	-	100	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 3.0 mAdc, V_{CE} = 10 Vdc) 2N3283, 2N3284 2N3285, 2N3286	h_{FE}	10 5.0	30 15	- -	-
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250	400	800	MHz
Maximum Frequency of Oscillation (I_C = 3.0 mAdc, V_{CE} = 10 Vdc)	f_{max}	-	2000	-	MHz
Output Capacitance* (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}*	-	1.0	1.5	pF
Small-Signal Current Gain (I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3283, 2N3284 2N3285, 2N3286	h_{fe}	10 5.0	- -	200 200	-
Collector-Base Time Constant (I_E = 3.0 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)	$r_b'C_c$	-	10	25	ps
Noise Figure (I_C = 3.0 mAdc, V_{CE} = 10 Vdc, f = 200 MHz) 2N3283 2N3284 2N3286	NF	- - -	4.0 5.0 5.0	5.0 6.0 -	dB
FUNCTIONAL TESTS					
Common-Emitter Amplifier Power Gain (V_{CE} = 10 Vdc, I_C = 3.0 mAdc, f = 200 MHz) 2N3283, 2N3284 2N3286	G_{pe}	16 14	20 -	23 -	dB
Power Gain (AGC)** (V_{CE} = 5.0 Vdc, I_C = 20 mAdc, f = 200 MHz, Figure 1) 2N3283 2N3284	G_{pe}(AGC)**	- -	- 0	0 -	dB
Power Output (V_{EE} = 12 Vdc, f = 247 MHz) 2N3285	P_{out}	2.0	-	-	mW

* C_{ob} is measured in a guarded circuit such that the can capacitance is not included.

** AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = 10 Vdc and I_C = 3.0 mAdc operation.

FIGURE 1 — 200 MHz POWER GAIN AND NOISE FIGURE TEST CIRCUIT


SHIELD
CN
.7-9*
T-1
L-1
OUT
50Ω
R_L
2-8
.7-9*
470
IN
50 Ω
Rg
470
2-8
.001μF
3.9 μH
470
I_E
$-V_{CC}$

NOTES:

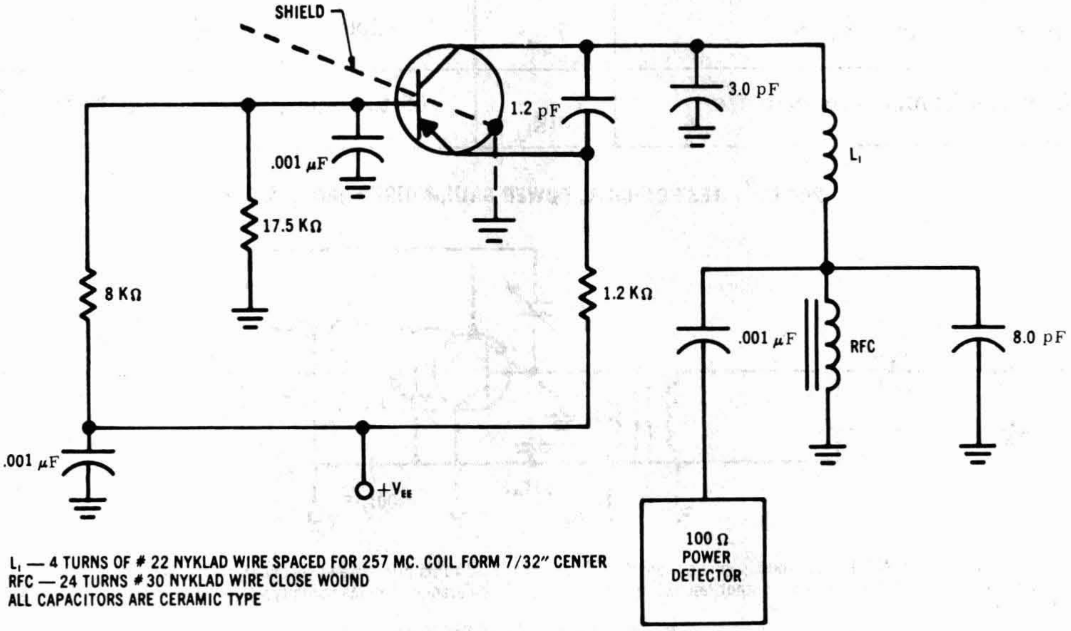
L-1 ¼ inch inside diameter, ½ inch length, 4 turns #20 solid copper wire, center tapped.

T-1 ¼ inch inside diameter, close wound, 3 turns #26 solid copper wire. 1:1 ratio bi-filler wound.

* High Quality piston type capacitor.

Distance from emitter contact of transistor to ground side of bypass capacitor should be kept minimum

FIGURE 2 — 257 MHz OSCILLATOR POWER OUTPUT TEST CIRCUIT


SHIELD
1.2 pF
3.0 pF
.001 μF
L_1
17.5 KΩ
8 KΩ
1.2 KΩ
.001 μF
RFC
8.0 pF
.001 μF
$+V_{EE}$
100 Ω
POWER
DETECTOR

L_1 — 4 TURNS OF # 22 NYKLAD WIRE SPACED FOR 257 MC. COIL FORM 7/32″ CENTER
RFC — 24 TURNS # 30 NYKLAD WIRE CLOSE WOUND
ALL CAPACITORS ARE CERAMIC TYPE

2N3287 thru 2N3290 (SILICON)

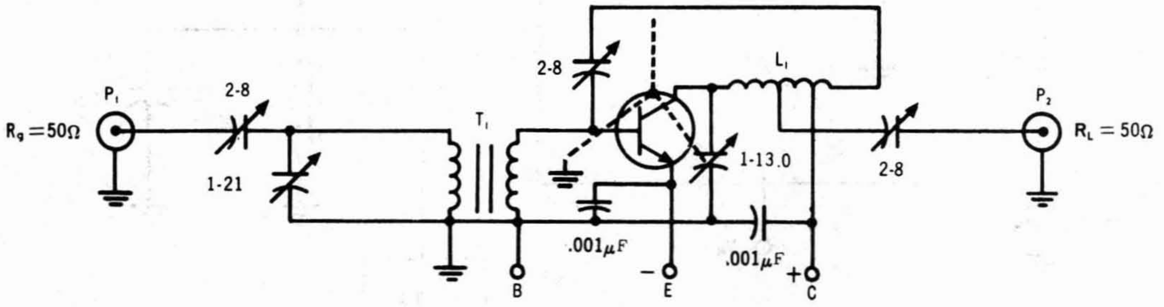
CASE 20
(TO-72)

NPN silicon annular transistors for high-gain, low-noise amplifier, oscillator, mixer and frequency multiplier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3287 2N3288	2N3289 2N3290	Unit
Collector - Base Voltage	V_{CB}	40	30	Volts
Collector - Emitter Voltage	V_{CES}	40	30	Volts
Collector - Emitter Voltage	V_{CEO}	20	15	Volts
Emitter - Base Voltage	V_{EB}	3.0	3.0	Volts
Collector Current	I_C	50	50	mA
Power Dissipation at 25°C Case Above 25°C derate 1.71 mW/°C	P_D	300	300	mW
Power Dissipation at 25° C amb. Above 25°C derate 1.14 mW/°C	P_D	200	200	mW
Junction Temperature	T_J,	+200	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	-65 to +200	°C

200 MHz TEST CIRCUIT: POWER GAIN, NOISE FIGURE, & AGC



L_1-6 turns of #16 tinned wire; 3/8" ID; Air wound; winding length 3/4"; V_{CC} feeds tap 4¾ turns from collector end; output tap 3½ turns from collector end.

T_1-3 turns primary and secondary Bifilar wound (close wound) on ¼" ceramic form (cambion type) with brass slug. #22 enameled wire.

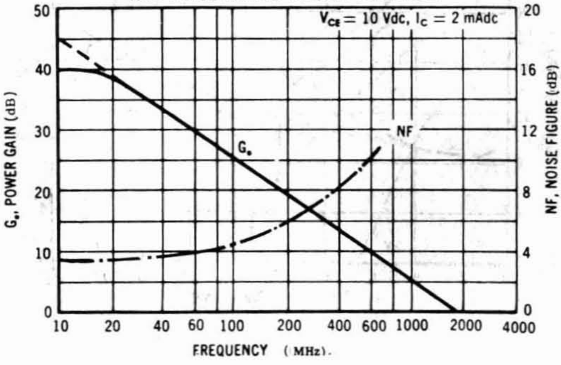
P_1-General Radio 874 G6 Pad (6dB)
P_2-General Radio 874 G6 Pad (6dB)

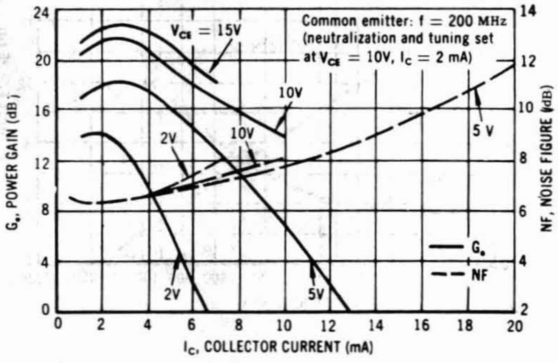
ELECTRICAL CHARACTERISTICS (At 25°C Ambient unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	I_C = 10 μAdc, I_E = 0 2N3287, 2N3288 2N3289, 2N3290	 40 30	 — —	 — —	Vdc
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 10 μAdc, V_{BE} = 0 2N3287, 2N3288 2N3289, 2N3290	 40 30	 — —	 — —	Vdc
Collector-Emitter Breakdown Voltage	BV_{CEO}	I_C = 2.0 mAdc, I_B = 0 2N3287, 2N3288 2N3289, 2N3290	 20 15	 — —	 — —	Vdc
Emitter-Base Breakdown Voltage	BV_{EBO}	I_E = 10 μAdc, I_C = 0	3.0	—	—	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 15 Vdc All Types V_{CB} = 15 Vdc, T = 150°C 2N3287, 2N3288	— —	— —	.010 3.0	μAdc
DC Forward Current Transfer Ratio	h_{FE}	V_{CE} = 10 Vdc, I_C = 2 mAdc 2N3287, 2N3288 2N3289, 2N3290	 15 10	 — —	 100 150	—
Collector-Emitter Saturation Voltage	$V_{CE\,(sat)}$	I_C = 5 mAdc, I_B = 0.5 mAdc 2N3287, 2N3288 2N3289, 2N3290	 — —	 — —	 0.3 0.4	Vdc
Base-Emitter Saturation Voltage	$V_{BE\,(sat)}$	I_C = 5 mAdc, I_B = 0.5 mAdc 2N3287, 2N3288 2N3288, 2N3290	 — —	 — —	 0.9 1.0	Vdc
AC Current Gain	h_{fe}	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 1 kHz 2N3287, 2N3288 2N3289, 2N3290	 15 10	 — —	 150 200	—
Output Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 0.1 MHz (Note 1) 2N3287 2N3288 thru 2N3290	 — —	 0.9 1.2	 1.1 1.5	pF
Collector-Base Time Constant	$r_b{}'C_c$	V_{CB} = 10 Vdc, I_C = 2 mAdc, f = 31.8 MHz 2N3287, 2N3288 2N3289, 2N3290	 3 3	 8 8	 15 20	ps
Current Gain - Bandwidth Product	f_T	V_{CE} = 10 Vdc, I_C = 2 mAdc 2N3287, 2N3288 2N3289, 2N3290	 350 300	 600 500	 1200 1200	MHz
Maximum Frequency of Oscillation	f_{max}	V_{CE} = 10 Vdc, I_C = 2 mAdc	—	2000	—	MHz
Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 200 MHz All Types	 17	 —	 24	dB
Noise Figure	NF	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 200 MHz 2N3287, 2N3288 2N3289, 2N3290	 — —	 4.9 6.0	 6.0 7.0	dB
Power Gain (AGC)	G_e	V_{CE} = 5.0 Vdc, I_C = 20 mAdc, f = 200MHz (Note 2) 2N3287 2N3289 2N3288, 2N3290	 — — —	 — — 0	 0 +5 —	dB

Note 1. C_{ob} is measured in guarded circuit such that the can capacitance is not included.

Note 2. AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = 10 Vdc, I_C = 2 mAdc operation.


NEUTRALIZED POWER GAIN AND NOISE FIGURE versus FREQUENCY


POWER GAIN AND NOISE FIGURE versus COLLECTOR CURRENT

2N3291 thru 2N3294 (SILICON)

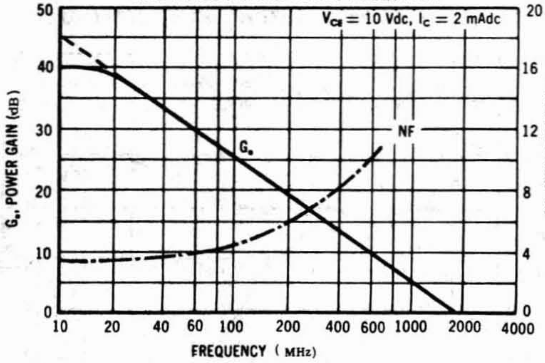
CASE 20
(TO-72)

NPN silicon annular transistor for TV and FM mixer, RF and IF amplifier and general-purpose, low-noise, high-gain amplifier applications.

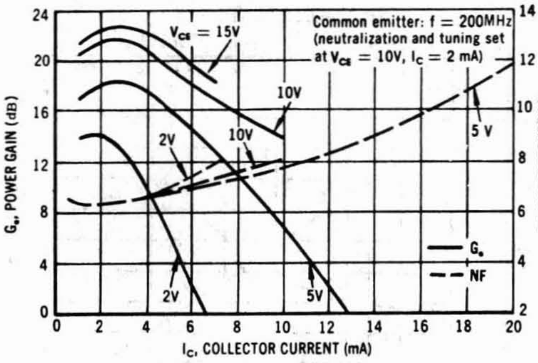
MAXIMUM RATINGS

Rating	Symbol	2N3291 2N3292	2N3293 2N3294	Unit
Collector - Base Voltage	V_{CB}	25	20	Volts
Collector - Emitter Voltage	V_{CES}	25	20	Volts
Emitter - Base Voltage	V_{EB}	3.0	3.0	Volts
Collector Current	I_C	50	50	mA
Power Dissipation at 25°C Case Above 25°C derate 1.71 mW/°C	P_D	300	300	mW
Power Dissipation at 25°C Amb. Above 25°C derate 1.14 mW/°C	P_D	200	200	mW
Junction Temperature	T_J	+200	+200	°C
Storage Temperature Range	T_{stg}	← -65 to +200 →		°C

NEUTRALIZED POWER GAIN AND NOISE FIGURE versus FREQUENCY



POWER GAIN AND NOISE FIGURE versus COLLECTOR CURRENT



2N3291 thru 2N3294 (Continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 25 µAdc, V_{BE} = 0 2N3291, 2N3292 2N3293, 2N3294	25 20	35 30	— —	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 10 Vdc, I_E = 0	—	.01	0.1	µAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 0.5 Vdc, I_C = 0	—	—	100	µAdc
DC Forward Current Transfer Ratio	h_{FE}	V_{CE} = 10 Vdc, I_C = 2 mAdc	10	—	—	—
AC Current Gain	h_{fe}	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 1 kHz	10	—	200	—
Output Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz , Note 1	—	1.0	2.0	pF
AC Current Gain	$\lvert h_{fe} \rvert$	V_{CE} = 10 Vdc, I_C = 2 mAdc f = 100 MHz	2.5	6.0	12	—
Collector-Base Time Constant	$r_b'C_c$	V_{CB} = 10 Vdc, I_C = 2 mAdc f = 31.8 MHz	—	15	30	ps
Maximum Frequency of Oscillation	f_{max}	V_{CE} = 10 Vdc, I_C = 2 mA	—	2000	—	MHz

2N3291

Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 200 MHz	16	20	24	dB
Noise Figure	NF		—	6	8	dB
Power Gain (AGC)	G_e	Note 2 V_{CE} = 5 Vdc, I_C = 20 mAdc f = 200 MHz	—	—	0	dB

2N3292

Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 2 mAdc f = 200 MHz	16	20	24	dB
Noise Figure	NF		—	7	9	dB
Power Gain (AGC)	G_e	Note 2 V_{CE} = 5 Vdc, I_C = 20 mAdc f = 200 MHz	—	0	—	dB

2N3293

Power Output	P_{out}	V_{EE} = -11 Vdc, f = 257 MHz	2	—	—	mW

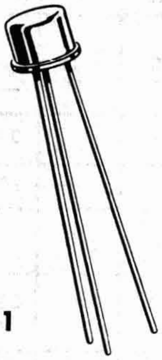
2N3294

Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 2 mAdc f = 200 MHz	14	—	—	dB
Noise Figure	NF		—	7	—	dB

Note 1. C_{ob} is measured in guarded circuit such that the can capacitance is not included.

Note 2. AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = 10 Vdc, I_C = 2 mAdc operation.

2N3295 (SILICON)



CASE 31
(TO-5)

NPN silicon annular Star transistor for linear amplifier applications from 2 to 100 MHz.

Collector connected to case

MAXIMUM RATINGS*

Rating	Symbol	Rating	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CES}	60	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current (Continuous)	I_C	250	mAdc
Base Current (Continuous)	I_B	50	mAdc
Total Device Dissipation (25°C Case Temperature) Derate above 25°C	P_D	2 13.3	Watts mW/°C
Total Device Dissipation (25°C Ambient Temperature) Derate above 25°C	P_D	0.8 5.33	Watts mW/°C
Junction Temperature Range	T_J	-65 to 175	°C
Storage Temperature Range	T_{stg}	-65 to 175	°C

* The maximum ratings as given for DC conditions can be exceeded on a pulse basis. See Electrical Characteristics.

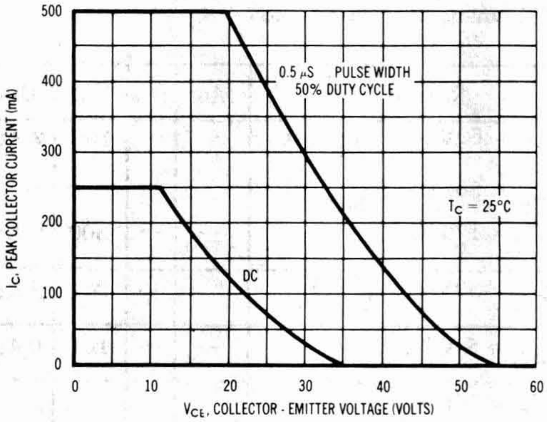
ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Rating	Min	Typ	Max	Unit
Collector-Emitter Current	I_{CES}	V_{CE} = 60Vdc, V_{BE} = 0	--	--	100	μ Adc
		V_{CE} = 50Vdc, V_{BE} = 0, T_C = 175°C	--	--	500	μ Adc
Collector Cutoff Current	I_{CBO}	V_{CB} = 50Vdc, I_E = 0	--	--	0.1	μ Adc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 5 Vdc, I_C = 0	--	--	100	μ Adc
DC Current Gain	h_{FE}	I_C = 10mAdc, V_{CE} = 10Vdc	20	--	60	--
		I_C = 150mAdc, V_{CE} = 10Vdc *	20	--	--	--
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 150mAdc, I_B = 15mAdc	--	--	0.5	Vdc
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	I_C = 150mAdc, I_B = 15mAdc	--	--	2.0	Vdc
Collector-Emitter Sustain Voltage	$V_{CES(sus)}$*	I_C = 100mA, R_{BE} = 0	30	--	--	Volts
Collector-Emitter Open Base Sustain Voltage	$V_{CEO(sus)}$*	I_C = 100mA, I_B = 0	20	--	--	Volts
AC Current Gain	$\|h_{fe}\|$	V_{CE} = 10Vdc, I_C = 10mAdc, f=50 MHz	4.0	--	--	--
Collector Output Capacitance	C_{ob}	V_{CB} = 10Vdc, I_E = 0, f = 100 kHz	--	--	8	pF
Power Input (PEP) (Note 1)	P_{in}	P_{out} = 0.3 Watts PEP (0.15 W rms) f = 30 MHz, V_{CE} = 15.0Vdc $I_{C(max)}$ = 40 mA	--	--	12	mW
Power Gain	G_e		14	17	--	dB
Intermodulation Distortion Ratio	I_m		30	32	--	dB
Efficiency	η		25	30	--	%

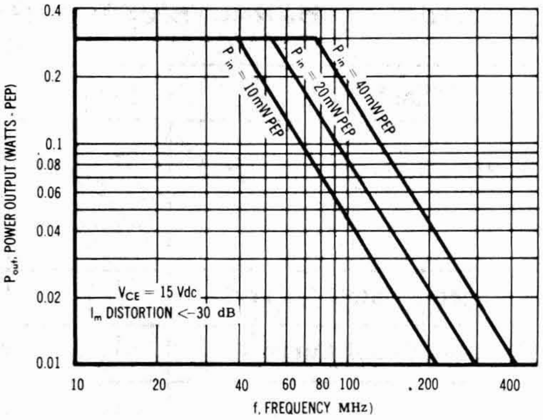
* Pulse Test: Pulse Width = 100 μs, Duty Cycle = 2 %

Note 1. PEP. Peak Envelope Power

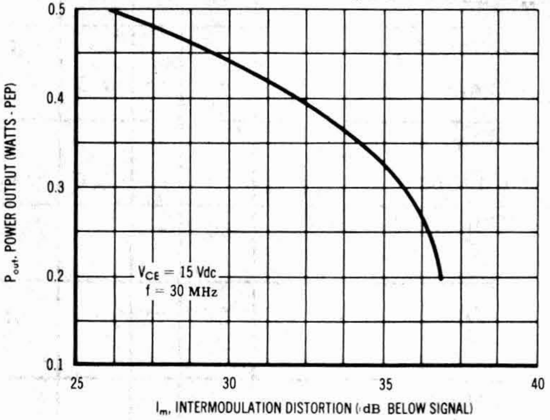
SAFE OPERATING AREA



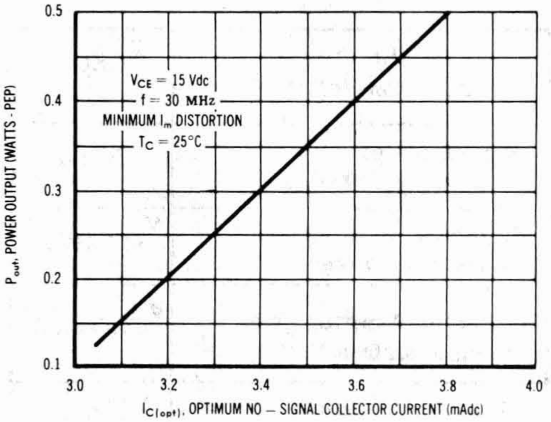
POWER OUTPUT versus FREQUENCY



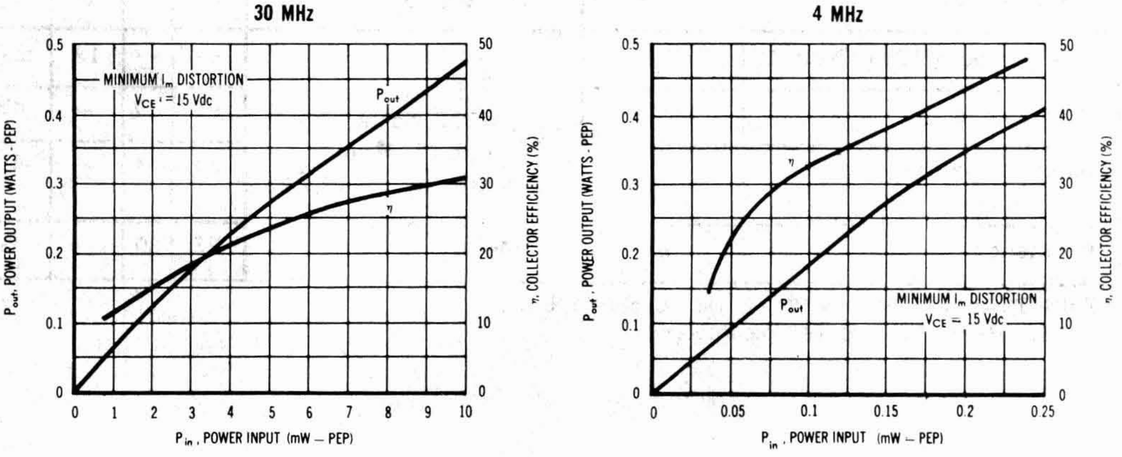
MAXIMUM POWER OUTPUT FOR GIVEN I_m DISTORTION LEVEL



POWER OUTPUT versus OPTIMUM BIAS



OUTPUT CHARACTERISTICS versus POWER INPUT


30 MHz

4 MHz

2N3296 (SILICON)

CASE 24
(TO-102)
Collector connected to case;
stud isolated from case

NPN silicon annular transistor for linear amplifier applications from 2 to 100 MHz.

MAXIMUM RATINGS (Note 1)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CES}	60	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current (Continuous)	I_C	700	mAdc
Base Current (Continuous)	I_B	100	mAdc
RF Input Power (Note 2)	P_{in}	1.0	Watt (PEP)
RF Output Power (Note 2)	P_{out}	5.0	Watts (PEP)
Total Device Dissipation (25°C Case Temperature) Derating Factor above 25°C	P_D	6.0 40	Watts mW/°C
Total Device Dissipation at (25°C Ambient Temperature) Derating Factor above 25°C	P_D	0.7 4.67	Watts mW/°C
Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

Note 1: The maximum ratings as given for dc conditions can be exceeded on a pulse basis. See Electrical Characteristics.

Note 2: PEP = Peak Envelope Power.

2N3296 (Continued)

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Conditions	Min	Typ	Max	Unit
Collector-Emitter Sustain Voltage	$V_{CES(sus)}$*	$I_C = 0.200A,\ R_{BE} = 0$	85	120	--	Volts
Collector Emitter-Open Base Sustain Voltage	$V_{CEO(sus)}$*	$I_C = 0.200A,\ I_B = 0$	40	--	--	Volts

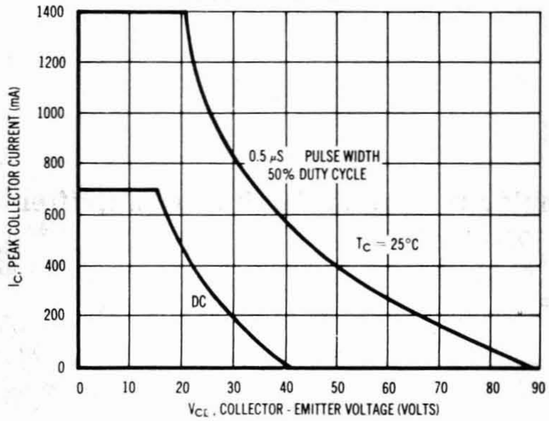
Collector-Emitter Current	I_{CES}	$V_{CE} = 60Vdc,\ V_{BE} = 0$	--	--	100	µAdc
		$V_{CE} = 50Vdc,\ V_{BE} = 0,\ T_C = +175°C$	--	--	500	
Collector-Cutoff Current	I_{CBO}	$V_{CB} = 50Vdc,\ I_E = 0$	--	--	0.1	µAdc
Emitter-Cutoff Current	I_{EBO}	$V_{EB} = 3Vdc,\ I_C = 0$	--	--	100	µAdc
DC Current Gain	h_{FE}	$V_{CE} = 2.0Vdc,\ I_C = 40mAdc$	5.0	--	50	--
		$V_{CE} = 2.0Vdc,\ I_C = 400mAdc$	5.0	--	--	--
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	$I_C = 400mAdc,\ I_B = 80mAdc$	--	--	0.5	Vdc
Emitter-Base Saturation Voltage	$V_{BE(sat)}$	$I_C = 400mAdc,\ I_B = 80mAdc$	--	--	2.0	Vdc

AC Current Gain	$\lvert h_{fe} \rvert$	$V_{CE} = 2.0Vdc, I_C = 40mAdc, f = 50MHz$	2.0	--	--	--
Collector Output Capacitance	C_{ob}	$V_{CB} = 25Vdc,\ I_E = 0,\ f = 100kHz$	--	--	20	pF

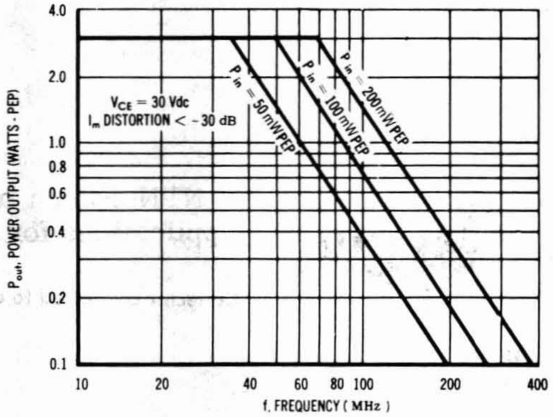
Power Input (PEP) (Note 2)	P_{in}	$P_{out} = 3.0$ Watts (PEP) (1.5 W rms) $V_{CE} = 30$ Volts, f = 30 MHz $I_{C(max)} = 125\,mA$	--	--	75	mW
Power Gain	G_e		16	19	--	dB
Intermodulation Distortion Ratio	I_m		30	35	--	dB
Efficiency	η		40	48	--	%

*Pulse Test. Pulse Width = 100 µsec. Duty Cycle = 2%.
Note 2 PEP. Peak Envelope Power.

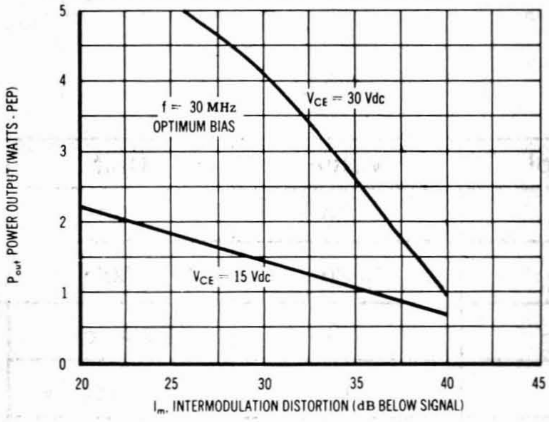
SAFE OPERATING AREA



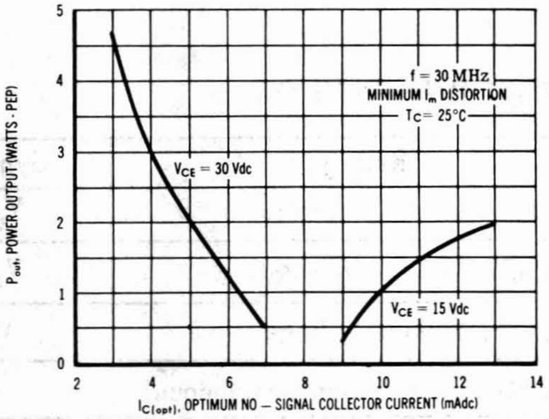
POWER OUTPUT versus FREQUENCY



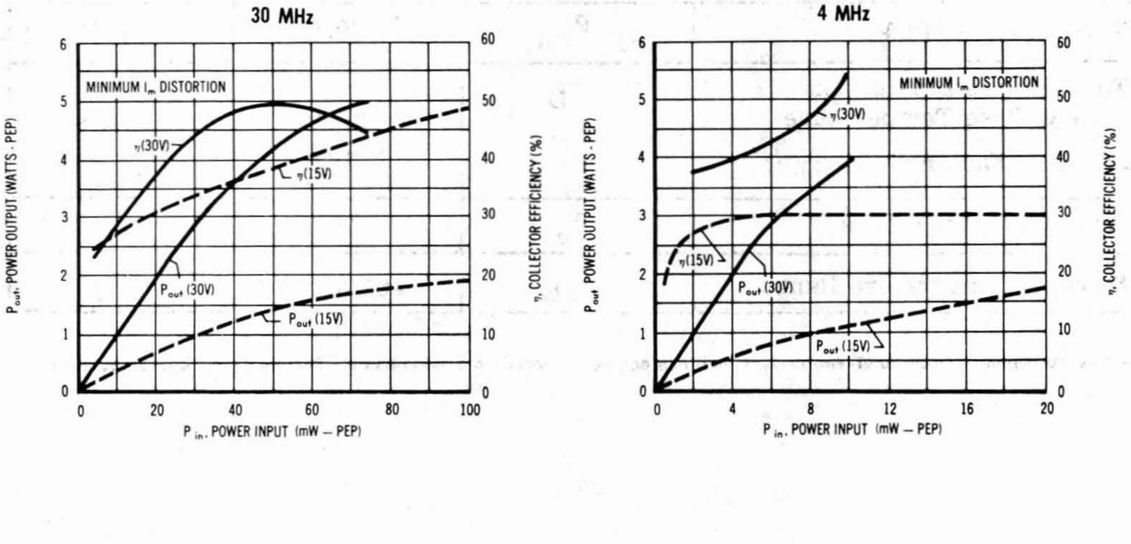
MAXIMUM POWER OUTPUT FOR GIVEN I_m DISTORTION LEVEL



POWER OUTPUT versus OPTIMUM BIAS

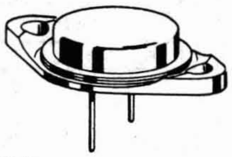


OUTPUT CHARACTERISTICS versus POWER INPUT


30 MHz

4 MHz

2N3297 (SILICON)



CASE 1
(TO-3)

NPN silicon annular transistor for linear amplifier applications for 2 to 100 MHz.

Collector connected to case

MAXIMUM RATINGS *

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CES}	60	Vdc
Emitter-Base Voltage	V_{EB}	3	Vdc
Collector Current (Continuous)	I_C	1.5	Adc
Base-Current (Continuous)	I_B	500	mAdc
Power Input (PEP)	P_{in}	5.0	Watts (PEP)
Power Output (PEP)	P_{out}	20.0	Watts (PEP)
Total Device Dissipation @ 25°C Case Temperature Derating Factor above 25°C	P_D	25.0 167	Watts mW/°C
Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

* **The maximum ratings as given for** dc **conditions can be exceeded on a pulse basis. See electrical characteristics**

2N3297 (Continued)

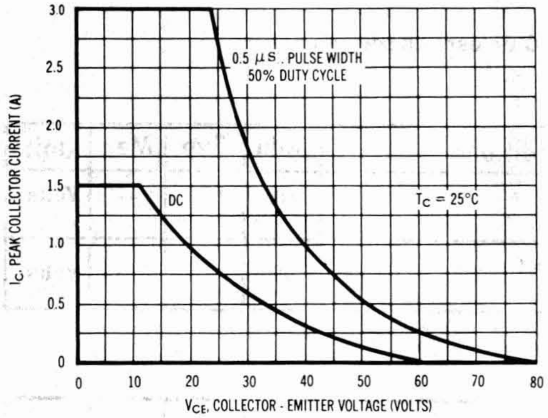
ELECTRICAL CHARACTERISTICS **(Tc = 25°C unless otherwise noted)**

Characteristic	Symbol	Conditions	Min	Typ	Max	Unit
Collector-Emitter Sustain Voltage	$V_{CES(sus)}$*	$I_C = 0.250A$, $R_{BE} = 0$	80	100	--	Volts
Collector Emitter-Open Base Sustain Voltage	$V_{CEO(sus)}$*	$I_C = 0.250A$, $I_B = 0$	40	--	--	Volts
Collector-Emitter Current	I_{CES}	$V_{CE} = 60Vdc$, $V_{BE} = 0$ $V_{CE} = 50Vdc$, $V_{BE} = 0$, $T_C = +175°C$	-- --	-- --	0.5 1.0	mAdc
Collector-Cutoff Current	I_{CBO}	$V_{CB} = 50Vdc$, $I_E = 0$	--	--	1.0	μAdc
Emitter-Cutoff Current	I_{EBO}	$V_{EB} = 3Vdc$, $I_C = 0$	--	--	100	μAdc
DC Current Gain	h_{FE}	$I_C = 400mAdc$, $V_{CE} = 2Vdc$ $I_C = 1Adc$, $V_{CE} = 2Vdc$	2.5 2.5	-- --	35 --	--
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	$I_C = 1Adc$, $I_B = 500mAdc$	--	--	0.5	Vdc
Emitter-Base Saturation Voltage	$V_{BE(sat)}$	$I_C = 1Adc$, $I_B = 500mAdc$	--	--	2.0	Vdc
AC Current Gain	$\|h_{fe}\|$	$V_{CE} = 2Vdc$, $I_C = 400mAdc$, f = 50MHz	2.0	--	--	--
Collector Output Capacitance	C_{ob}	$V_{CB} = 25Vdc$, $I_E = 0$, f = 100kHz	--	--	60	pF
Power Input (PEP) Note 2	P_{in}	P_{out} = 12 Watts PEP (6.0W rms) V_{CE} = 30 Volts, f = 30MHz $I_{C(max)}$ = 0.50 Amp	--	--	1.2	Watts PEP
Power Gain	G_e		10	13	--	dB
Intermodulation Distortion Ratio	I_m		30	33	--	dB
Efficiency	η		40	45	--	%

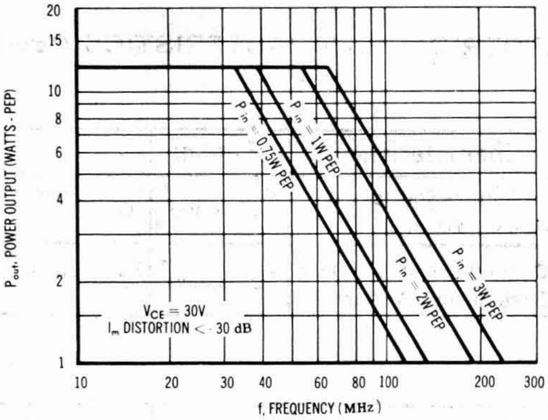
* Pulse Test: Pulse Width = 100μs, Duty Cycle = 2 %
Note 2. PEP. Peak Envelope Power

2N3297 (Continued)

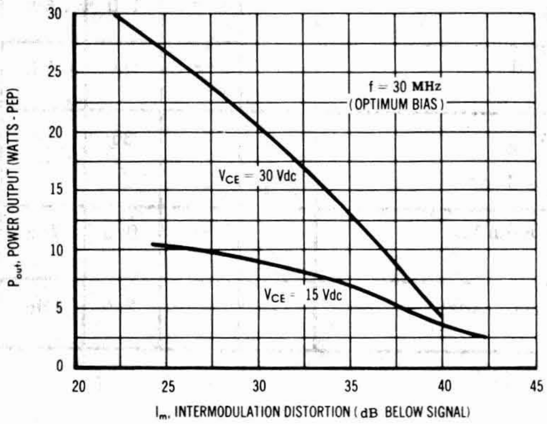
SAFE OPERATING AREA



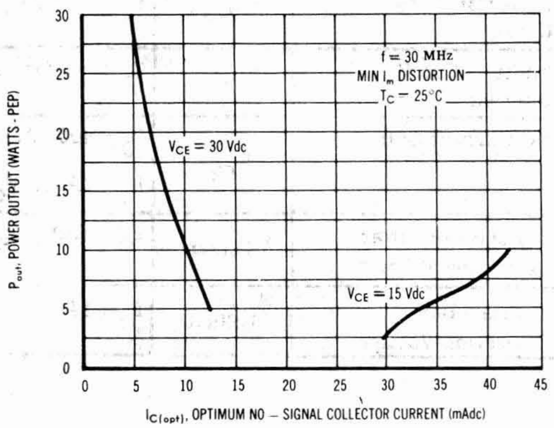
POWER OUTPUT versus FREQUENCY



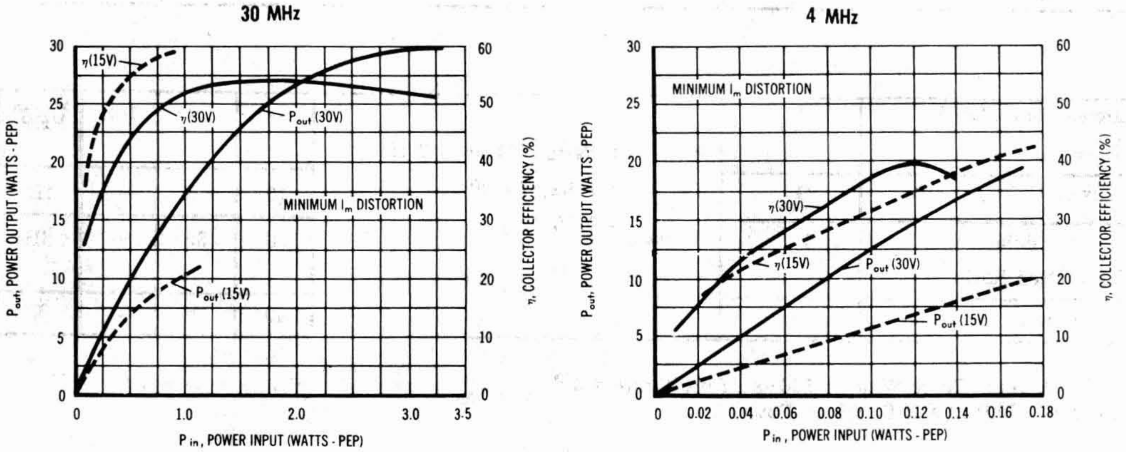
MAXIMUM POWER OUTPUT FOR GIVEN I$_m$ DISTORTION LEVEL



POWER OUTPUT versus OPTIMUM BIAS



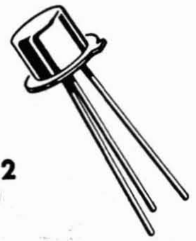
OUTPUT CHARACTERISTICS versus POWER INPUT



30 MHz

4 MHz

2N3298 (SILICON)



CASE 22
(TO-18)

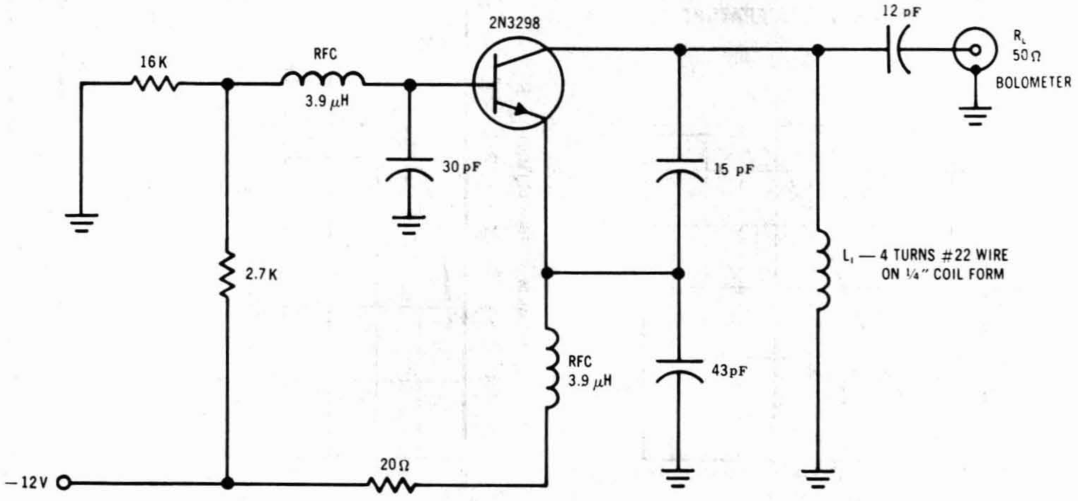
NPN silicon annular transistor for power oscillator applications to 150 MHz.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Vdc
Collector-Emitter Voltage	V_{CES}	25	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	100	mA
Total Device Dissipation (25°C Case Temperature) Derate Above 25°C	P_D	1.0 6.67	Watt mW/°C
Total Device Dissipation (25°C Ambient Temperature) Derate Above 25°C 2mW/°C	P_D	0.3 2	Watt mW/°C
Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

80 MHz OSCILLATOR POWER OUTPUT TEST CIRCUIT


2N3298
16K
RFC
3.9 µH
30 pF
2.7K
12 pF
R_L
50Ω
BOLOMETER
15 pF
L₁ — 4 TURNS #22 WIRE
ON 1/4" COIL FORM
RFC
3.9 µH
43pF
20Ω
−12V

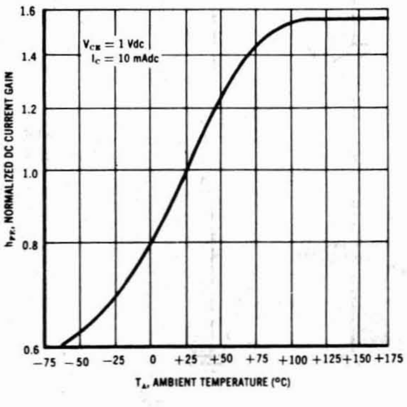
2N3298 (Continued)

ELECTRICAL CHARACTERISTICS (At 25°C Ambient unless otherwise noted)

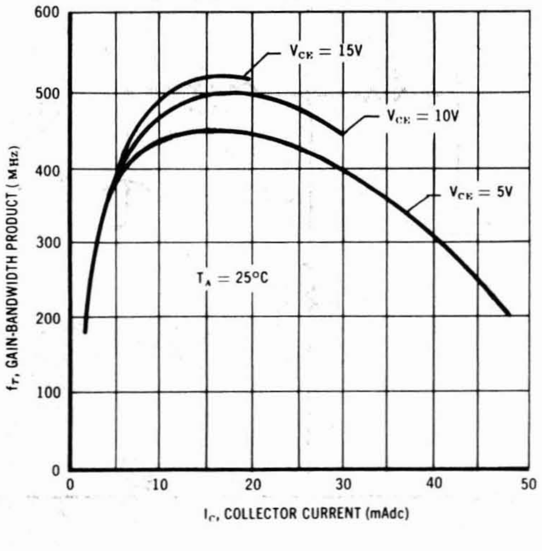
Characteristic	Symbol	Conditions	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C=25 μAdc, V_{BE}=0	25	35	-	Vdc
Collector-Emitter Open Base Sustaining Voltage	$BV_{CEO(sus)}$*	I_C=10mA, I_B=0	15	24	-	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB}=10 Vdc, I_E=0 V_{CB}=10 Vdc, I_E=0, T_A=150°C	- -	0.01 10	0.5 50	μAdc
Emitter Cutoff Current	I_{EBO}	V_{EB}=3 Vdc, I_C = 0	-	-	10	μAdc
DC Current Gain	h_{FE}	V_{CE}= 1 Vdc, I_C= 10 mAdc	60	90	120	-
AC Current Gain	$\|h_{fe}\|$	V_{CE}= 10 Vdc, I_C= 10mAdc, f= 100 MHz	2	-	-	-
Collector Output Capacitance	C_{ob}	V_{CB}= 10 Vdc, I_E=0, f=100 kHz	-	5	6	pF
Power Output	P_{out}	f= 80 MHz V_{CC} = 12 Vdc $I_{C(max)}$ = 20 mA	60	-	100	mW
Efficiency	η		25	40	-	%

*Pulse Width = 300 μs, Duty Cycle = 2%

NORMALIZED DC CURRENT GAIN versus AMBIENT TEMPERATURE



f_T versus COLLECTOR CURRENT



2N3299 thru 2N3302 (SILICON)

CASE 31
(TO-5)
2N3299
2N3300

CASE 22
(TO-18)
2N3301
2N3302

NPN silicon annular transistors for high-speed switching circuits and DC to UHF amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value		Unit
Collector-Emitter Voltage (Applicable 0 to 10 mAdc)	V_{CEO}	30		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	500		mAdc
Operating Junction Temperature Range	T_J	-65 to +200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		2N3299 2N3300	2N3301 2N3302	
Total Device Dissipation @ $T_A = 25°C$	P_D	0.8	0.36	Watt
Derate above 25°C		4.56	2.06	mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D	3.0	1.8	Watts
Derate above 25°C		17.2	10.3	mW/°C

FIGURE 1 — SATURATED TURN-ON SWITCHING TIME TEST CIRCUIT

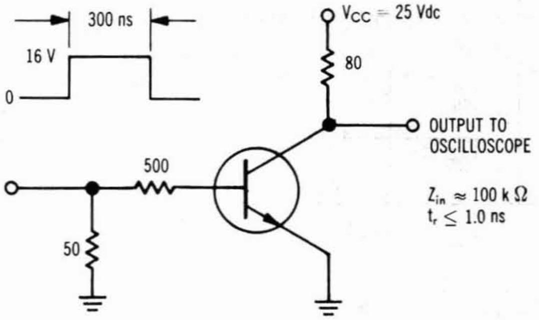
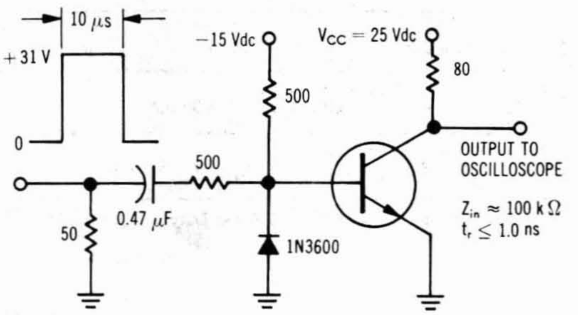

300 ns
16 V
0
V_CC = 25 Vdc
80
OUTPUT TO OSCILLOSCOPE
500
50
Z_in ≈ 100 k Ω
t_r ≤ 1.0 ns

FIGURE 2 — SATURATED TURN-OFF SWITCHING TIME TEST CIRCUIT


10 µs
+31 V
0
−15 Vdc
500
V_CC = 25 Vdc
80
500
0.47 µF
50
1N3600
OUTPUT TO OSCILLOSCOPE
Z_in ≈ 100 k Ω
t_r ≤ 1.0 ns

2N3299 thru 2N3302 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)		BV_{CEO}*	30	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 50 Vdc, V_{BE} = 0)		I_{CES}	-	0.01	μAdc
(V_{CE} = 50 Vdc, V_{BE} = 0, T_A = 150°C)			-	10	
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)		I_{EBO}	-	10	nAdc
Base Current (V_{CE} = 50 Vdc, V_{BE} = 0)		I_B	-	10	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N3299, 2N3301	h_{FE}	20	-	-
	2N3300, 2N3302		35	-	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	2N3299, 2N3301		25	-	
	2N3300, 2N3302		50	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)*	2N3299, 2N3301		35	-	
	2N3300, 2N3302		75	-	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)*	2N3299, 2N3301		20	-	
	2N3300, 2N3302		50	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)*	2N3299, 2N3301		40	120	
	2N3300, 2N3302		100	300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)*	2N3299, 2N3301		20	-	
	2N3300, 2N3302		50	-	
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{CE(sat)}$	-	0.22	Vdc
(I_C = 300 mAdc, I_B = 30 mAdc)			-	0.45	
(I_C = 500 mAdc, I_B = 50 mAdc)			-	0.6	
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)		$V_{BE(sat)}$	-	1.1	Vdc
(I_C = 300 mAdc, I_B = 30 mAdc)			-	1.3	
(I_C = 500 mAdc, I_B = 50 mAdc)			-	1.5	
Base-Emitter On Voltage (I_C = 150 mAdc, V_{CE} = 10 Vdc)		$V_{BE(on)}$	-	1.1	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	250	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)		C_{ob}	-	8.0	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 140 kHz)		C_{ib}	-	20	pF
Turn-On Time (Figure 1) (V_{CC} = 25 Vdc, I_C ≈ 300 mAdc, I_{B1} ≈ 30 mAdc)		t_{on}	-	60	ns
Turn-Off Time (Figure 2) (V_{CC} = 25 Vdc, I_C ≈ 300 mAdc, I_{B1} = I_{B2} ≈ 30 mAdc)		t_{off}	-	150	ns

* Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2%.

2N3303 (SILICON)

CASE 94

NPN silicon annular transistor designed for high-speed, high-current switching and driving applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector Current-Continuous	I_C	1.0	Adc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.6 3.43	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	3 17.2	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Voltage* ($I_C = 30$ mAdc, $I_B = 0$)	BV_{CEO}*	12	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 0.5$ mAdc, $I_E = 0$)	BV_{CBO}	25	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 0.1$ mAdc, $I_C = 0$)	BV_{EBO}	4	-	Vdc
Collector Cutoff Current ($V_{CE} = 15$ Vdc, $V_{BE} = 0$)	I_{CES}	-	100	μAdc
Base Current ($V_{CE} = 15$ Vdc, $V_{BE} = 0$)	I_B	-	100	μAdc

*Pulse Test: Pulse Width = 300 μs, Duty Cycle ≤ 2%

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Max	Unit
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			
(I_C = 10 mAdc, V_{CE} = 0.5 Vdc)		20	-	
(I_C = 100 mAdc, V_{CE} = 0.5 Vdc)*		30	-	
(I_C = 300 mAdc, V_{CE} = 0.5 Vdc)*		30	120	
(I_C = 300 mAdc, V_{CE} = 0.5 Vdc, T_A = -55°C)*		10	-	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		-	0.25	
(I_C = 100 mAdc, I_B = 10 mAdc)*		-	0.23	
(I_C = 300 mAdc, I_B = 30 mAdc)*		-	0.33	
(I_C = 300 mAdc, I_B = 30 mAdc, T_A = 125°C)*		-	0.50	
(I_C = 1 Adc, I_B = 100 mAdc)*		-	0.70	
Base-Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)		-	0.78	
(I_C = 100 mAdc, I_B = 10 mAdc)*		-	1.10	
(I_C = 300 mAdc, I_B = 30 mAdc)*		-	1.30	
(I_C = 1 Adc, I_B = 100 mAdc)*		-	2.1	
DYNAMIC CHARACTERISTICS				
Current-Gain – Bandwidth Product (I_C = 100 mAdc, V_{CE} = 5 Vdc, f = 100 MHz)	f_T	450	-	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	15	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	25	pF
Turn-On Time (Figure 1) ($V_{EB(off)} \approx$ 4 Vdc, $I_C \approx$ 1 Adc, $I_{B1} \approx$ 100 mAdc)	t_{on}	-	15	ns
Turn-Off Time (Figure 1) ($I_C \approx$ 1 Adc, $I_{B1} \approx I_{B2} \approx$ 100 mAdc)	t_{off}	-	25	ns
Storage Time (Figure 2) ($I_C \approx$ 100 mAdc, $I_{B1} \approx I_{B2} \approx$ 100 mAdc)	t_s	-	15	ns

*Pulse Test: Pulse Width = 300 μs, Duty Cycle ≤ 2%

FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT

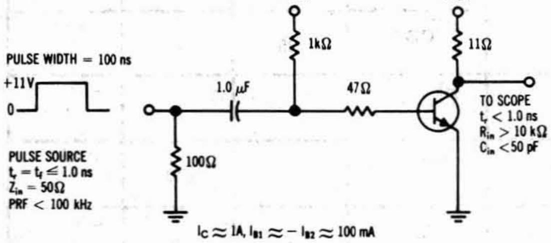
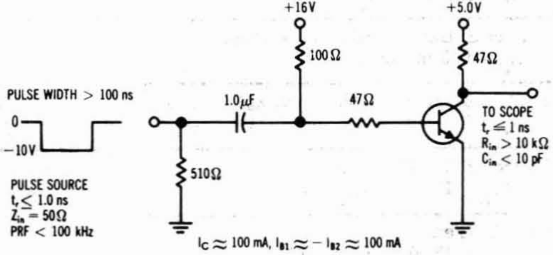

V_{BB}
−4.0V
V_{CC}
+12V
1kΩ
11Ω
PULSE WIDTH = 100 ns
+11V
0
1.0 μF
47Ω
TO SCOPE
t_r < 1.0 ns
R_{in} > 10 kΩ
C_{in} < 50 pF
PULSE SOURCE
$t_r = t_f \leq$ 1.0 ns
Z_{in} = 50Ω
PRF < 100 kHz
100Ω
$I_C \approx$ 1A, $I_{B1} \approx -I_{B2} \approx$ 100 mA

FIGURE 2 — STORAGE TIME TEST CIRCUIT


V_{CC}
+16V
V_{CC}
+5.0V
100Ω
47Ω
PULSE WIDTH > 100 ns
0
−10V
1.0μF
47Ω
TO SCOPE
$t_r \leq$ 1 ns
R_{in} > 10 kΩ
C_{in} < 10 pF
510Ω
PULSE SOURCE
$t_r \leq$ 1.0 ns
Z_{in} = 50Ω
PRF < 100 kHz
$I_C \approx$ 100 mA, $I_{B1} \approx -I_{B2} \approx$ 100 mA

2N3304 (SILICON)

CASE 22
(TO-18)

PNP silicon annular transistor designed for low-level, high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS

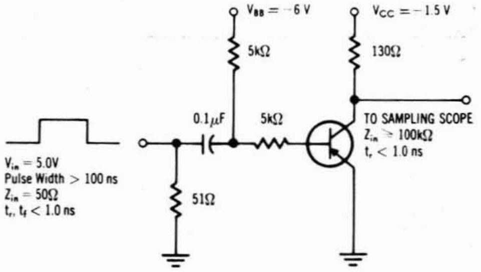
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	6	Vdc
Collector-Base Voltage	V_{CB}	6	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 1.72	mW mW/°C
Total Device Dissipation @ T_C = 100°C Derate above 100°C	P_D	500 5	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to+200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	6		Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	6	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	6	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4	—	Vdc
Collector-Cutoff Current (V_{CE} = 3 Vdc, V_{BE} = 0) (V_{CE} = 3 Vdc, V_{BE} = 0, T_A = +125°C)	I_{CES}	— —	0.01 10	μAdc
Base Current (V_{CE} = 3 Vdc, V_{BE} = 0)	I_B	—	10	nAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 1 mAdc, V_{CE} = 0.5 Vdc) (I_C = 10 mAdc, V_{CE} = 0.3 Vdc, T_A = -55°C) (I_C = 10 mAdc, V_{CE} = 0.3 Vdc) (I_C = 50 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}*	15 12 30 20	— — 120 —	—
Collector-Emitter Saturation Voltage (I_C = 1 mAdc, I_B = 0.1 mAdc) (I_C = 10 mAdc, I_B = 1 mAdc, T_A = +125°C) (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc)	$V_{CE(sat)}$	— — — —	0.15 0.23 0.16 0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 1 mAdc, I_B = 0.1 mAdc) (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc)	$V_{BE(sat)}$	0.7 0.8 —	0.8 1.0 1.5	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 5 Vdc, f = 100 MHz)	f_T	500	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	3.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	—	3.5	pF
Turn-On Time (Figure 1) (V_{CC} = 1.5 Vdc, V_{BB} = 6 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 0.5 mAdc)	t_{on}	—	60	ns
Turn-Off Time (Figure 1) (V_{CC} = 1.5 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 0.5 mAdc)	t_{off}	—	60	ns
Charge-Storage Time (Figure 2) (I_C = 10 mAdc, V_{CC} = 3 Vdc, I_{B1} = I_{B2} = 10 mAdc)	t_s	—	30	ns

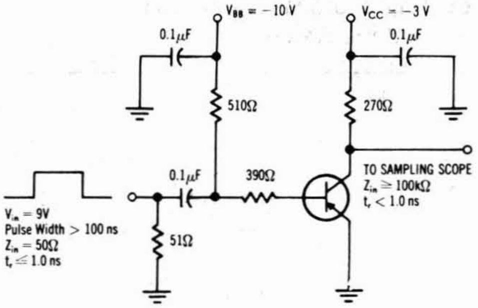
*Pulse Test: Pulse Width = 300 μs; Duty Cycle = 2%

FIGURE 1 — TURN-ON & TURN-OFF TIME TEST CIRCUIT



$V_{BB} = -6$ V
$V_{CC} = -1.5$ V
5kΩ
130Ω
0.1μF
5kΩ
TO SAMPLING SCOPE
$Z_{in} \geq 100k\Omega$
$t_r < 1.0$ ns
$V_{in} = 5.0V$
Pulse Width > 100 ns
$Z_{in} = 50\Omega$
$t_r, t_f < 1.0$ ns
51Ω

FIGURE 2 — CHARGE-STORAGE TIME TEST CIRCUIT



$V_{BB} = -10$ V
$V_{CC} = -3$ V
0.1μF
0.1μF
510Ω
270Ω
0.1μF
390Ω
TO SAMPLING SCOPE
$Z_{in} \geq 100k\Omega$
$t_r < 1.0$ ns
$V_{in} = 9V$
Pulse Width > 100 ns
$Z_{in} = 50\Omega$
$t_r \leq 1.0$ ns
51Ω

2N3307 (SILICON)
2N3308

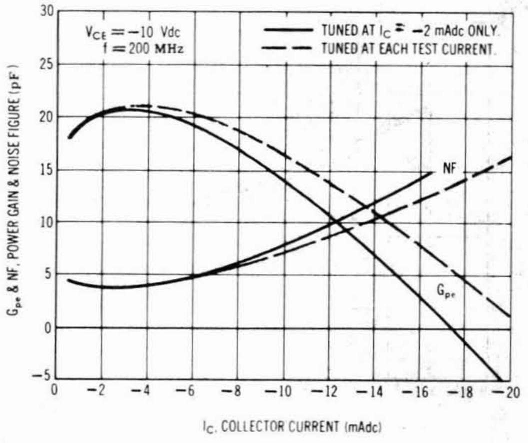
CASE 20
(TO-72)

PNP silicon annular transistors for high-gain, low-noise amplifier, oscillator, mixer and frequency multiplier applications.

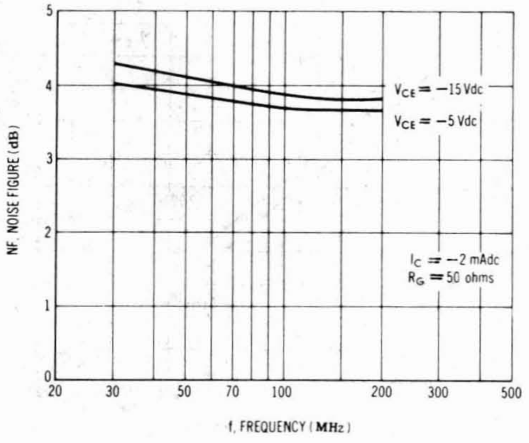
MAXIMUM RATINGS

Rating	Symbol	Value		Unit
		2N3307	2N3308	
Collector-Base Voltage	V_{CB}	40	30	Vdc
Collector-Emitter Voltage	V_{CES}	40	30	Vdc
Collector-Emitter Voltage	V_{CEO}	35	25	Vdc
Emitter-Base Voltage	V_{EB}	3.0		Vdc
Collector Current	I_C	50		mAdc
Power Dissipation at T_C = 25°C Derate above 25°C	P_D	300 1.71		mW mW/°C
Power Dissipation at T_A = 25°C Derate above 25°C	P_D	200 1.14		mW mW/°C
Junction Temperature	T_J	200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

COMMON EMITTER AVERAGE SMALL POWER GAIN & NOISE FIGURE versus COLLECTOR CURRENT



NOISE FIGURE versus FREQUENCY



2N3307, 2N3308 (Continued)

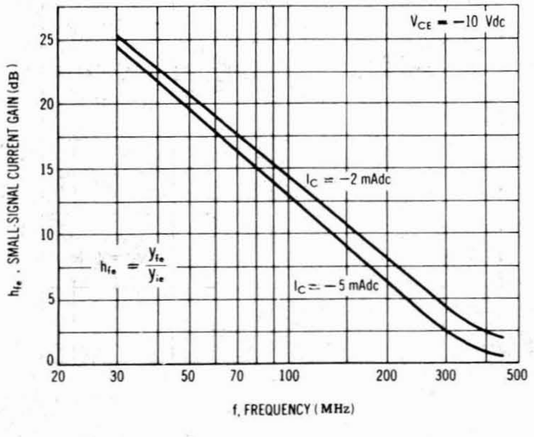
ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

Characteristic	Symbol	Test Conditions		Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	I_C = 10 μAdc, I_E = 0	2N3307	40	—	—	Vdc
			2N3308	30	—	—	
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 10 μAdc, V_{BE} = 0	2N3307	40	—	—	Vdc
			2N3308	30	—	—	
Collector-Emitter Breakdown Voltage	BV_{CEO}	I_C = 2.0 mAdc, I_B = 0	2N3307	35	—	—	Vdc
			2N3308	25	—	—	
Emitter-Base Breakdown Voltage	BV_{EBO}	I_E = 10 μAdc, I_C = 0	Both Types	3.0	—	—	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 15 Vdc	Both Types	—	0.001	0.010	μAdc
		V_{CB} = 15 Vdc, T = 150 °C	2N3307	—	0.5	3.0	
DC Current Gain	h_{FE}	V_{CE} = 10 Vdc, I_C = 2 mAdc	2N3307	40	—	250	—
			2N3308	25	—	250	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 3 mAdc, I_B = 0.6 mAdc	Both Types	—	—	0.4	Vdc
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	I_C = 3 mAdc, I_B = 0.6 mAdc	Both Types	—	—	1.0	Vdc
AC Current Gain	h_{fe}	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 1 kHz	2N3307	40	—	250	—
			2N3308	25	—	250	
Output Capacitance •	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 0.1 MHz	2N3307	—	1.0	1.3	pF
			2N3308	—	1.2	1.6	
Collector-Base Time Constant	$r_b'C_c$	V_{CB} = 10 Vdc, I_C = 2 mAdc, f = 31.8 MHz	2N3307	2	—	15	ps
			2N3308	2	—	20	
Current Gain-Bandwidth Product	f_T	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 100 MHz	Both Types	300	—	1200	MHz
Maximum Frequency of Oscillation	f_{max}	V_{CE} = 10 Vdc, I_C = 2 mAdc	Both Types	—	2000	—	MHz
Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 200 MHz	Both Types	17	—	24	dB
Noise Figure	NF	V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 200 MHz	2N3307	—	4.0	4.5	dB
			2N3308	—	5.0	6.0	
Power Gain (AGC) • •	G_e	V_{CE} = 5.0 Vdc, I_C = 20 mAdc, f = 200 MHz	2N3307	—	—	0	dB
			2N3308	—	0	—	

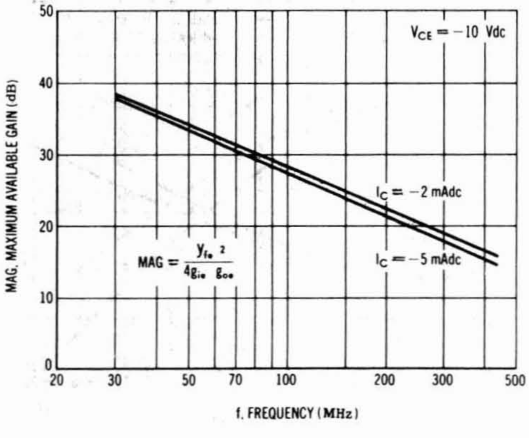
• C_{ob} is measured in guarded circuit such that the can capacitance is not included.

• • AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = -10 Vdc, I_C = -2 mAdc operation.

SMALL SIGNAL CURRENT GAIN versus FREQUENCY



MAXIMUM AVAILABLE GAIN versus FREQUENCY



2N3311 thru 2N3316 (GERMANIUM)

PNP germanium power transistors for high–power applications.

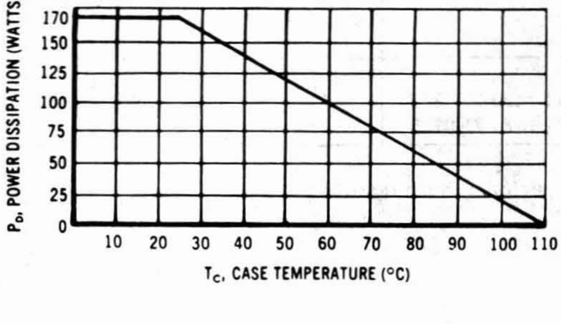
CASE 5
(TO-36)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N3311 2N3314	2N3312 2N3315	2N3313 2N3316	Unit
Collector-Base Voltage	V_{CB}	30	45	60	Volts
Collector-Emitter Voltage	V_{CES}	30	45	60	Volts
Collector-Emitter Voltage	V_{CEO}	20	30	40	Volts
Emitter-Base Voltage	V_{EB}	20	25	30	Volts
Collector Current (Continuous)	I_C	5.0			Amp
Power Dissipation at $T_C = 25^{\circ}C$	P_D	170			Watts
Junction Temperature Range	T_J	-65 to +110			$^{\circ}C$
Thermal Resistance	θ_{JC}	0.5			°C/W

POWER-TEMPERATURE DERATING CURVE



The maximum continuous power is related to maximum junction temperature by the thermal resistance factor. This curve has a value of 170 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that:

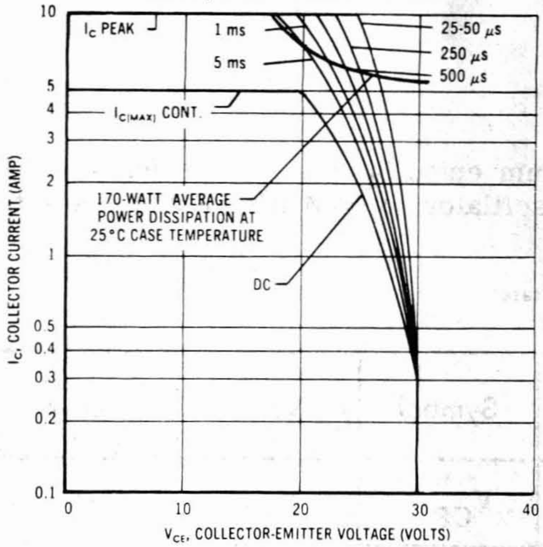
$$\text{allowable } P_D = \frac{110^{\circ} - T_c}{0.5}$$

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage*		BV_{CEO}*			Vdc
(I_C = 500 mAdc, I_B = 0)	2N3311, 2N3314		20	-	
	2N3312, 2N3315		30	-	
	2N3313, 2N3316		40	-	
Collector-Emitter Breakdown Voltage*		BV_{CES}*			Vdc
(I_C = 300 mAdc, V_{BE} = 0)	2N3311, 2N3314		30	-	
	2N3312, 2N3315		45	-	
	2N3313, 2N3316		60	-	
Collector Cutoff Current		I_{CEO}			mAdc
(V_{CE} = 10 Vdc, I_B = 0)	2N3311, 2N3314		-	200	
(V_{CE} = 15 Vdc, I_B = 0)	2N3312, 2N3315		-	200	
(V_{CE} = 20 Vdc, I_B = 0)	2N3313, 2N3316		-	200	
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 25 Vdc, V_{BE} = 1.0 Vdc, T_C = 100°C)	2N3311, 2N3314		-	35	
(V_{CE} = 40 Vdc, V_{BE} = 1.0 Vdc, T_C = 100°C)	2N3312, 2N3315		-	35	
(V_{CE} = 55 Vdc, V_{BE} = 1.0 Vdc, T_C = 100°C)	2N3313, 2N3316		-	35	
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = $V_{CB\ max}$)			-	5.0	
(V_{CB} = 2.0 Vdc, I_E = 0)			-	0.3	
Emitter-Base Cutoff Current (V_{BE} = $V_{BE\ max}$, I_C = 0)		I_{EBO}	-	4.0	mAdc
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			-
(I_C = 500 mAdc, V_{CB} = 2.0 Vdc)	2N3311 thru 2N3313		-	150	
	2N3314 thru 2N3316		-	250	
(I_C = 3.0 Adc, V_{CB} = 2.0 Vdc)	2N3311 thru 2N3313		60	120	
	2N3314 thru 2N3316		100	200	
Collector-Emitter Saturation Voltage (I_C = 3.0 Adc, I_B = 300 mAdc)		$V_{CE(sat)}$	-	0.1	Vdc
Base-Emitter Voltage		$V_{BE(on)}$			Vdc
(I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	2N3311 thru 2N3313		-	0.6	
	2N3314 thru 2N3316		-	0.5	
DYNAMIC CHARACTERISTICS					
Common Emitter Cutoff Frequency (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)		$f_{\alpha e}$	1.0	-	kHz
Small Signal Current Gain		h_{fe}			-
(I_C = 3.0 Adc, V_{CE} = 2.0 Vdc, f = 0.5 kHz)	2N3311 thru 2N3313		30	90	
	2N3314 thru 2N3316		40	120	

*To avoid excessive heating of the collector junction, perform these tests with an oscilloscope.

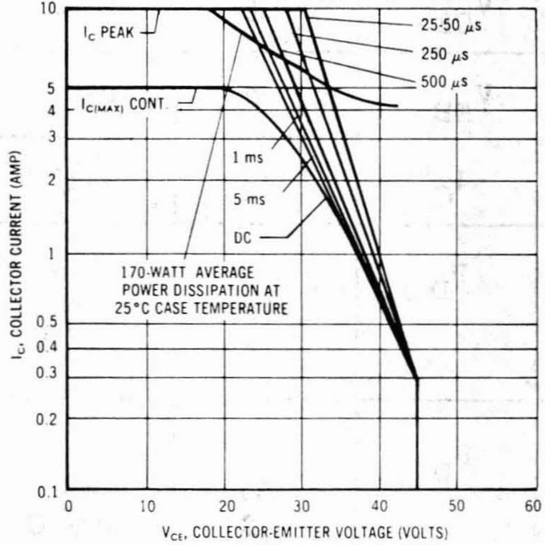
2N3311, 2N3314 (25 μsec to 5 msec pulse)



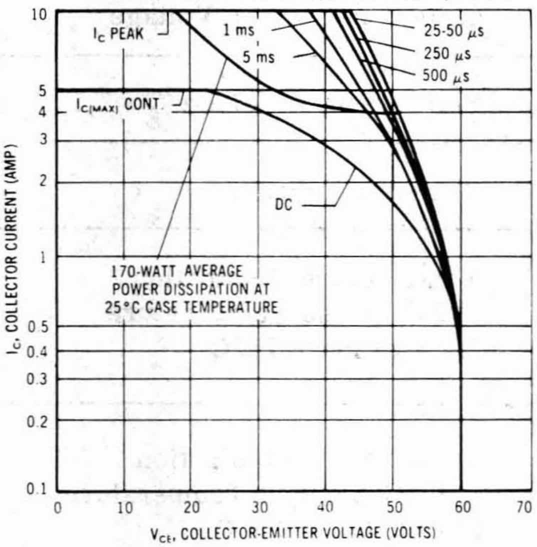
SAFE OPERATING AREA

The Safe Operating Area Curves indicate the I_C-V_{CE} limits below which the devices will not go into secondary breakdown. As the safe operating areas shown are independent of temperature and duty cycle, these curves can be used as long as the average power derating curve is also taken into consideration to insure operation below the maximum junction temperature.

2N3312, 2N3315 (25 μs to 5 ms pulse)

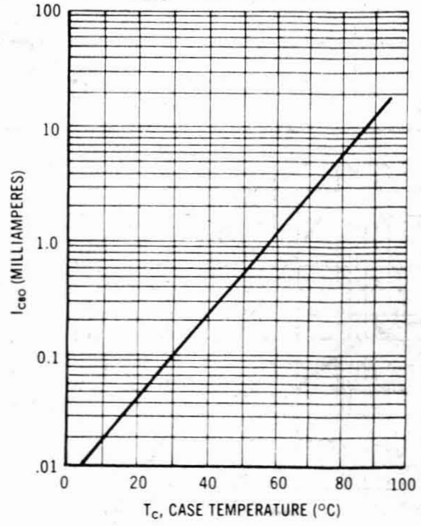


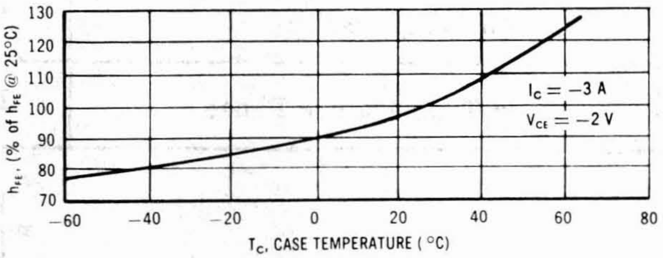
2N3313, 2N3316 (25 μs to 5 ms pulse)



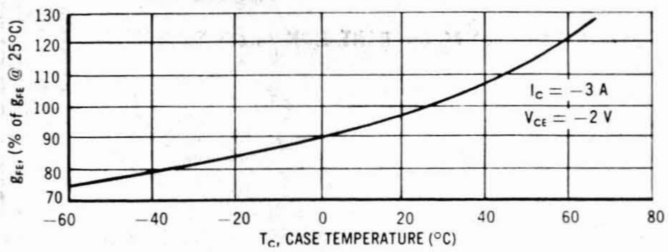
TEMPERATURE CHARACTERISTICS

I_{CBO} versus TEMPERATURE





DC TRANSCONDUCTANCE versus CASE TEMPERATURE



2N3323 (GERMANIUM)
2N3324
2N3325

CASE 22
(TO-18)

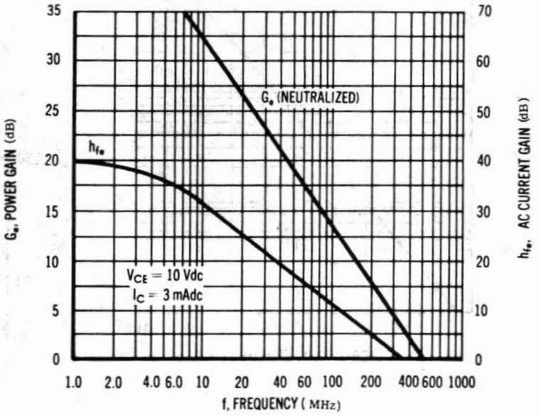
PNP germanium epitaxial transistors for FM RF, IF, mixer and oscillator and AM RF, IF and converter applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	35	Volts
Collector-Emitter Voltage	V_{CES}	35	Volts
Emitter-Base Voltage	V_{EB}	3.0	Volts
Collector Current	I_C	100	mA
Total Device Dissipation 25°C Case Temperature Derate Above 25°C	P_D	300 4	mW mW/°C
Total Device Dissipation 25°C Ambient Temperature Derate Above 25°C	P_D	150 2	mW mW/°C
Junction Temperature	T_J	+100	°C
Storage Temperature Range	T_{stg}	-65 to +100	°C

POWER GAIN AND AC CURRENT GAIN versus FREQUENCY



ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Conditions	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage	BV_{CER}	I_C = 100 μAdc, R_{BE} = 10K	35	40	--	Vdc
Collector-Emitter Current	I_{CES}	V_{CE} = 35 Vdc, V_{BE} = 0	--	--	100	μAdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 10 Vdc, I_E = 0	--	0.5	10	μAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 2 Vdc, I_C = 0	--	--	100	μAdc
DC Current Gain	h_{FE}	V_{CE} = 10 Vdc, I_C = 3 mAdc	30	--	200	--
AC Current Gain	h_{fe}	V_{CE} = 10 Vdc, I_C = 3 mAdc f = 1 kHz	30	--	225	--
Current-Gain — Bandwidth Product	f_T	V_{CE} = 10 Vdc, I_C = 3 mAdc f = 100 MHz	200	--	600	MHz
Collector-Base Time Constant	$r_b'C_C$	V_{CE} = 10 Vdc, I_C = 3 mAdc f = 31.8 MHz	--	50	100	ps
Output Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0 f = 100 kHz	--	2.2	3.0	pF
Maximum Frequency of Oscillation	f_{max}	V_{CE} = 10 Vdc, I_C = 3mAdc	--	500	--	MHz
Input Resistance, Parallel Equivalent	R_{ie}	V_{CE} = 10 Vdc, I_C = 3 mAdc f = 10 MHz	--	1200	--	ohms
Output Resistance, Parallel Equivalent	R_{oe}		--	11	--	kohms
Input Resistance, Parallel Equivalent	R_{ie}	V_{CE} = 10 Vdc, I_C = 3 mAdc f = 100 MHz	--	100	--	ohms
Output Resistance, Parallel Equivalent	R_{oe}		--	1.0	--	kohms

2N3323

Power Gain	G_e	Test Circuit Figure 1 V_{CE} = 10 Vdc, I_C = 3 mAdc f = 100 MHz	11	--	15	dB

2N3324

Power Gain	G_e	Test Circuit Figure 2 V_{CE} = 10 Vdc, I_C = 3 mAdc f = 10 MHz	24	--	31	dB

FIGURE 1: 100 MHz POWER GAIN TEST CIRCUIT – 2N3323

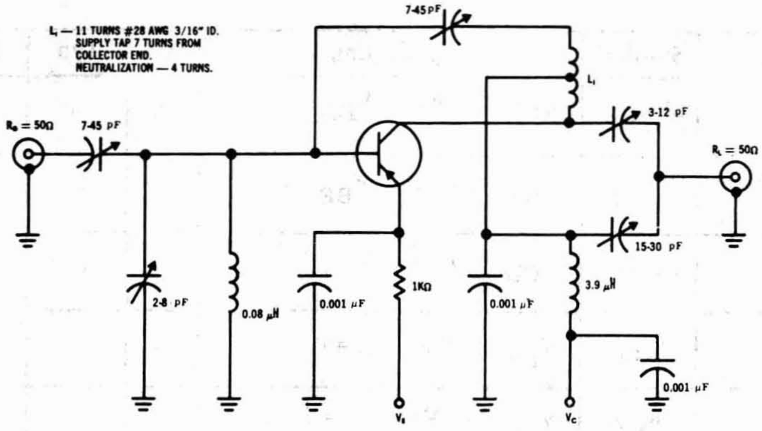
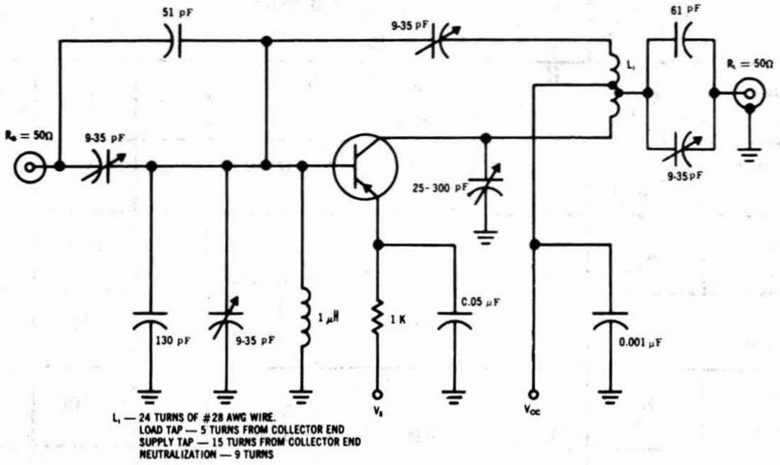

L₁ — 11 TURNS #28 AWG 3/16" ID.
SUPPLY TAP 7 TURNS FROM
COLLECTOR END.
NEUTRALIZATION — 4 TURNS.
7-45 pF
L₁
3-12 pF
Rₒ = 50Ω
7-45 pF
Rₗ = 50Ω
15-30 pF
2-8 pF
0.08 μH
0.001 μF
1KΩ
0.001 μF
3.9 μH
0.001 μF
V_E
V_C

FIGURE 2: 10 MHz POWER GAIN TEST CIRCUIT – 2N3324


51 pF
9-35 pF
61 pF
L₁
Rₗ = 50Ω
Rₒ = 50Ω
9-35 pF
25-300 pF
9-35 pF
130 pF
9-35 pF
1 μH
1 K
C.05 μF
0.001 μF
V_E
V_CC
L₁ — 24 TURNS OF #28 AWG WIRE.
LOAD TAP — 5 TURNS FROM COLLECTOR END
SUPPLY TAP — 15 TURNS FROM COLLECTOR END
NEUTRALIZATION — 9 TURNS

2N3375 (SILICON)
2N3553
2N3632
2N3961

***CASE 79**
(TO-39)

2N3553

****CASE 24**
(TO-102)

2N3961

*****CASE 36**
(TO-60)

2N3375
2N3632

***Collector connected to case**

****Emitter connected to case and stud**

*****Collector isolated from case and stud electrically**

NPN silicon RF Power transistors, optimized for large-signal power amplifier and driver applications to 400MHz, provide wide choice of power levels and guaranteed safe operating areas.

MAXIMUM RATINGS

Rating	Symbol	2N3375	2N3553	2N3632	2N3961	Unit
Collector-Emitter Voltage	V_{CEO}	← 40 →				Vdc
Collector-Base Voltage	V_{CB}	← 65 →				Vdc
Emitter-Base Voltage	V_{EB}	← 4.0 →				Vdc
Collector Current	I_C	1.5	1.0	3.0	1.0	Adc
Total Device Dissipation @ T_C = 25°C	P_D	11.6	7.0	23	10	Watts
Derate above 25°C		66.4	40	131	57.2	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →				°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage*		$BV_{CEO(sus)}$*			Vdc
(I_C = 200 mAdc, I_B = 0)	2N3375, 2N3553, 2N3632		40	-	
(I_C = 400 mAdc, I_B = 0)	2N3961		40	-	
Emitter-Base Breakdown Voltage		BV_{EBO}			Vdc
(I_E = 0.25 mAdc, I_C = 0)	2N3632		4.0	-	
(I_E = 0.1 mAdc, I_C = 0)	2N3375, 2N3553		4.0	-	
(I_E = 1.0 mAdc, I_C = 0)	2N3961		4.0	-	
Collector Cutoff Current		I_{CEO}			mAdc
(V_{CE} = 30 Vdc, I_B = 0)	2N3375, 2N3553		-	0.1	
	2N3632		-	0.25	
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 200°C)	2N3375, 2N3553		-	5.0	
	2N3632		-	10	
(V_{CE} = 65 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N3375, 2N3553		-	1.0	
	2N3632		-	5.0	
Collector Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 28 Vdc, I_E = 0, T_A = 150°C)	2N3961		-	5.0	
(V_{CB} = 65 Vdc, I_E = 0)	2N3632		-	0.5	
	2N3961		-	1.0	
Emitter Cutoff Current		I_{EBO}			mAdc
(V_{BE} = 4.0 Vdc, I_C = 0)	2N3375, 2N3553		-	0.1	
	2N3632		-	0.25	

* Pulsed thru 25 mH inductor (See Figures 5 and 6).

2N3375, 2N3553, 2N3632, 2N3961 (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS						
DC Current Gain		h_{FE}				-
(I_C = 250 mAdc, V_{CE} = 5.0 Vdc)	2N3375, 2N3553, 2N3632		10	-	-	
(I_C = 1.0 Adc, V_{CE} = 5.0 Vdc)	2N3632		5.0	-	-	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 250 mAdc, I_B = 50 mAdc)	2N3553		-	-	1.0	
(I_C = 500 mAdc, I_B = 100 mAdc)	2N3375, 2N3632		-	-	1.0	
Base-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 5.0 Adc)	2N3632	$V_{BE(sat)}$	-	-	1.5	Vdc
DYNAMIC CHARACTERISTICS						
Current-Gain—Bandwidth Product		f_T				MHz
(I_C = 100 mAdc, V_{CE} = 28 Vdc, f = 100 MHz)	2N3553, 2N3961		- -	500	- -	
(I_C = 150 mAdc, V_{CE} = 28 Vdc, f = 100 MHz)	2N3375 2N3632		- -	500 400	- -	
Output Capacitance		C_{ob}				pF
(V_{CB} = 28 Vdc, I_E = 0, f = 100 kHz)	2N3961		-	8.0	10	
(V_{CB} = 30 Vdc, I_E = 0, f = 100 kHz)	2N3375, 2N3553 2N3632		- -	8.0 16	10 20	

FUNCTIONAL TESTS

2N3375

Power Input	Test Circuit Figure 7 (V_{CE} = 28 Vdc, P_{out} = 7.5 Watts, f = 100 MHz)	P_{in}	-	-	1.0	Watt
Common-Emitter Amplifier Power Gain		G_{pe}	8.75	-	-	dB
Collector Efficiency		η	65	-	-	%
Power Input	Test Circuit Figure 8 (V_{CE} = 28 Vdc, P_{out} = 3.0 Watts, f = 400 MHz)	P_{in}	-	-	1.0	Watt
Common-Emitter Amplifier Power Gain		G_{pe}	4.77	-	-	dB
Collector Efficiency		η	40	-	-	%

2N3553

Power Input	Test Circuit Figure 9 (V_{CE} = 28 Vdc, P_{out} = 2.5 Watts, f = 175 MHz)	P_{in}	-	-	0.25	Watt
Common-Emitter Amplifier Power Gain		G_{pe}	10	-	-	dB
Collector Efficiency		η	50	-	-	%

2N3632

Power Input	Test Circuit Figure 10 (V_{CE} = 28 Vdc, P_{out} = 13.5 Watts, f = 175 MHz)	P_{in}	-	-	3.5	Watts
Common-Emitter Amplifier Power Gain		G_{pe}	5.86	-	-	dB
Collector Efficiency		η	70	-	-	%

2N3961

Power Input	Test Circuit Figure 11 (V_{CE} = 12.5 Vdc, P_{out} = 2.0 Watts, R_S = 50 ohms, R_L = 50 ohms, f = 135 MHz)	P_{in}	-	-	0.5	Watt
Common-Emitter Amplifier Power Gain		G_{pe}	6.0	-	-	dB
Collector Efficiency		η	60	-	-	%
Power Input	Test Circuit Figure 12 (V_{CE} = 28 Vdc, P_{out} = 4.0 Watts, R_S = 50 ohms, R_L = 50 ohms, f = 175 MHz)	P_{in}	-	-	0.5	Watt
Common-Emitter Amplifier Power Gain		G_{pe}	9.0	-	-	dB
Collector Efficiency		η	60	-	-	%

POWER OUTPUT versus FREQUENCY

COMMON EMITTER — V_{CE} = 28 Vdc, T_C = 25°C

FIGURE 1 – 2N3375

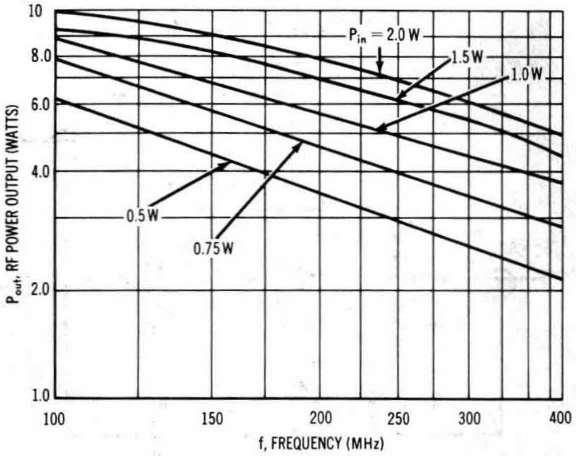


FIGURE 2 – 2N3553

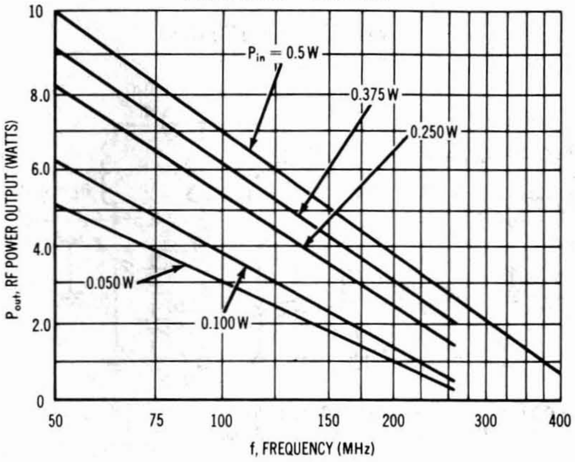


FIGURE 3 – 2N3632

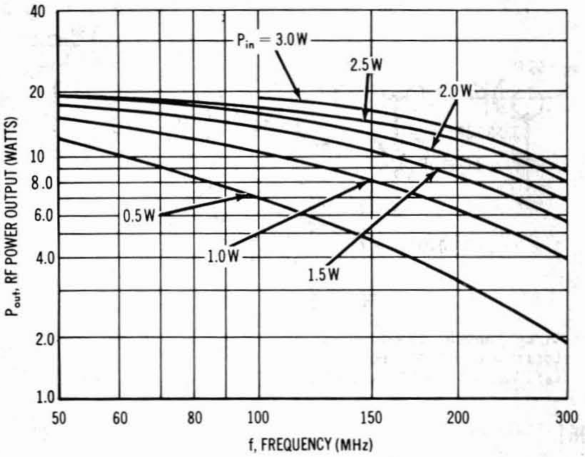
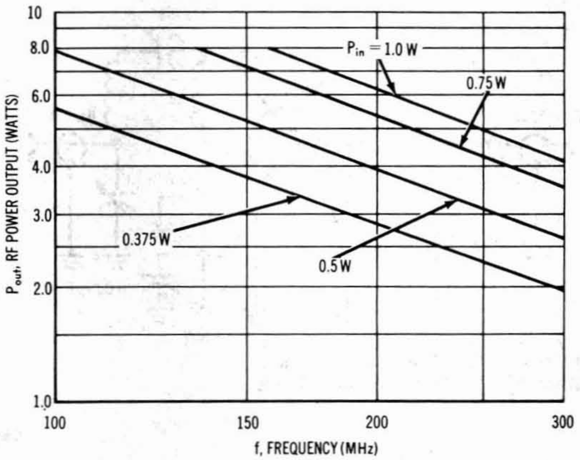


FIGURE 4 – 2N3961



$BV_{CEO(sus)}$ PULSE TEST CIRCUITS

FIGURE 5 – 2N3375, 2N3553, 2N3632

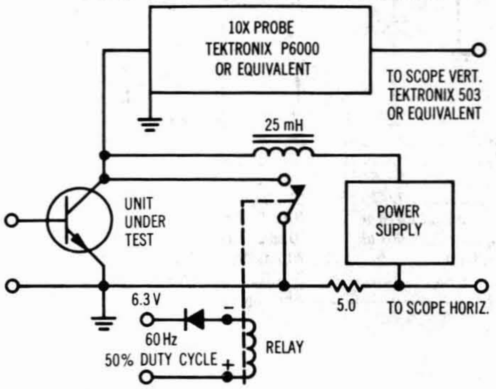
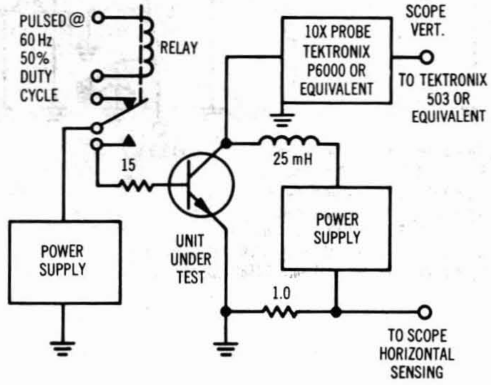

10X PROBE TEKTRONIX P6000 OR EQUIVALENT
TO SCOPE VERT. TEKTRONIX 503 OR EQUIVALENT
25 mH
UNIT UNDER TEST
POWER SUPPLY
6.3 V
–
5.0
TO SCOPE HORIZ.
60 Hz 50% DUTY CYCLE
+
RELAY

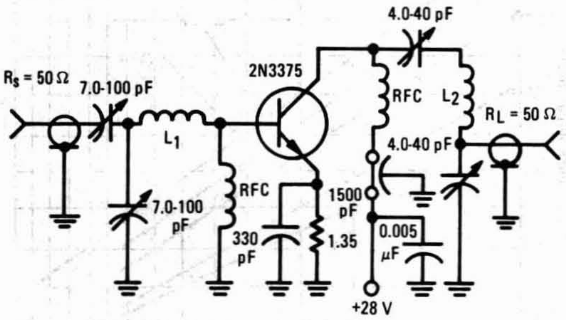
FIGURE 6 – 2N3961


PULSED @ 60 Hz 50% DUTY CYCLE
RELAY
10X PROBE TEKTRONIX P6000 OR EQUIVALENT
TO SCOPE VERT.
TO TEKTRONIX 503 OR EQUIVALENT
25 mH
15
UNIT UNDER TEST
POWER SUPPLY
POWER SUPPLY
1.0
TO SCOPE HORIZONTAL SENSING

TEST CIRCUITS

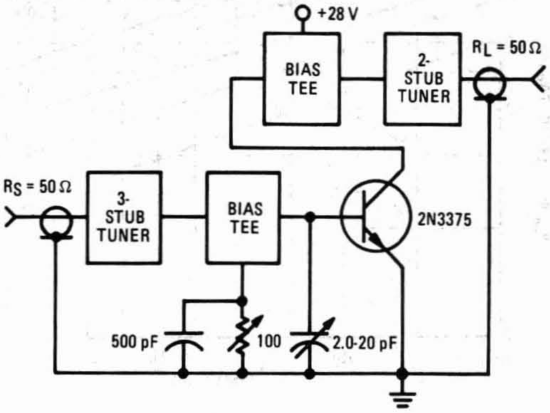
2N3375

FIGURE 7 – 100 MHz


4.0-40 pF
2N3375
Rs = 50 Ω
7.0-100 pF
L1
RFC
L2
RL = 50 Ω
4.0-40 pF
RFC
7.0-100 pF
330 pF
1.35
1500 pF
0.005 μF
+28 V

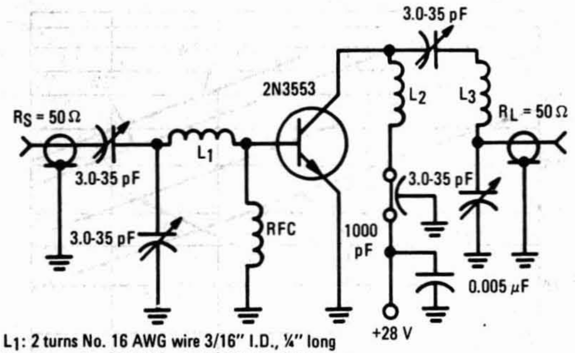
L1: 3 turns No. 16 AWG wire ¼" I.D., 5/16" long
L2: 5 turns No. 16 AWG wire 5/16" I.D., 7/16" long

FIGURE 8 – 400 MHz


+28 V
BIAS TEE
2-STUB TUNER
RL = 50 Ω
RS = 50 Ω
3-STUB TUNER
BIAS TEE
2N3375
500 pF
100
2.0-20 pF

2N3553

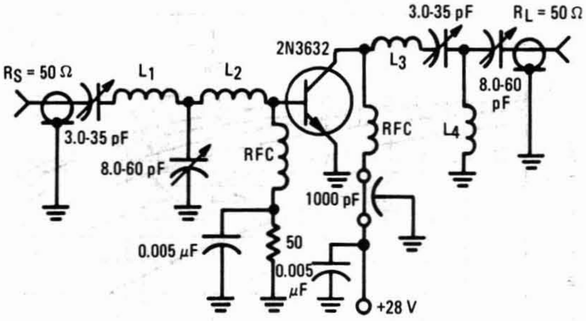
FIGURE 9 – 175 MHz


3.0-35 pF
2N3553
RS = 50 Ω
L1
L2
L3
RL = 50 Ω
3.0-35 pF
3.0-35 pF
RFC
1000 pF
3.0-35 pF
0.005 μF
+28 V

L1: 2 turns No. 16 AWG wire 3/16" I.D., ¼" long
L2: 2 turns No. 16 AWG wire 3/16" I.D., ¼" long
L3: 3 turns No. 16 AWG wire 3/8" I.D., 3/8" long

2N3632

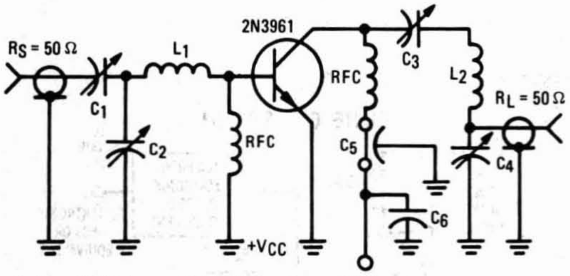
FIGURE 10 – 175 MHz


3.0-35 pF
RL = 50 Ω
2N3632
RS = 50 Ω
L1
L2
L3
8.0-60 pF
3.0-35 pF
RFC
L4
8.0-60 pF
RFC
1000 pF
0.005 μF
50
0.005 μF
+28 V

L1, L3: 4 turns No. 18 AWG wire ¼" I.D. 3/16" long
L2: 1 turn No. 16 AWG wire ¼" I.D., 3/16" long
L4: 2½ turns No. 16 AWG wire ¼" I.D., ¼" long

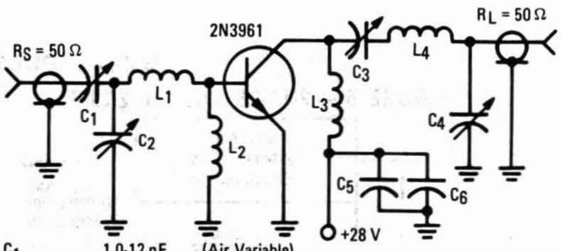
2N3961

FIGURE 11 – 135 MHz


2N3961
RS = 50 Ω
L1
RFC
C3
L2
RL = 50 Ω
C1
C2
RFC
C5
C4
C6
+VCC
+12.5 V

C1, C3 = 5.0-50 pF (Air Variable)
C2 = 7.0-100 pF (Air Variable)
C4 = 1.0-30 pF (Air Variable)
C5 = 1000 pF (Disc Ceramic)
C6 = 0.02 μF (Disc Ceramic)
L1 = 3 turns No. 16 AWG wire, 5/16" I.D., 5/16" long
L2 = 5 turns No. 16 AWG wire, 7/16" I.D., 5/8" long

FIGURE 12 – 175 MHz

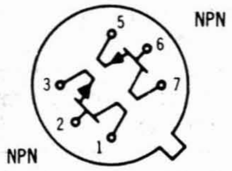

RL = 50 Ω
2N3961
RS = 50 Ω
L4
C3
L1
L3
C1
C2
L2
C4
C5
C6
+28 V

C1	1.0-12 pF	(Air Variable)
C2	1.0-30 pF	(Air Variable)
C3	5.0-50 pF	(Air Variable)
C4	7.0-75 pF	(Air Variable)
C5	470 pF	(Disc Ceramic)
C6	0.001 μF	(Disc Ceramic)
L1, L3, L4		2 turns No. 18 AWG enameled wire ¼" I.D., air wound 3/16" long
L2		RFC, $Q_U < 1$

2N3409 thru 2N3411 (SILICON)

CASE 32C

NPN silicon annular Star dual transistors for differential amplifiers and other applications requiring a matched pair with a high degree of parameter uniformity.



Pins 4 and 8 omitted
Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	60		Vdc
Collector-Collector Voltage	V_{CCO}	100		Vdc
Collector-Emitter Voltage	V_{CEO}	30		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
D.C. Collector Current (Limited by P_D)	I_C	500		mAdc
Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation (25°C Ambient Temperature) Derate above 25°C	P_D	500 2.9	600 3.4	mW mW/°C

ELECTRICAL CHARACTERISTICS (each side)

($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 μAdc)	BV_{CBO}	60	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc)	BV_{CEO}*	30	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc)	BV_{EBO}	5	—	Vdc

*Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2%

ELECTRICAL CHARACTERISTICS (each side) (continued)

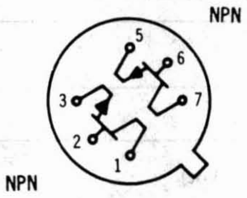
Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 50 Vdc)			—	.010	
(V_{CB} = 50 Vdc, T_A = 150°C)			—	10	
Emitter Cutoff Current		I_{EBO}			nAdc
(V_{BE} = 3 Vdc)			—	10	
Collector to Collector Current		I_{CCO}			nAdc
(V_{CC} = 100 Vdc)			—	100	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			—	0.15	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			—	0.85	
DC Forward Current Transfer Ratio		h_{FE}			—
(I_C = 10 μAdc, V_{CE} = 10 Vdc)	2N3410, 2N3411		20	100	
(I_C = 100 μAdc, V_{CE} = 10 Vdc)	All Types		30	120	
(I_C = 1 mAdc, V_{CE} = 10 Vdc)	All Types		40	160	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	All Types		50	200	
DC Current Gain Ratio **		h_{FE1}/h_{FE2} **			—
(I_C = 100 μAdc, V_{CE} = 10 Vdc)	2N3409		0.8	1.0	
	2N3410, 2N3411		0.9	1.0	
(I_C = 1 mAdc, V_{CE} = 10 Vdc)	2N3411		0.9	1.0	
Base Voltage Differential		$\lvert V_{BE1}-V_{BE2} \rvert$			mVdc
(I_C = 100 μAdc, V_{CE} = 10 Vdc)	2N3409, 2N3410		—	10	
	2N3411		—	5	
(I_C = 1 mAdc, V_{CE} = 10 Vdc)	2N3411		—	5	
Base Voltage Differential Change		$\Delta(V_{BE1}-V_{BE2})$			mVdc
(I_C = 100 μAdc, V_{CE} = 10 Vdc, T_A = -55 to +25°C)	2N3409		—	1.6	
	2N3410, 2N3411		—	0.8	
(I_C = 100 μAdc, V_{CE} = 10 Vdc, T_A = 25 to 125°C)	2N3409		—	2.0	
	2N3410, 2N3411		—	1.0	
Collector Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, f = 1 MHz)			—	8	
Collector Input Capacitance		C_{ib}			pF
(V_{BE} = 0.5 Vdc, f = 1 MHz)			—	25	
Small-Signal Forward Current Transfer Ratio		h_{fe}			—
(I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)			2.5	—	
Noise Figure		NF			dB
(I_C = 100 μA, V_{CE} = 5 V, f =1 kHz BW = 1 Hz, R_S = 1 kΩ)			—	4	

**The lowest h_{FE} reading is taken as h_{FE1} for this ratio

2N3423 (SILICON)
2N3424

Dual NPN silicon transistors designed for use as sense and high-frequency differential amplifiers.

CASE 32 C



PINS 4 AND 8 OMITTED

Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Collector-Base Voltage	V_{CB}	30		Vdc
Emitter-Base Voltage	V_{EB}	3.0		Vdc
Collector Current	I_C	50		mAdc
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ T_A = 25°C	P_D	0.3	0.45	Watt
Derate above 25°C		1.72	2.57	mW/°C
Total Device Dissipation @ T_C = 100°C	P_D	0.344	0.685	Watt
T_C = 25°C		0.6	1.2	Watt
Derate above 25°C		3.44	6.85	mW/°C

2N3423, 2N3424 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 3.0 mAdc, I_B = 0)	$BV_{CEO(sus)}^{*}$	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	BV_{CBO}	30	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	3.0	-	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	 - -	 0.01 1.0	μAdc
Emitter Cutoff Current (V_{EB} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	10	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 3.0 mAdc, V_{CE} = 1.0 Vdc) (I_C = 3.0 mAdc, V_{CE} = 3.0 Vdc)	h_{FE}	 20 20	 - 200	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	-	0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	-	1.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 4.0 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	600	1200	MHz
Output Capacitance (V_{CB} = 0, I_E = 0, f = 140 kHz) (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	 - -	 3.0 1.7	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	2.0	pF
Real Part of Input Impedance (I_C = 3.0 mAdc, V_{CE} = 3.0 Vdc, f = 350 MHz)	$Re(h_{ie})$	-	45	Ohm
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 3.0 mAdc, V_{CE} = 3.0 Vdc) 2N3423 2N3424	h_{FE1}/h_{FE2}^{**}	 0.8 0.9	 1.0 1.0	--
Base Voltage Differential (I_C = 3.0 mAdc, V_{CE} = 3.0 Vdc) 2N3423 2N3424	$\lvert V_{BE1}-V_{BE2}\rvert$	 - -	 10 5.0	mVdc
Base Voltage Differential Gradient (I_C = 3.0 mAdc, V_{CE} = 3.0 Vdc, T_{A1} = +25°C, T_{A2} = -55°C) 2N3423 2N3424 (I_C = 3.0 mAdc, V_{CE} = 3.0 Vdc, T_{A1} = +25°C, T_{A2} = +125°C) 2N3423 2N3424	$\Delta(V_{BE1}-V_{BE2})$	 - - - -	 3.2 1.6 4.0 2.0	mVdc

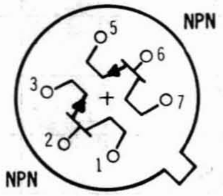
*Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2%

** Lowest of the two h_{FE} readings is taken as h_{FE1} for purposes of this ratio.

2N3425 (SILICON)

Dual NPN silicon transistor designed for use as a high-frequency sense amplifier.

CASE 32C


NPN
5
6
3
+
7
2
1
NPN

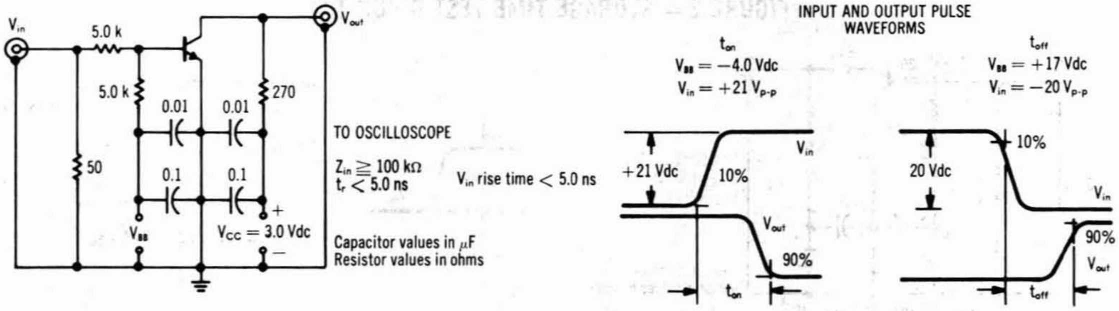
PINS 4 AND 8 OMITTED

Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Collector-Emitter Voltage ($R_{BE} \leqq 10$ ohms)	V_{CER}	20		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Operating Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D	0.3	0.4	Watt
Derate above 25°C		1.72	2.28	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	0.75	1.5	Watt
T_C = 100°C		0.43	0.86	Watt
Derate above 25°C		4.3	8.55	mW/°C

FIGURE 1 — SWITCHING-TIME TEST CIRCUIT


V_{in}
5.0 k
V_{out}
5.0 k
0.01
0.01
270
50
0.1
0.1
+
V_{BB}
V_{CC} = 3.0 Vdc
−
TO OSCILLOSCOPE
$Z_{in} \geqq 100\ k\Omega$
$t_r < 5.0$ ns
V_{in} rise time < 5.0 ns
Capacitor values in μF
Resistor values in ohms
INPUT AND OUTPUT PULSE WAVEFORMS
t_{on}
V_{BB} = −4.0 Vdc
V_{in} = +21 $V_{p\text{-}p}$
+21 Vdc
V_{in}
10%
V_{out}
90%
t_{on}
t_{off}
V_{BB} = +17 Vdc
V_{in} = −20 $V_{p\text{-}p}$
20 Vdc
10%
V_{in}
90%
V_{out}
t_{off}

2N3425 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	15	-	Vdc
Collector-Emitter Sustaining Voltage* (I_C = 30 mAdc, $R_{BE} \leq$ 10 ohms)	$BV_{CER(sus)}$*	20	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 0.25 Vdc, T_A = 125°C)	I_{CEX}	-	15	µAdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.025 15	µAdc
Emitter Cutoff Current (V_{EB} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	0.2	µAdc

ON CHARACTERISTICS

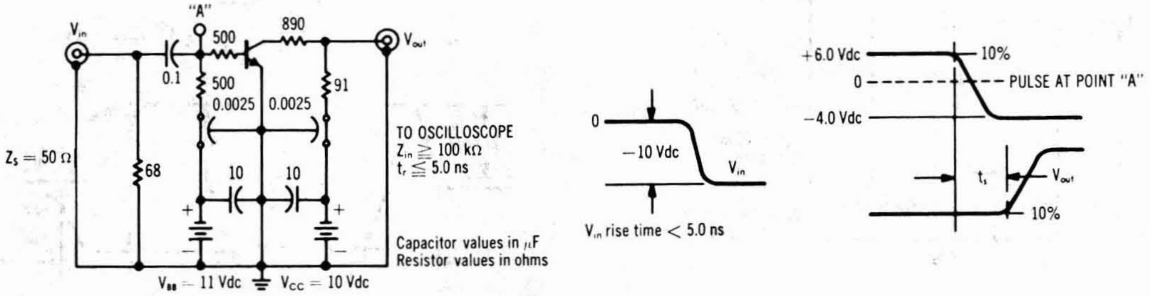
Characteristic	Symbol	Min	Max	Unit
DC Current Gain (I_C = 0.5 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)	h_{FE}	12 30 12	- 120 -	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 7.0 mAdc, I_B = 0.7 mAdc, T_A = -55°C to +125°C)	$V_{CE(sat)}$	- -	0.4 0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 7.0 mAdc, I_B = 0.7 mAdc, T_A = -55°C)	$V_{BE(sat)}$	0.7 -	0.85 0.9	Vdc

DYNAMIC CHARACTERISTICS

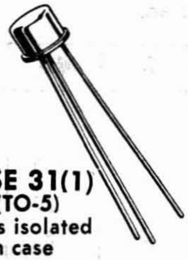
Characteristic	Symbol	Min	Max	Unit
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	6.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	9.0	pF
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, f = 1.0 kHz)	h_{fe}	20	-	-
Real Part of Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 300 MHz)	$Re(h_{ie})$	-	50	Ohms
Turn-On Time (Figure 1) (V_{CC} = 3.0 Vdc, $V_{EB(off)}$ = 2.0 Vdc, I_C ≈ 10 mAdc, I_{B1} ≈ 3.0 mAdc)	t_{on}	-	50	ns
Turn-Off Time (Figure 1) (V_{CC} = 3.0 Vdc, I_C ≈ 10 mAdc, I_{B1} ≈ 3.0 mAdc, I_{B2} ≈ 1.0 mAdc)	t_{off}	-	90	ns
Storage Time (Figure 2) (I_C ≈ 10 mAdc, I_{B1} ≈ 10 mAdc, I_{B2} ≈ 10 mAdc)	t_s	-	40	ns

*** Pulse Test: Pulse width ≤ 300 µs, duty cycle ≤ 1%**

FIGURE 2 — STORAGE TIME TEST CIRCUIT


"A"
V_{in}
500
890
V_{out}
0.1
500
91
0.0025
0.0025
Z_s = 50 Ω
68
10
10
+
−
+
−
V_{BB} = 11 Vdc
V_{CC} = 10 Vdc
TO OSCILLOSCOPE
$Z_{in} \geq$ 100 kΩ
$t_r \leq$ 5.0 ns
Capacitor values in µF
Resistor values in ohms
0
−10 Vdc
V_{in}
V_{in} rise time < 5.0 ns
+6.0 Vdc
10%
0
PULSE AT POINT "A"
−4.0 Vdc
t_s
V_{out}
10%

2N3427, 2N3428 (GERMANIUM)



CASE 31(1)
(TO-5)
All leads isolated from case

PNP germanium transistors for audio amplifier and medium-speed switching applications.

MAXIMUM RATINGS

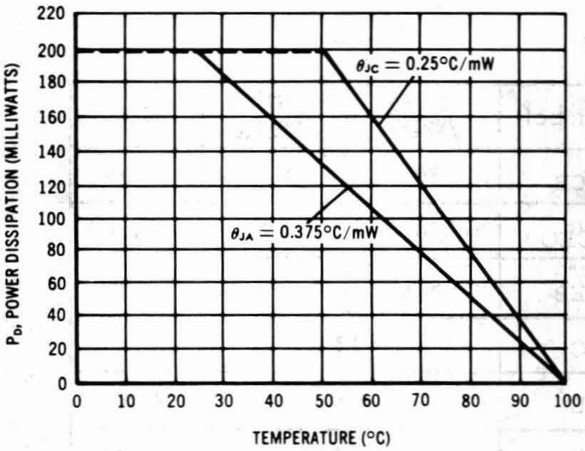
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	45	Vdc
Collector-Emitter Voltage	V_{CER}	30	Vdc
Emitter-Base Voltage	V_{EB}	30	Vdc
Collector Current (Continuous)	I_C	500*	mAdc
Base Current (Continuous)	I_B	50*	mAdc
Storage and Operating Temperature Range	T_{stg}, T_J	-65 to +100	°C
Collector Dissipation, Ambient Derate Above 25°C	P_D	200 2.67	mW mW/°C

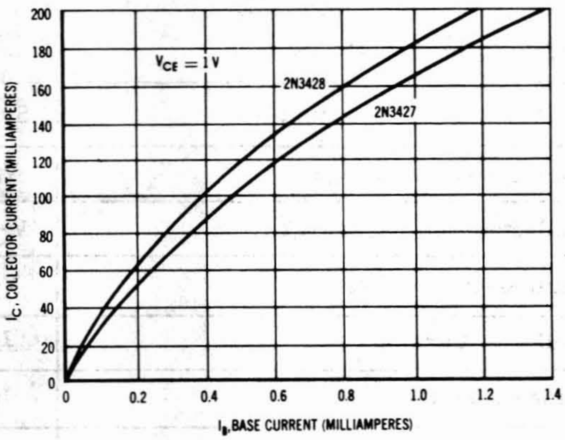
*Limited by power dissipation

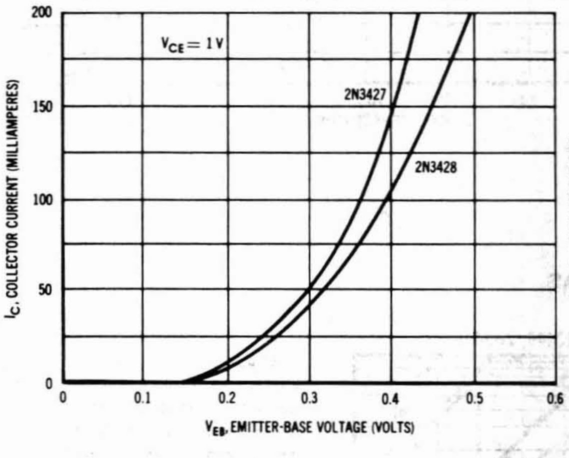
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

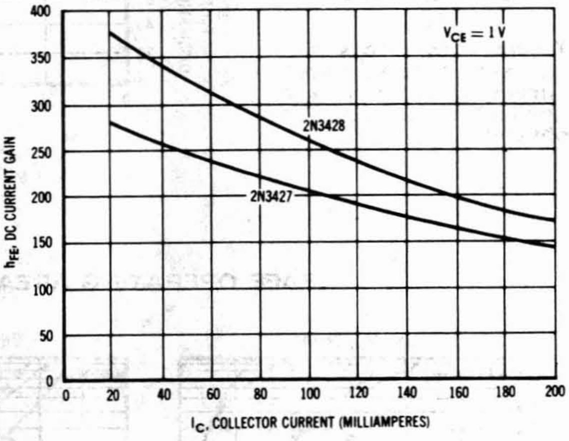
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 1.5 Vdc, I_E = 0)			–	3.0	5.0	
(V_{CB} = 10 Vdc, I_E = 0, T_A = +71°C)			–	–	100	
(V_{CB} = 30 Vdc, I_E = 0)			–	–	10	
(V_{CB} = 45 Vdc, I_E = 0)			–	–	50	
Emitter-Base Cutoff Current (V_{EB} = 30 Vdc, I_C = 0)		I_{EBO}	–	3.0	10	μAdc
Collector-Emitter Leakage Current (V_{CE} = 30 Vdc, R_{BE} = 10K ohms)		I_{CER}	–	–	600	μAdc
Collector-Emitter Punch-Thru Voltage (V_{fl} = 1.0 Vdc, VTVM impedance ≥ 1 megohm)		V_{pt}	30	–	–	Vdc
Output Capacitance (V_{CB} = 6 Vdc, I_E = 0, f = 1 MHz)		C_{ob}	–	10	20	pF
Noise Figure (V_{CE} = 4.5 Vdc, I_E = 0.5 mAdc, R_s = 1 K ohms, f = 1 kHz, Δf = 1 Hz)		NF	–	5.0	10	dB
Small-Signal Current-Gain Cutoff Frequency (V_{CB} = 6 Vdc, I_E = 1 mAdc)	2N3427	$f_{\alpha b}$	4.0	6.0	–	MHz
	2N3428		5.0	8.0	–	
Input Impedance (V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)		h_{ib}	25	–	35	Ohms
Output Admittance (V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)		h_{ob}	0.05	–	0.50	μmho
Small-Signal Current Gain (V_{CE} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	2N3427	h_{fe}	200	325	500	–
	2N3428		350	475	800	
Small-Signal Current Gain (V_{CE} = 6 Vdc, I_E = 1 mAdc, f = 2 MHz)	2N3427	$\|h_{fe}\|$	2.0	–	7.0	–
	2N3428		2.5	–	8.0	
DC Current Gain		h_{FE}				–
(I_C = 20 mAdc, V_{CE} = 1 Vdc)	2N3427		150	275	–	
	2N3428		250	375	–	
(I_C = 100 mAdc, V_{CE} = 1 Vdc)	2N3427		100	210	350	
	2N3428		150	260	400	
(I_C = 200 mAdc, V_{CE} = 1 Vdc)	2N3427		75	–	–	
	2N3428		125	–	–	
Base-Emitter Input Voltage (V_{CE} = 1 Vdc, I_C = 100 mAdc)		V_{BE}	–	–	0.5	Vdc
Collector-Emitter Saturation Voltage		V_{CE} (sat)				Vdc
(I_C = 100 mAdc, I_B = 2 mAdc)	2N3427		–	0.155	0.200	
	2N3428		–	0.150	0.190	
(I_C = 200 mAdc, I_B = 4 mAdc)	2N3427		–	0.220	0.300	
	2N3428		–	0.200	0.280	

2N3427, 2N3428 (continued)


POWER-TEMPERATURE DERATING CURVE


COLLECTOR CURRENT versus BASE CURRENT

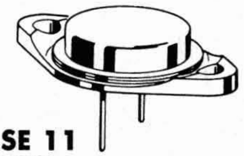

OUTPUT CURRENT versus BASE DRIVE VOLTAGE


DC CURRENT GAIN versus COLLECTOR CURRENT

2N3444 (SILICON)

For Specifications, See 2N3252 Data.

2N3445 thru 2N3448 (SILICON)



CASE 11
(TO-3)
Collector connected to case

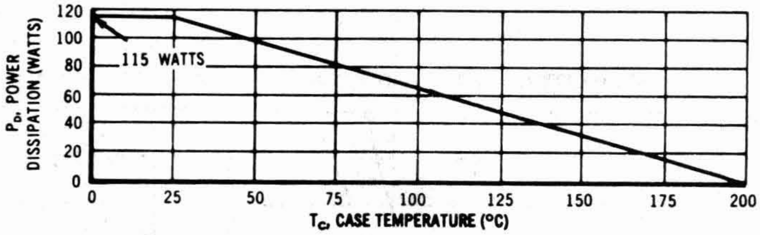
NPN silicon power transistors for switching and amplifier applications requiring fast response, wide band and good Beta linearity.

MAXIMUM RATINGS

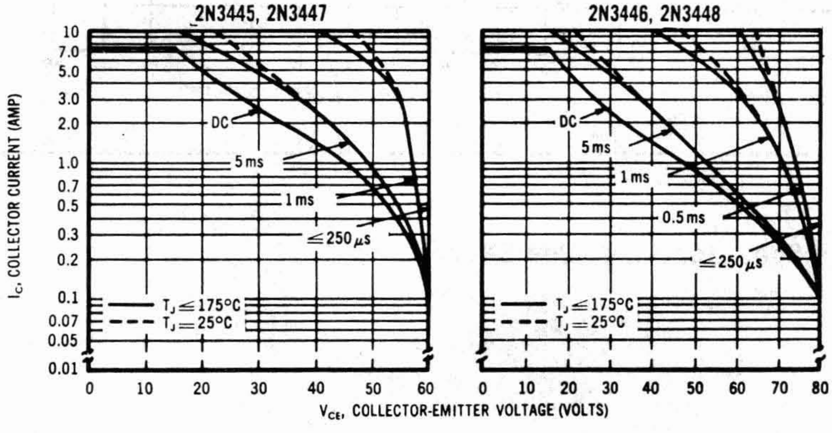
Rating	Symbol	2N3445 2N3447	2N3446 2N3448	Unit
Collector-Base Voltage	V_{CB}	80	100	Volts
Collector-Emitter Voltage	V_{CEO}	60	80	Volts
Emitter-Base Voltage	V_{EB}	6.0	10	Volts
Collector Current	I_C	7.5		Amp
Base Current	I_B	4.0		Amp
Power Dissipation	P_D	115		Watts
Junction Operating Temperature Range	T_J	-65 to +200		°C

POWER-TEMPERATURE DERATING CURVE

These transistors are also subject to safe area curves. Both limits are applicable and must be observed.



SAFE OPERATING AREAS

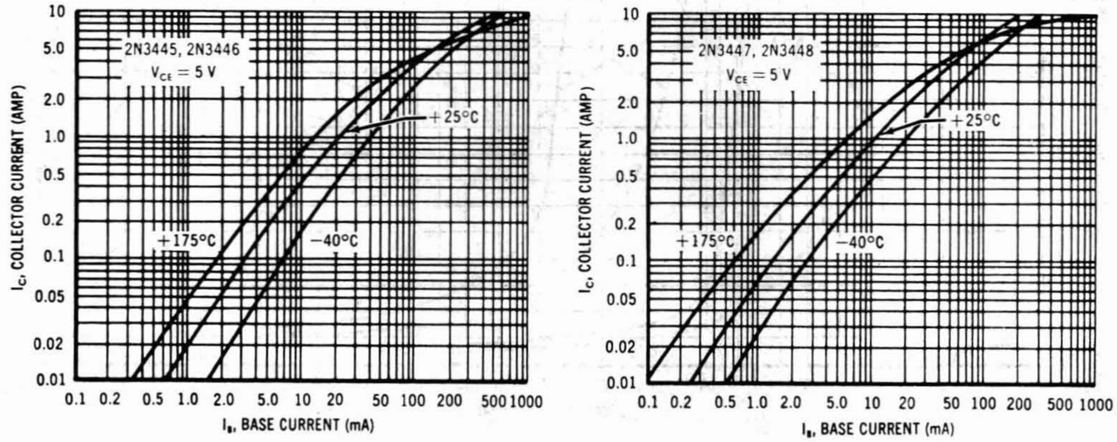


The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

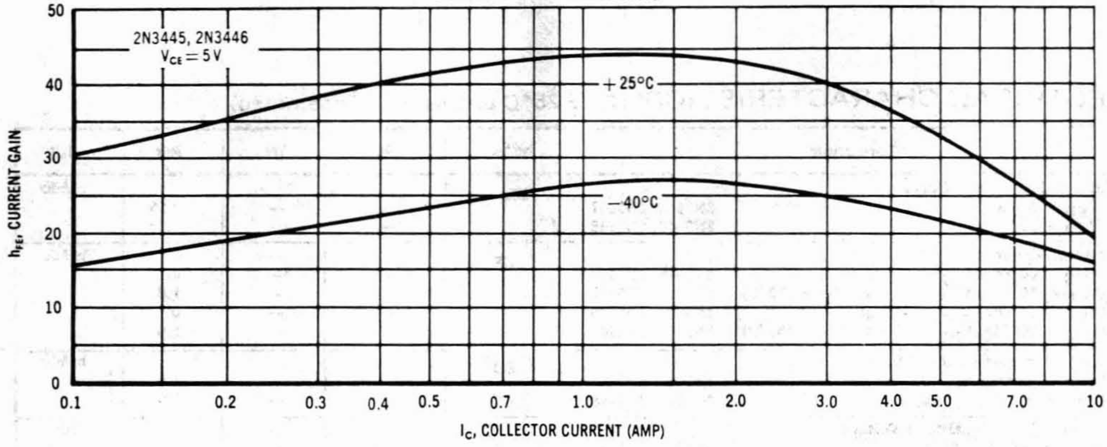
Characteristic		Symbol	Min	Typ	Max	Unit
Emitter-Base Cutoff Current		I_{EBO}				mAdc
(V_{EB} = 6 Vdc)	2N3445, 2N3447		—	—	0.25	
(V_{EB} = 10 Vdc)	2N3446, 2N3448		—	—	0.25	
Collector-Emitter Cutoff Current		I_{CEX}				mAdc
(V_{CE} = 60 Vdc, V_{BE} = -1 Vdc)	2N3445, 2N3447		—	—	0.1	
(V_{CE} = 60 Vdc, V_{BE} = -1 Vdc, T_C = 150°C)	2N3445, 2N3447		—	—	1.0	
(V_{CE} = 80 Vdc, V_{BE} = -1 Vdc)	2N3446, 2N3448		—	—	0.1	
(V_{CE} = 80 Vdc, V_{BE} = -1 Vdc, T_C = 150°C)	2N3446, 2N3448		—	—	1.0	
Collector-Emitter Cutoff Current		I_{CEO}				mAdc
(V_{CE} = 40 Vdc, I_B = 0)	2N3445, 2N3447		—	—	1.0	
(V_{CE} = 60 Vdc, I_B = 0)	2N3446, 2N3448		—	—	1.0	
Collector-Base Breakdown Voltage		BV_{CBO}				Vdc
(I_C = 1 mAdc, I_E = 0)	2N3445, 2N3447		80	—	—	
	2N3446, 2N3448		100	—	—	
Collector-Emitter Sustaining Voltage		$V_{CEO(sus)}$				Vdc
(I_C = 100 mAdc, I_B = 0)	2N3445, 2N3447		60	—	—	
	2N3446, 2N3448		80	—	—	
DC Current Gain		h_{FE}				—
(I_C = 0.5 Adc, V_{CE} = 5 Vdc)	2N3445, 2N3446		20	45	—	
	2N3447, 2N3448		40	85	—	
(I_C = 3 Adc, V_{CE} = 5 Vdc)	2N3445, 2N3446		20	40	60	
(I_C = 5 Adc, V_{CE} = 5 Vdc)	2N3447, 2N3448		40	75	120	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 3 Adc, I_B = 0.3 Adc)	2N3445, 2N3446		—	0.6	1.5	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N3447, 2N3448		—	0.8	1.5	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$				Vdc
(I_C = 3 Adc, I_B = 0.3 Adc)	2N3445, 2N3446		—	1.0	1.5	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N3447, 2N3448		—	1.0	1.5	
Base-Emitter Voltage		V_{BE}				Vdc
(I_C = 3 Adc, V_{CE} = 5 Vdc)	2N3445, 2N3446		—	1.0	1.5	
(I_C = 5 Adc, V_{CE} = 5 Vdc)	2N3447, 2N3448		—	1.0	1.4	
Small Signal Current Gain		h_{fe}				—
(V_{CE} = 10 Vdc, I_C = 0.5 Adc, f = 1 kHz)	2N3445, 2N3446		20	—	100	
	2N3447, 2N3448		40	—	200	
(V_{CE} = 10 Vdc, I_C = 0.5 Adc, f = 10 MHz)			1.0	1.6	—	
Common Base Output Capacitance		C_{ob}				pF
(V_{CB} = 10 Vdc, f = 0.1 MHz)			—	260	400	
Switching Times						µs
(V_{CC} ≈ 25 Vdc, R_L = 5 ohms, I_C = 5 A, I_{B1} = I_{B2} = 0.5 A)						
Delay Time plus Rise Time		$t_d + t_r$	—	0.15	0.35	
Storage Time		t_s	—	0.9	2.0	
Fall Time		t_f	—	0.15	0.35	

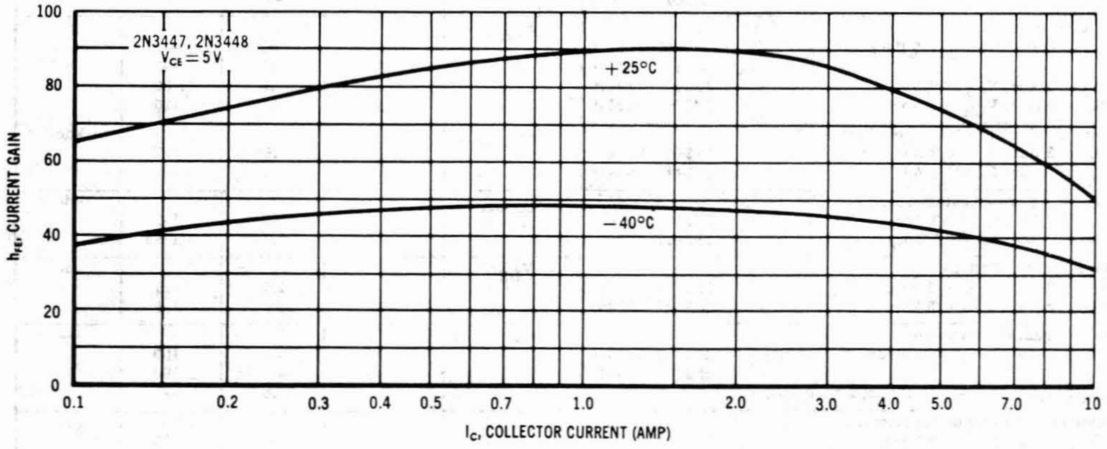
COLLECTOR CURRENT versus BASE CURRENT



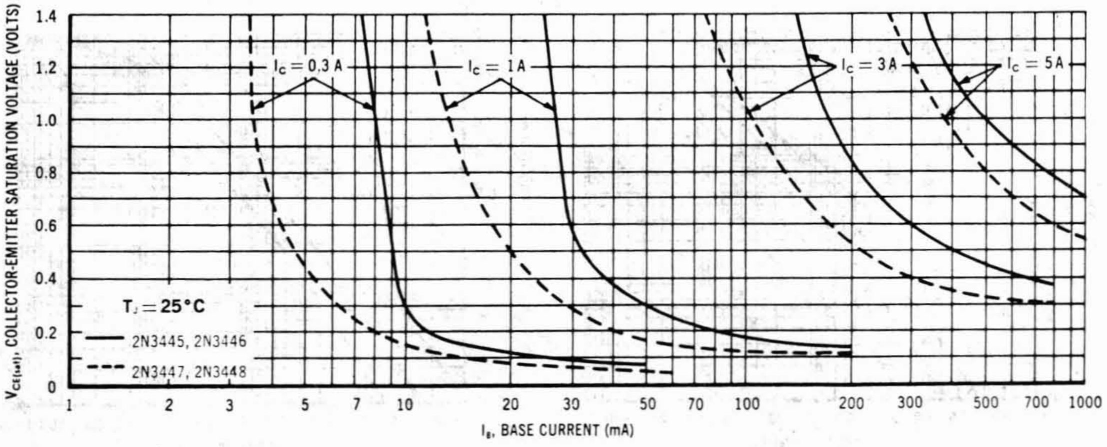
2N3445 thru 2N3448 (continued)

CURRENT GAIN VARIATIONS

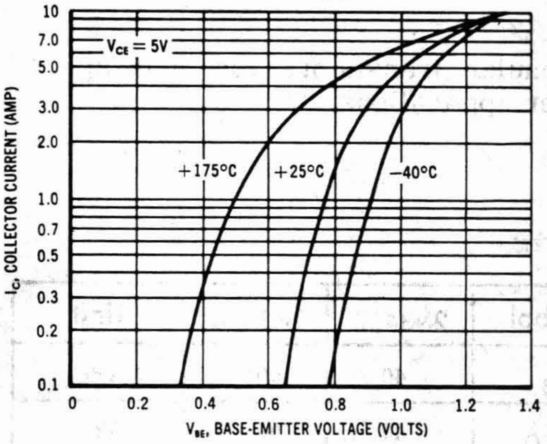




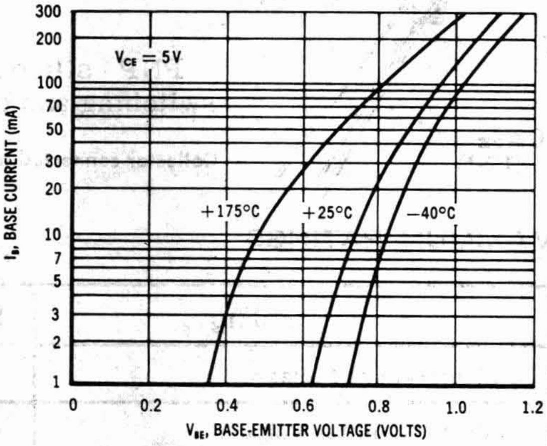
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS



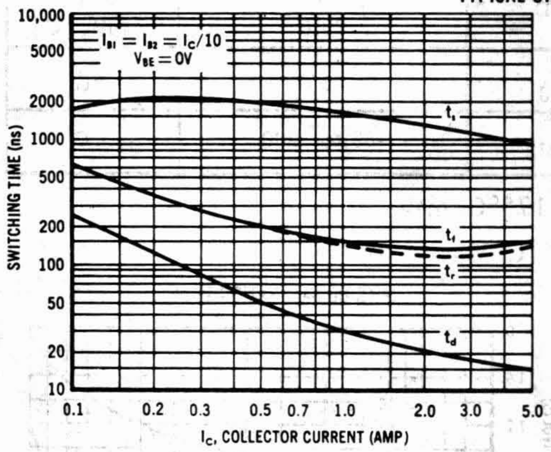
COLLECTOR CURRENT-VOLTAGE VARIATIONS



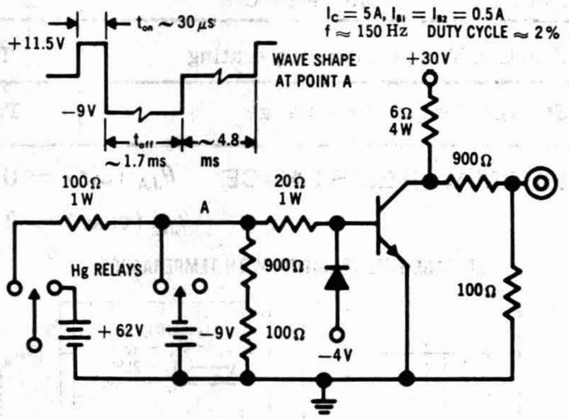
BASE CURRENT-VOLTAGE VARIATIONS



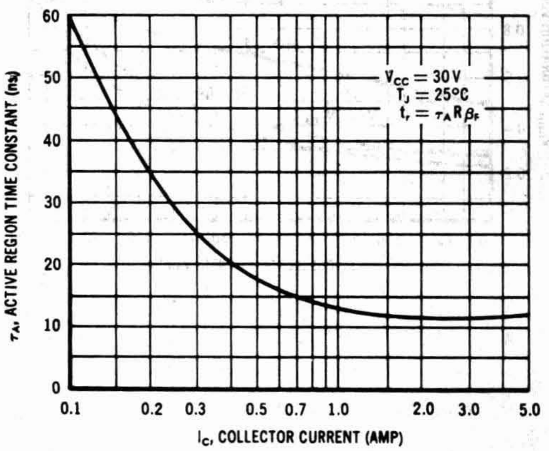
TYPICAL SWITCHING TIMES



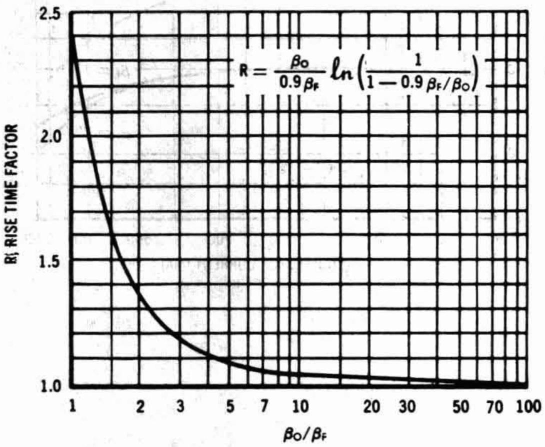
TEST CIRCUIT


$I_C = 5A$, $I_{B1} = I_{B2} = 0.5A$
f ≈ 150 Hz DUTY CYCLE ≈ 2%
$t_{on} \sim 30\,\mu s$
+11.5V
−9V
t_{off}
~1.7 ms
~4.8 ms
WAVE SHAPE AT POINT A
+30V
6Ω 4W
900Ω
100Ω 1W
A
20Ω 1W
900Ω
100Ω
Hg RELAYS
+62V
−9V
100Ω
−4V

ACTIVE REGION TIME CONSTANT



RISE TIME FACTOR



2N3467 (SILICON)
2N3468

CASE 31
(TO-5)

PNP silicon annular transistors for high-speed switching and driver applications.

Collector connected to case

MAXIMUM RATINGS

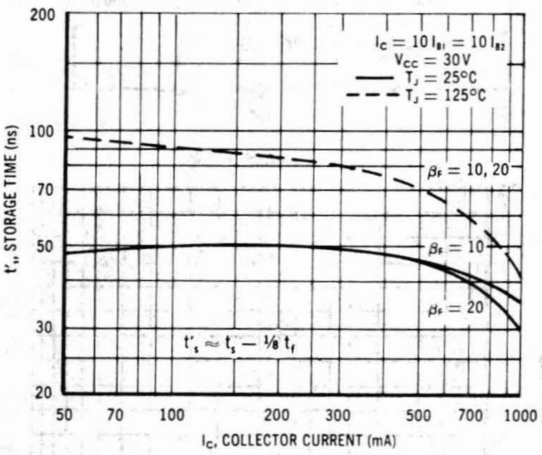
Rating	Symbol	2N3467	2N3468	Unit
Collector-Base Voltage	V_{CB}	40	50	Vdc
Collector-Emitter Voltage	V_{CEO}	40	50	Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	1		Adc
Total Device Dissipation @ $T_A = 25^oC$ Derating Factor Above 25^oC	P_D	1.0 5.71		Watt $mW/^oC$
Total Device Dissipation @ $T_C = 25^oC$ Derating Factor Above 25^oC	P_D	5 28.6		Watts $mW/^oC$
Junction Temperature, Operating	T_J	+200		^oC
Storage Temperature Range	T_{stg}	-65 to +200		^oC

THERMAL RESISTANCE

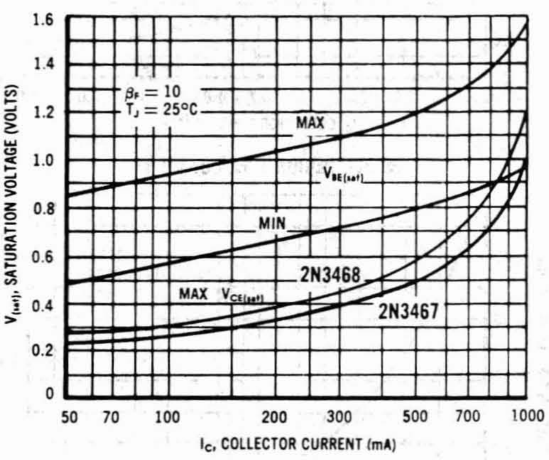
θ_{JA} (air) = 0.175°C/mW

θ_{JC} (case) = 35°C/W

STORAGE TIME VARIATION WITH TEMPERATURE



LIMITS OF SATURATION VOLTAGE



ELECTRICAL CHARACTERISTICS (At 25°C unless otherwise noted)

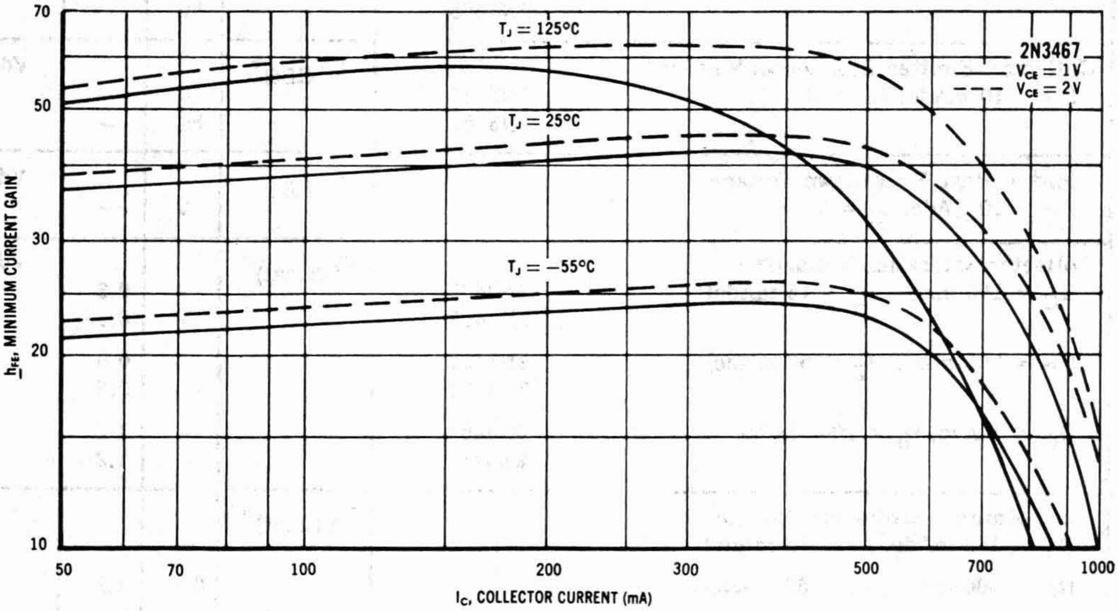
Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 30 Vdc, I_E = 0)			—	0.10	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 100°C)			—	15	
Collector Cutoff Current		I_{CEX}			nAdc
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 3 Vdc)			—	100	
Base Cutoff Current		I_{BL}			nAdc
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 3 Vdc)			—	120	
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 10 μAdc, I_E = 0)	2N3467		40	—	
	2N3468		50	—	
Collector-Emitter Breakdown Voltage*		BV_{CEO}*			Vdc
(I_C = 10 mAdc, I_B = 0)	2N3467		40	—	
	2N3468		50	—	
Emitter-Base Breakdown Voltage		BV_{EBO}			Vdc
(I_E = 10 μAdc, I_C = 0)			5	—	
Collector Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)	2N3467		—	0.3	
	2N3468		—	0.35	
(I_C = 500 mAdc, I_B = 50 mAdc)	2N3467		—	0.5	
	2N3468		—	0.6	
(I_C = 1 Adc, I_B = 100 mAdc)	2N3467		—	1.0	
	2N3468		—	1.2	
Base-Emitter Saturation Voltage*		$V_{BE(sat)}$*			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			—	1.0	
(I_C = 500 mAdc, I_B = 50 mAdc)			0.8	1.2	
(I_C = 1 Adc, I_B = 100 mAdc)			—	1.6	
DC Forward Current Transfer Ratio*		h_{FE}*			—
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)	2N3467		40	—	
	2N3468		25	—	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)	2N3467		40	120	
	2N3468		25	75	
(I_C = 1 Adc, V_{CE} = 5 Vdc)	2N3467		40	—	
	2N3468		25	—	
Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)			—	25	
Input Capacitance		C_{ib}			pF
(V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)			—	100	
Current-Gain - Bandwidth Product		f_T			MHz
(I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3467		175	—	
	2N3468		150	—	

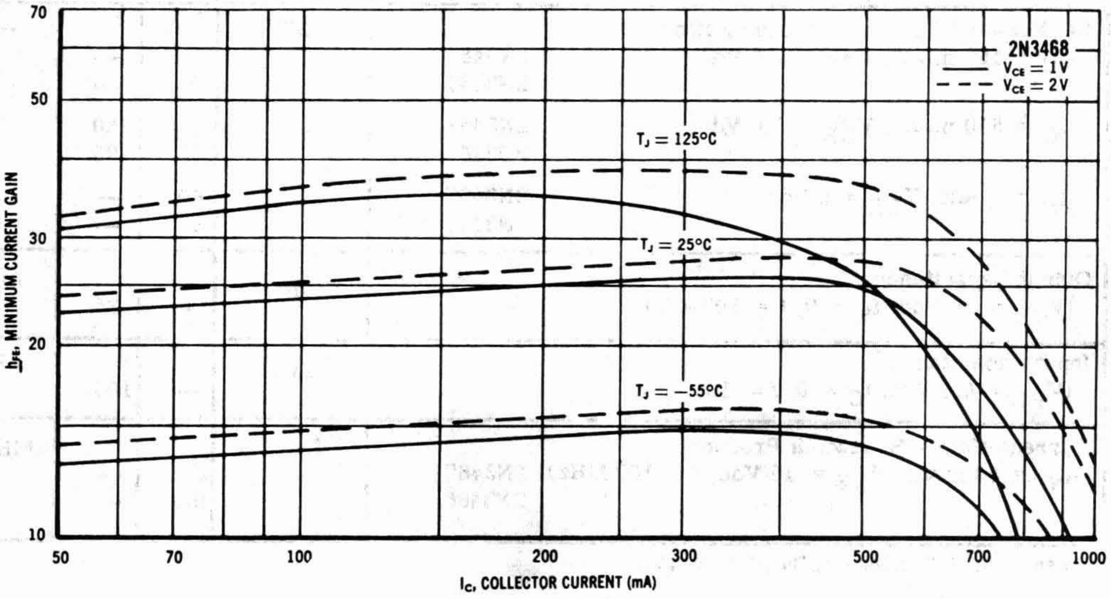
*Pulse Test: PW ≦ 300 μs, Duty Cycle ≦ 2%

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Max	Unit
Delay Time	(I_C = 500 mA, I_{B1} = 50 mA, V_{BE} = 2 V, V_{CC} = 30 V)	t_d	—	10	ns
Rise Time		t_r	—	30	ns
Storage Time	(I_C = 500 mA, I_{B1} = I_{B2} = 50 mA, V_{CC} = 30 V)	t_s	—	60	ns
Fall Time		t_f	—	30	ns
Total Control Charge (I_C = 500 mA, I_B = 50 mA, V_{CC} = 30 V)		Q_T	—	6	nC

MINIMUM CURRENT GAIN CHARACTERISTICS





2N3485, A (SILICON)
2N3486, A

For Specifications, See 2N2904 Data.

2N3487 thru 2N 3492 (SILICON)

CASE 9
(TO-61)

NPN silicon power transistors designed for switching and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3487 2N3490	2N3488 2N3491	2N3489 2N3492	Unit
Collector-Base Voltage	V_{CB}	80	100	120	Vdc
Collector-Emitter Voltage	V_{CEO}	60	80	100	Vdc
Emitter-Base Voltage	V_{EB}	10	10	10	Vdc
Collector Current (Continuous)	I_C	7.5	7.5	7.5	Adc
Base Current (Continuous)	I_B	4.0	4.0	4.0	Adc
Power Dissipation	P_D	117	117	117	Watts
Thermal Resistance, Junction to Case	θ_{JC}	1.5	1.5	1.5	$^{\circ}C/W$
Junction Operating Temperature Range	T_J	$-65^{\circ}C$ to $+200^{\circ}C$			$^{\circ}C$

2N3487 thru 2N3492 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = 10 Vdc)			-	0.10	
Collector-Emitter Cutoff Current		I_{CEX}			µAdc
(V_{CE} = 60 Vdc, V_{BE} = -1 Vdc)	2N3487, 2N3490		-	25	
(V_{CE} = 80 Vdc, V_{BE} = -1 Vdc)	2N3488, 2N3491		-	25	
(V_{CE} = 100 Vdc, V_{BE} = -1 Vdc)	2N3489, 2N3492		-	25	
(V_{CE} = 60 Vdc, V_{BE} = -1 Vdc, T_C = 150°C)	2N3487, 2N3490		-	250	
(V_{CE} = 80 Vdc, V_{BE} = -1 Vdc, T_C = 150°C)	2N3488, 2N3491		-	250	
(V_{CE} = 100 Vdc, V_{BE} = -1 Vdc, T_C = 150°C)	2N3489, 2N3492		-	250	
Collector-Emitter Cutoff Current		I_{CEO}			µAdc
(V_{CE} = 40 Vdc, I_B = 0)	2N3487, 2N3490		-	250	
(V_{CE} = 60 Vdc, I_B = 0)	2N3488, 2N3491		-	250	
(V_{CE} = 80 Vdc, I_B = 0)	2N3489, 2N3492		-	250	
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 100 µAdc, I_E = 0)	2N3487, 2N3490		80	-	
	2N3488, 2N3491		100	-	
	2N3489, 2N3492		120	-	
Collector-Emitter Sustaining Voltage		$V_{CEO(sus)}$			Vdc
(I_C = 100 mAdc, I_B = 0)	2N3487, 2N3490		60	-	
	2N3488, 2N3491		80	-	
	2N3489, 2N3490		100	-	
DC Current Gain		h_{FE}			-
(I_C = 0.5 Adc, V_{CE} = 5 Vdc)	2N3487, 2N3488, 2N3489		20	-	
	2N3490, 2N3491, 2N3492		40	-	
(I_C = 3.0 Adc, V_{CE} = 5 Vdc)	2N3487, 2N3488		20	60	
	2N3489		15	45	
(I_C = 5.0 Adc, V_{CE} = 5 Vdc)	2N3490, 2N3491		40	120	
	2N3492		30	90	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 1 Adc, I_B = 0.1 Adc)			-	0.3	
(I_C = 3 Adc, I_B = 0.3 Adc)	2N3487, 2N3488, 2N3489		-	1.2	
	2N3490, 2N3491, 2N3492		-	1.0	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N3490, 2N3491, 2N3492		-	1.5	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 3 Adc, I_B = 0.3 Adc)	2N3487, 2N3488, 2N3489		-	1.5	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N3490, 2N3491, 2N3492		-	1.5	
Base-Emitter Voltage		V_{BE}			Vdc
(I_C = 3 Adc, V_{CE} = 5 Vdc)	2N3487, 2N3488, 2N3489		-	1.5	
(I_C = 5 Adc, V_{CE} = 5 Vdc)	2N3490, 2N3491, 2N3492		-	1.4	
Small Signal Current Gain		h_{fe}			-
(V_{CE} = 10 Vdc, I_C = 0.5 Adc, f = 1 kHz)	2N3487, 2N3488, 2N3489		20	100	
	2N3490, 2N3491, 2N3492		40	200	
(V_{CE} = 10 Vdc, I_C = 0.5 Adc, f = 10 MHz)	All Types		1.0	-	
Common Base Output Capacitance		C_{ob}			pF
(V_{CB} = 10 Vdc, f = 0.1 MHz)			-	550	
Switching Times					µs
($V_{CC} \approx$ 25 Vdc, R_L = 5Ω, I_C = 5 Adc, $I_{B_1} = -I_{B_2}$ = 0.5 Adc)			-	-	
Delay Time plus Rise Time		$t_d + t_r$	-	0.35	µs
Storage Time		t_s	-	2.0	
Fall Time		t_f	-	0.35	

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE

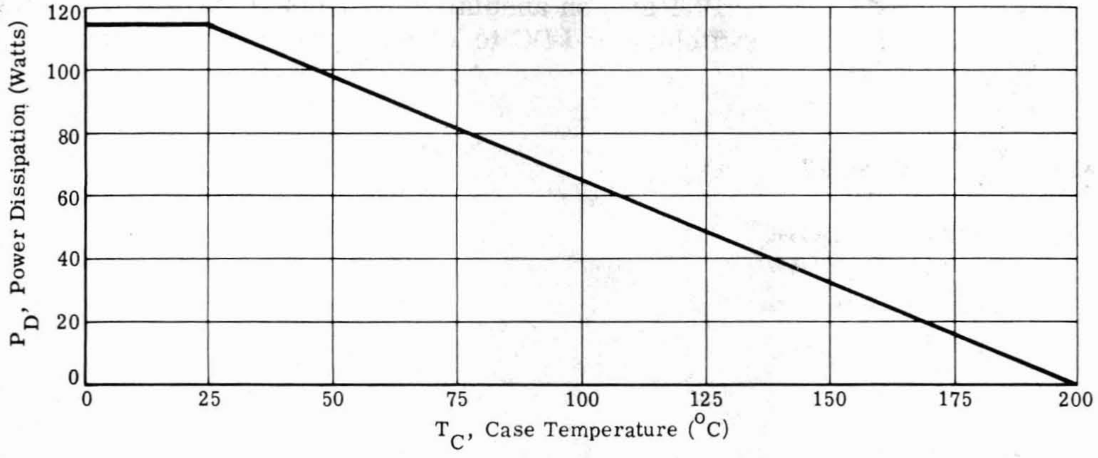
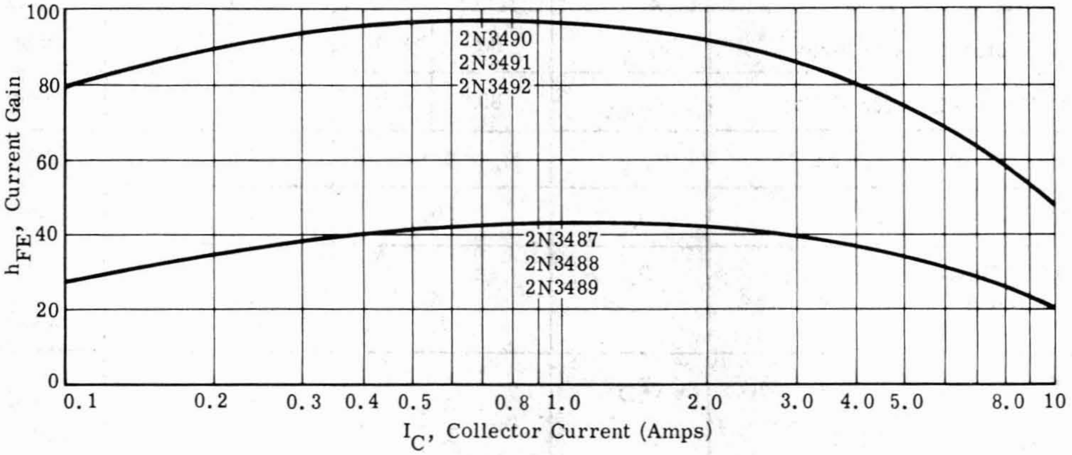


FIGURE 2 — DC CURRENT GAIN versus COLLECTOR CURRENT



ACTIVE - REGION SAFE OPERATING AREAS

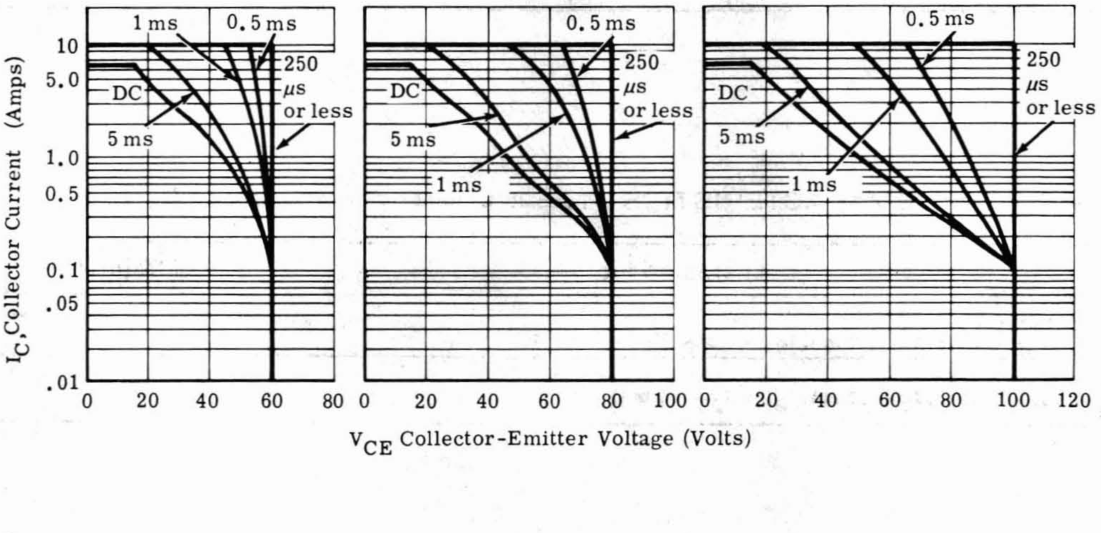
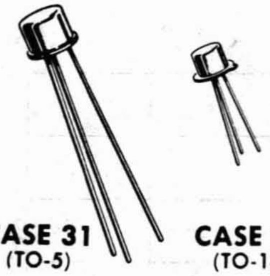


FIGURE 3 — 2N3487, 2N3490

FIGURE 4 — 2N3489, 2N3492

FIGURE 5 — 2N3488, 2N3491

2N3494 thru 2N3497 (SILICON)



CASE 31
(TO-5)

CASE 22
(TO-18)

CASE 31 (TO-5)	CASE 22 (TO-18)
2N3494	2N3496
2N3495	2N3497

Collector connected to case

PNP silicon annular Star transistors for high voltage switching and DC to VHF amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N 3494 (TO-5)	2N 3495 (TO-5)	2N 3496 (TO-18)	2N 3497 (TO-18)	Unit
Collector-Base Voltage	V_{CB}	80	120	80	120	Vdc
Collector-Emitter Voltage	V_{CEO}	80	120	80	120	Vdc
Emitter-Base Voltage	V_{EB}	4.5		4.5		Vdc
Collector Current	I_C	100		100		mA
Total Device Dissipation @ $T_C = 25^oC$ Derate Above 25^oC	P_D	3 17.2		1.8 10.3		Watts mW/^oC
Total Device Dissipation @ $T_A = 25^oC$ Derate Above 25^oC	P_D	600 3.43		400 2.28		mW mW/^oC
Junction Temperature	T_J	-65 to +200				^oC
Storage Temperature	T_{stg}	-65 to +200				^oC

SWITCHING CHARACTERISTICS ($T_A = 25°C$ unless otherwise specified)

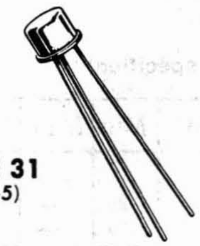
Characteristic	Symbol	Min	Max	Unit
Turn-On Time (V_{CC} = 30 V, I_C = 10 mA, I_{B1} = 1 mA, V_{BE} = 0)	t_{on}	—	300	ns
Turn-Off Time (V_{CC} = 30 V, I_C = 10 mA, $I_{B1} = I_{B2}$ = 1 mA)	t_{off}	—	450	ns

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise specified)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N3494, 2N3496	BV_{CBO}	80	—	Vdc
	2N3495, 2N3497		120	—	
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	2N3494, 2N3496	BV_{CEO}*	80	—	Vdc
	2N3495, 2N3497		120	—	
Emitter-Base Breakdown Voltage (I_E = 10 μ Adc, I_C = 0)		BV_{EBO}	4.5	—	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0)	2N3494, 2N3496	I_{CBO}	—	100	nAdc
(V_{CB} = 90 Vdc, I_E = 0)	2N3495, 2N3497		—	100	
Emitter-Base Leakage Current (V_{CB} = 3 Vdc)		I_{EBO}	—	25	nAdc
DC Forward Current Transfer Ratio (I_C = 100 μ Adc, V_{CE} = 10 Vdc)	All Types	h_{FE}	35	—	—
(I_C = 1 mAdc, V_{CE} = 10 Vdc)	All Types		40	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	All Types		40	—	
(I_C = 50 mAdc, V_{CE} = 10 Vdc)	All Types		40	—	
(I_C = 100 mAdc, V_{CE} = 10 Vdc)	2N3494, 2N3496		35	—	
Collector Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	2N3494, 2N3496	$V_{CE(sat)}$	—	0.3	Vdc
	2N3495, 2N3497		—	0.35	
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{BE(sat)}$	0.6	0.9	Vdc
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	2N3494, 2N3496	C_{ob}	—	7	pF
	2N3495, 2N3497		—	6	
Input Capacitance (V_{BE} = 2 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	30	pF
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3494, 2N3496	f_T	200	—	MHz
	2N3495, 2N3497		150	—	
Small Signal Current Gain (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)		h_{fe}	40	300	—
Input Impedance (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)		h_{ie}	0.1	1.2	kohms
Voltage Feedback Ratio (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)		h_{re}	—	2.0	$X10^{-4}$
Output Admittance (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)		h_{oe}	—	300	μ mhos
Extrinsic Base Resistance (V_{CE} = 10 V, I_C = 20 mA, f = 300 MHz)		r_b	—	30	ohms

* Pulse width ≤ 300 μs, Duty Cycle = 2%

2N3498 thru 2N3501 (SILICON)



CASE 31
(TO-5)

NPN silicon annular transistors for high-voltage switching and low-power amplifier applications.

Collector connected to case

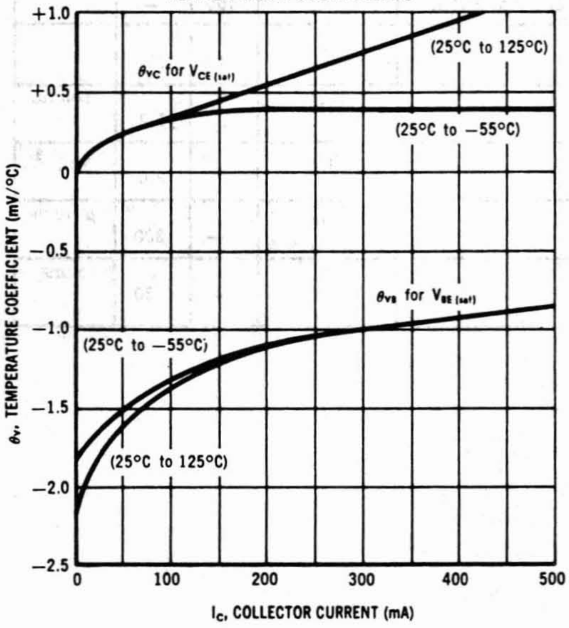
MAXIMUM RATINGS

Rating	Symbol	2N3498 2N3499	2N3500 2N3501	Unit
Collector-Emitter Voltage	V_{CEO}	100	150	Vdc
Collector-Base Voltage	V_{CB}	100	150	Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current	I_C	500	300	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 5.71		Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	5.0 28.6		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

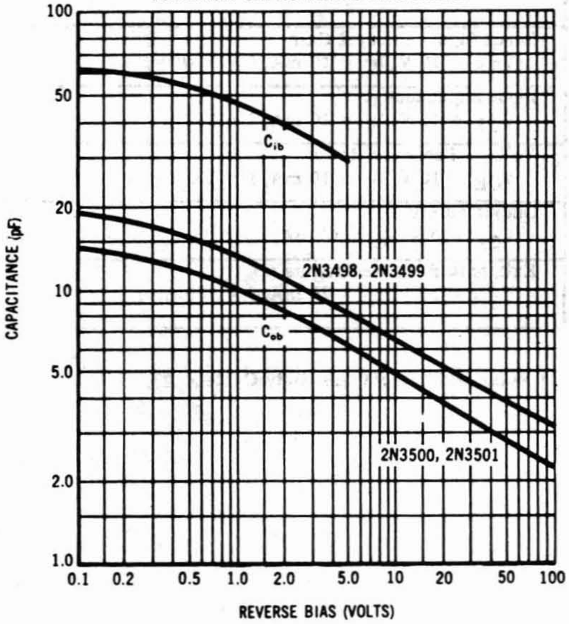
THERMAL CHARACTERISTICS

Characteristic	Symbol	2N3498 2N3499	2N3500 2N3501	Unit
Thermal Resistance, Junction to Case	θ_{JC}	35		°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	0.175		°C/mW

TEMPERATURE COEFFICIENTS



JUNCTION CAPACITANCE VARIATIONS



2N3498 thru 2N3501 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage*		BV_{CEO}*			Vdc
(I_C = 10 mAdc, I_B = 0)	2N3498, 2N3499		100	-	
	2N3500, 2N3501		150	-	
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 10 μAdc, I_E = 0)	2N3498, 2N3499		100	-	
	2N3500, 2N3501		150	-	
Emitter-Base Breakdown Voltage		BV_{EBO}			Vdc
(I_E = 10 μAdc, I_C = 0)			6.0	-	
Collector Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 50 Vdc, I_E = 0)	2N3498, 2N3499		-	0.050	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	2N3498, 2N3499		-	50	
(V_{CB} = 75 Vdc, I_E = 0)	2N3500, 2N3501		-	0.050	
(V_{CB} = 75 Vdc, I_E = 0, T_A = 150°C)	2N3500, 2N3501		-	50	
Emitter Cutoff Current		I_{EBO}			nAdc
(V_{EB} = 4.0 Vdc, I_C = 0)			-	25	
ON CHARACTERISTICS					
DC Current Gain*		h_{FE}*			-
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N3498, 2N3500		20	-	
	2N3499, 2N3501		35	-	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	2N3498, 2N3500		25	-	
	2N3499, 2N3501		50	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N3498, 2N3500		35	-	
	2N3499, 2N3501		75	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	2N3498, 2N3500		40	120	
	2N3499, 2N3501		100	300	
(I_C = 300 mAdc, V_{CE} = 10 Vdc)	2N3500		15	-	
	2N3501		20	-	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)	2N3498		15	-	
	2N3499		20	-	
Collector-Emitter Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)			-	0.2	
(I_C = 50 mAdc, I_B = 5.0 mAdc)			-	0.25	
(I_C = 150 mAdc, I_B = 15 mAdc)	2N3500, 2N3501		-	0.4	
(I_C = 300 mAdc, I_B = 30 mAdc)	2N3498, 2N3499		-	0.6	
Base-Emitter Saturation Voltage*		$V_{BE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)			-	0.8	
(I_C = 50 mAdc, I_B = 5.0 mAdc)			-	0.9	
(I_C = 150 mAdc, I_B = 15 mAdc)	2N3500, 2N3501		-	1.2	
(I_C = 300 mAdc, I_B = 30 mAdc)	2N3498, 2N3499		-	1.4	

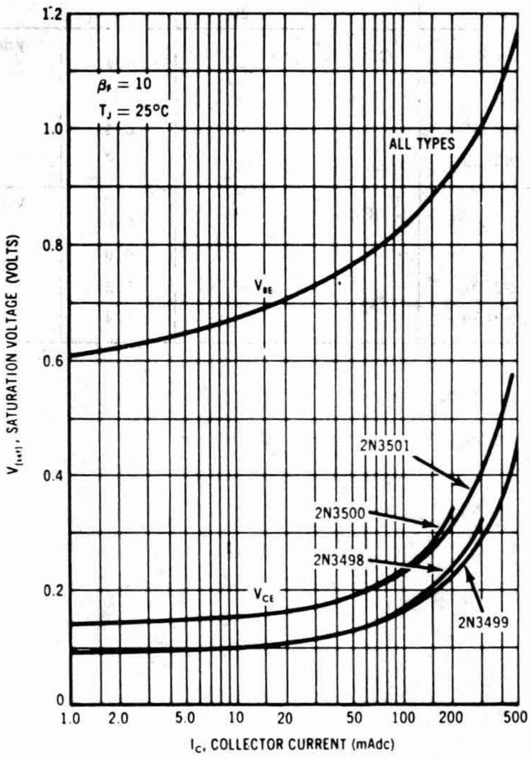
* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

ELECTRICAL CHARACTERISTICS (continued)

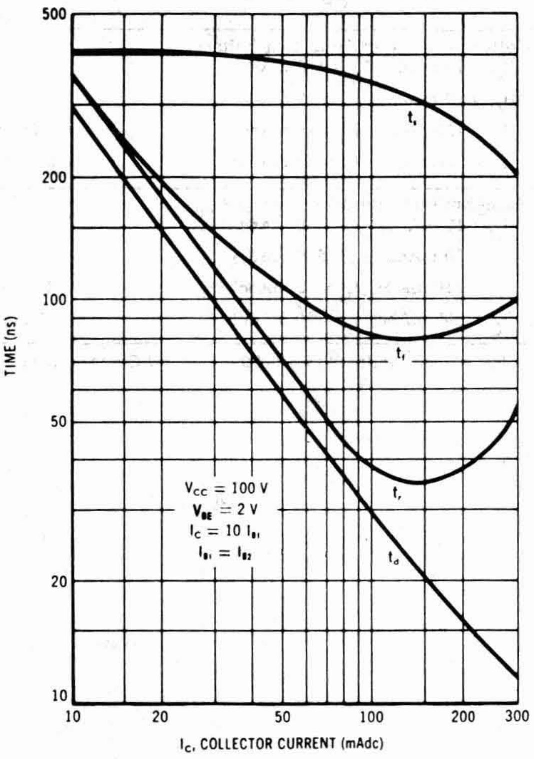
Characteristic	Symbol	Min	Max	Unit
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	150	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz) 2N3498, 2N3499 2N3500, 2N3501	C_{ob}	- -	10 8.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	80	pF
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3498, 2N3500 2N3499, 2N3501	h_{ie}	0.2 0.25	1.0 1.25	k ohms
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3498, 2N3500 2N3499, 2N3501	h_{re}	- -	2.5 4.0	X 10^{-4}
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3498, 2N3500 2N3499, 2N3501	h_{fe}	50 75	300 375	-
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3498, 2N3500 2N3499, 2N3501	h_{oe}	10 20	100 200	μmhos

SWITCHING CHARACTERISTICS			Typ	
Delay Time	(V_{CC} = 100 Vdc, $V_{BE(off)}$ = 2.0 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc)	t_d	20	ns
Rise Time		t_r	35	ns
Storage Time	(V_{CC} = 100 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc)	t_s	300	ns
Fall Time		t_f	80	ns

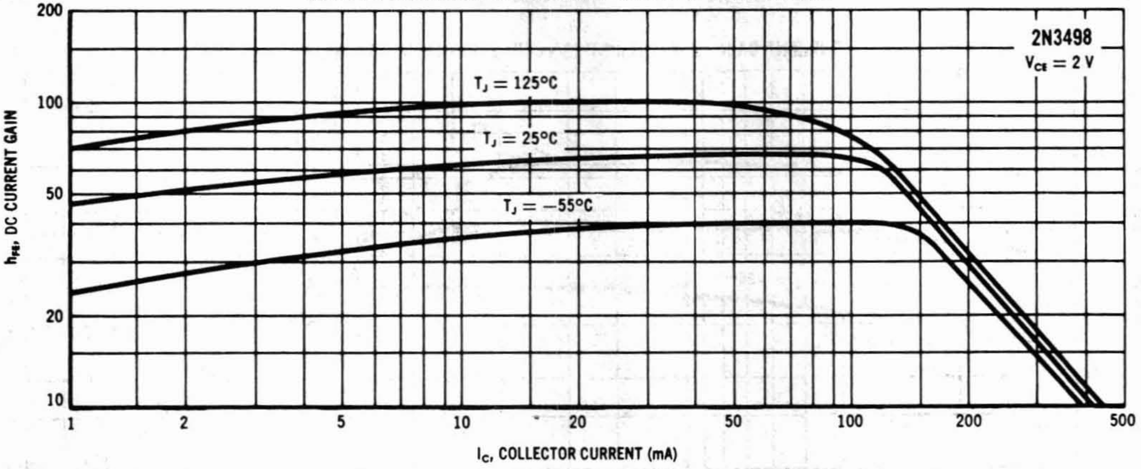
SATURATION VOLTAGES

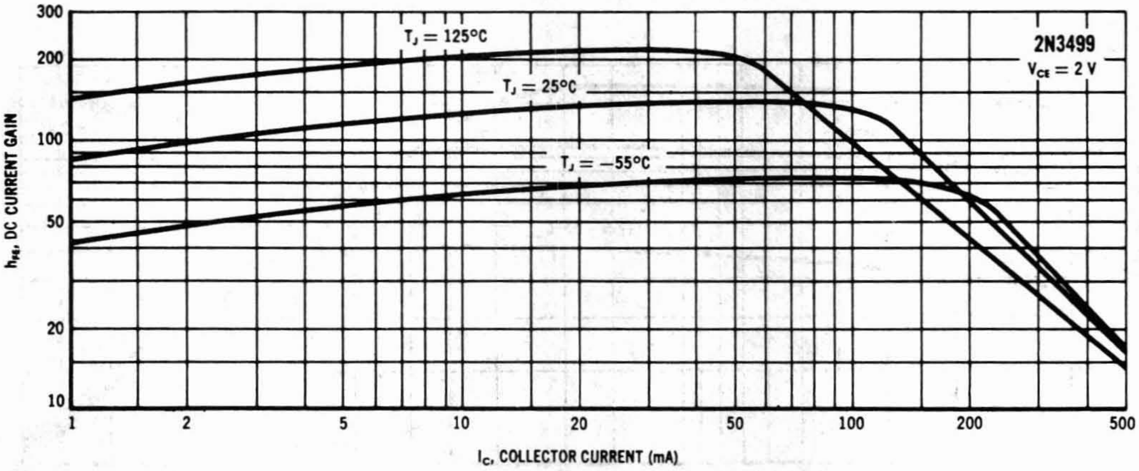


SWITCHING TIMES

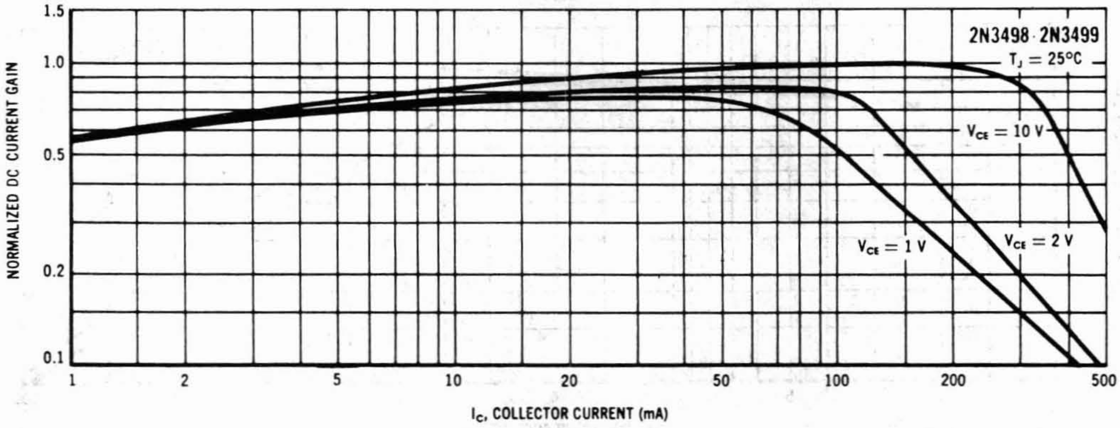


CURRENT GAIN CHARACTERISTICS vs JUNCTION TEMPERATURE

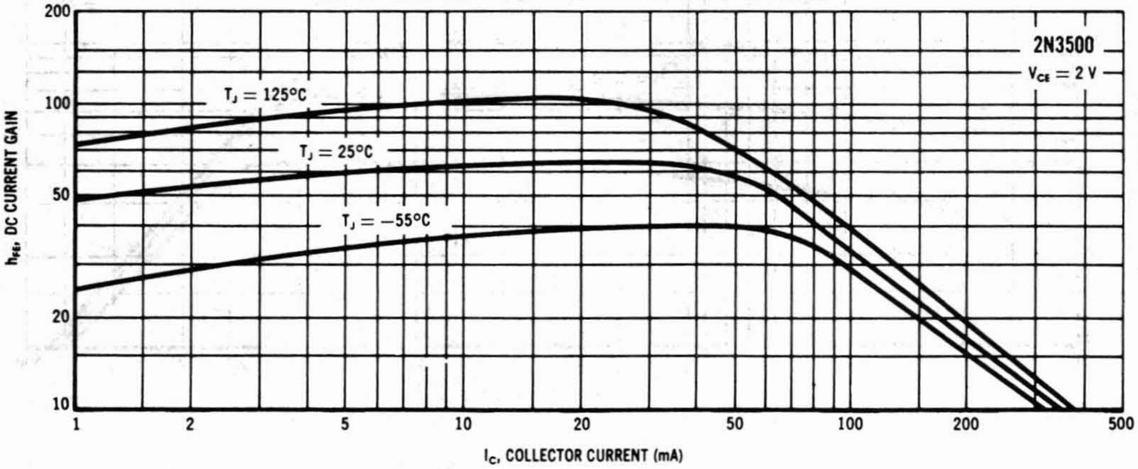


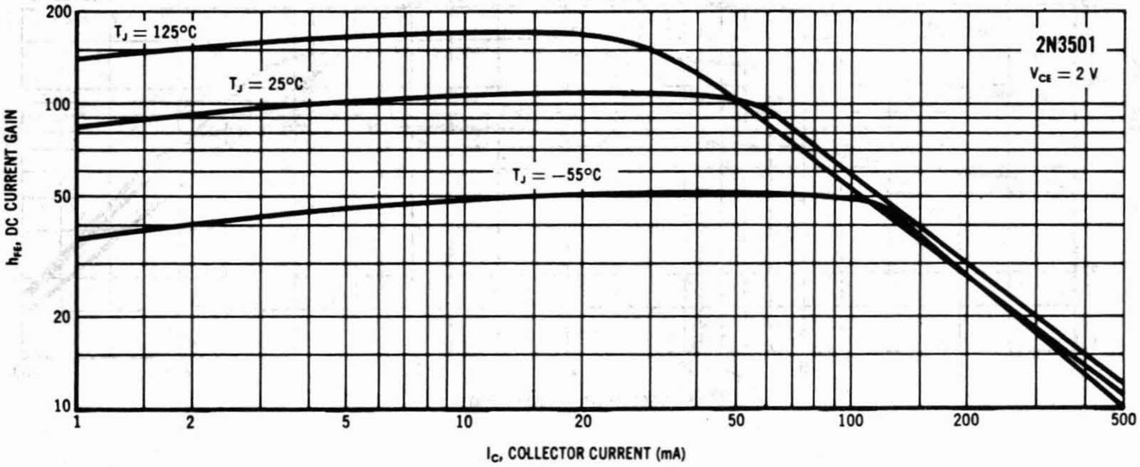


CURRENT GAIN CHARACTERISTICS versus COLLECTOR EMITTER VOLTAGE

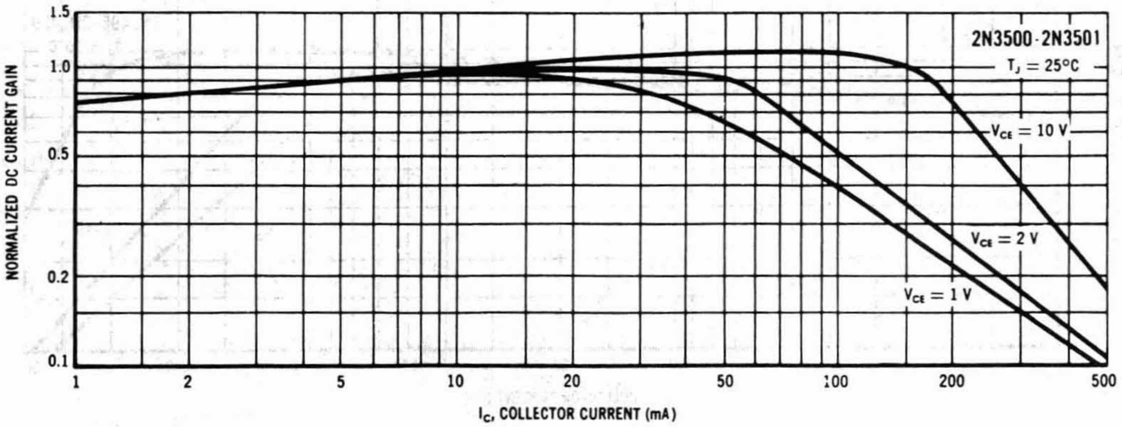


CURRENT GAIN CHARACTERISTICS vs JUNCTION TEMPERATURE



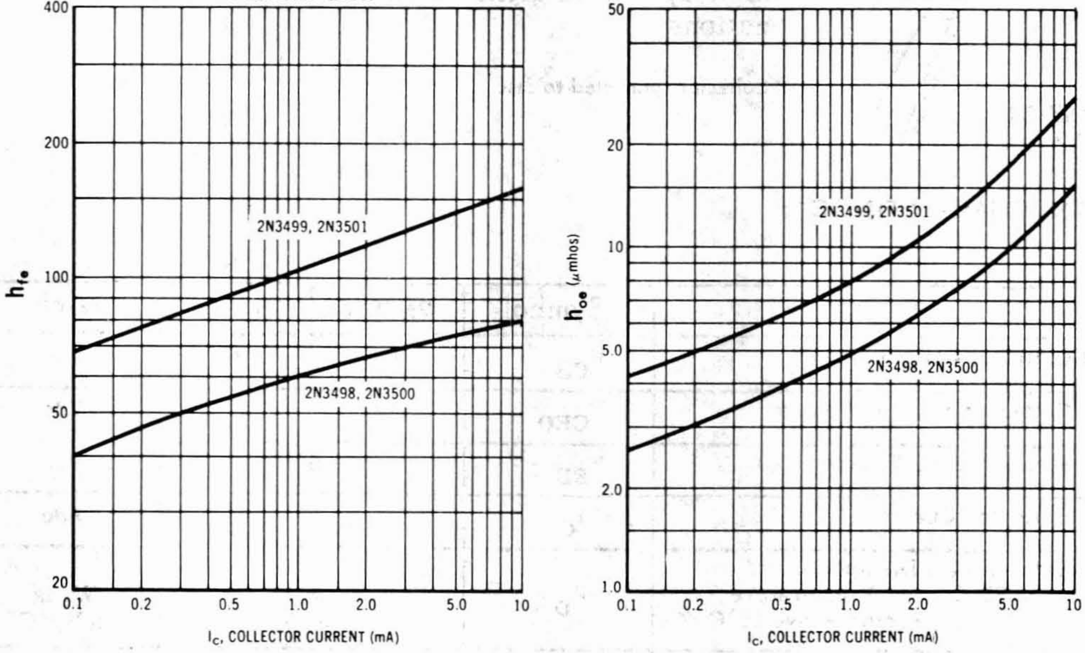


CURRENT GAIN CHARACTERISTICS versus COLLECTOR EMITTER VOLTAGE



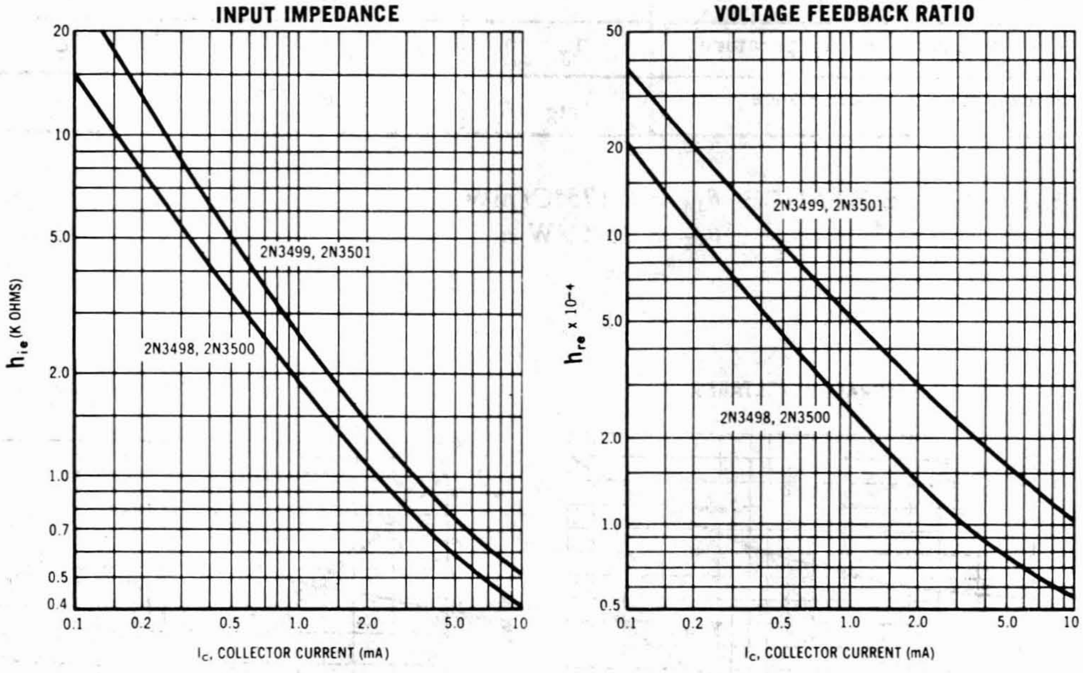
SMALL SIGNAL h PARAMETER CHARACTERISTICS

V_{CE} = 10 Vdc, f = 1.0 kHz, T_A = 25°C



CURRENT GAIN

OUTPUT IMPEDANCE



INPUT IMPEDANCE

VOLTAGE FEEDBACK RATIO

2N3506, 2N3507 (SILICON)

CASE 31
(TO-5)

NPN silicon annular transistors for high-current, high-speed, saturated switching and core driver applications.

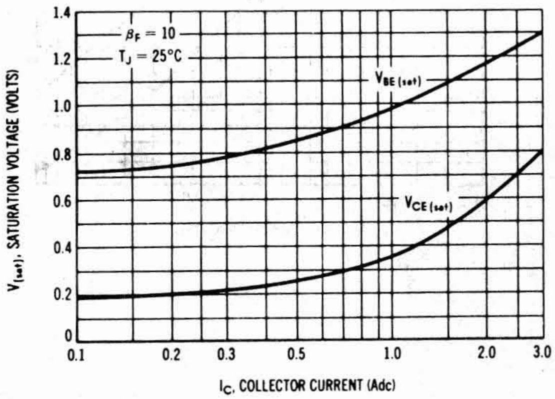
Collector connected to case

MAXIMUM RATINGS

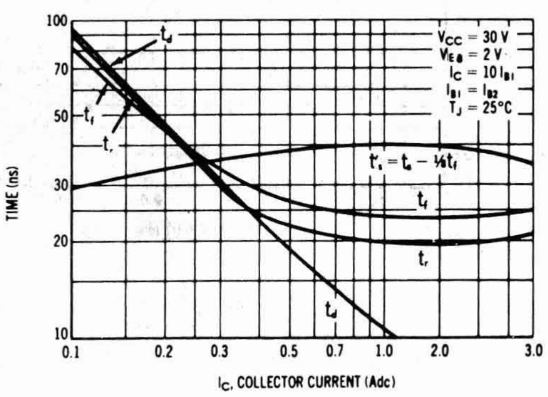
Rating	Symbol	2N3506	2N3507	Unit
Collector-Base Voltage	V_{CB}	60	80	Vdc
Collector-Emitter Voltage	V_{CEO}	40	50	Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	3		Adc
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	5 28.6		Watts mW/°C
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	1.0 5.71		Watts mW/°C
Junction Operating Temperature	T_J	200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

THERMAL RESISTANCE $\theta_{JA} = 0.175°C/mW$

$\theta_{JC} = 35°C/W$



SATURATION VOLTAGES



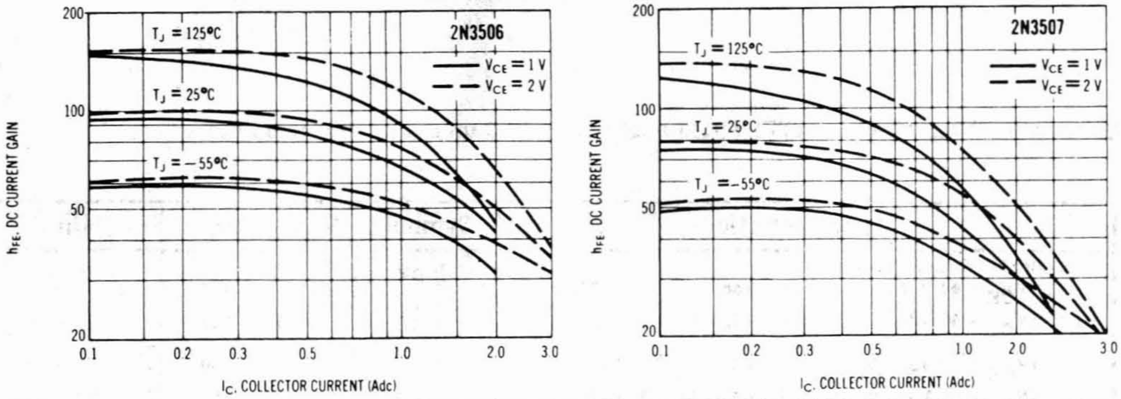
SWITCHING TIMES

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current		I_{CEX}			μAdc
(V_{CE} = 40 Vdc, $V_{EB(off)}$ = 4 Vdc)	2N3506		--	1.0	
(V_{CE} = 40 Vdc, $V_{EB(off)}$ = 4 Vdc, T_A = 100°C)			--	150	
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 4 Vdc)	2N3507		--	1.0	
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 4 Vdc, T_A = 100°C)			--	150	
Base Cutoff Current		I_{BL}			μAdc
(V_{CE} = 40 Vdc, $V_{EB(off)}$ = 4 Vdc)	2N3506		--	1.0	
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 4 Vdc)	2N3507		--	1.0	
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N3506 2N3507	BV_{CBO}	60 80	-- --	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, pulsed, I_B = 0)	2N3506 2N3507	BV_{CEO}*	40 50	-- --	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5	--	Vdc
Collector Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)			--	0.5	
(I_C = 1.5 Adc, I_B = 150 mAdc)			--	1.0	
(I_C = 2.5 Adc, I_B = 250 mAdc)			--	1.5	
Base-Emitter Saturation Voltage*		$V_{BE(sat)}$*			Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)			--	1.0	
(I_C = 1.5 Adc, I_B = 150 mAdc)			0.9	1.4	
(I_C = 2.5 Adc, I_B = 250 mAdc)			--	2.0	
DC Current Gain*		h_{FE}*			--
(I_C = 500 mAdc, V_{CE} = 1 Vdc)	2N3506 2N3507		50 35	-- --	
(I_C = 1.5 Adc, V_{CE} = 2 Vdc)	2N3506 2N3507		40 30	200 150	
(I_C = 2.5 Adc, V_{CE} = 3 Vdc)	2N3506 2N3507		30 25	-- --	
(I_C = 3.0 Adc, V_{CE} = 5 Vdc)	2N3506 2N3507		25 20	-- --	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	--	40	pF
Input Capacitance (V_{BE} = 3 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	--	300	pF
Current Gain-Bandwidth Product (I_C = 100 mAdc, V_{CE} = 5 Vdc, f = 20 MHz)		f_T	60	--	MHz
Delay Time	I_C = 1.5 Adc, I_{B1} = 150 mAdc	t_d		15	ns
Rise Time	V_{CC} = 30 V, V_{EB} = 0 V	t_r	--	30	ns
Storage Time	I_C = 1.5 Adc, I_{B1} = I_{B2} = 150 mAdc	t_s	--	55	ns
Fall Time	V_{CC} = 30 V	t_f	--	35	ns

*Pulse Test: Pulse width = 300 μs, duty cycle = 2%

CURRENT GAIN CHARACTERISTICS



2N3508 (SILICON)
2N3509

NPN silicon annular transistor for high-speed, low-current switching applications.

CASE 26
(TO-46)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current (10 μs pulse)	$I_{C(Peak)}$	500	mA
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor Above 25°C	P_D	0.40 2.29	Watt mW/°C
Total Device Dissipation @ 25°C Case Temperature Derating Factor Above 25°C	P_D	2.0 11.43	Watts mW/°C
Junction Temperature, Operating	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Thermal Resistance, Junction to Case Thermal Resistance, Junction to Ambient	θ_{JC} θ_{JA}	0.438 0.0875	°C/mW °C/mW

2N3508, 2N3509 (continued)

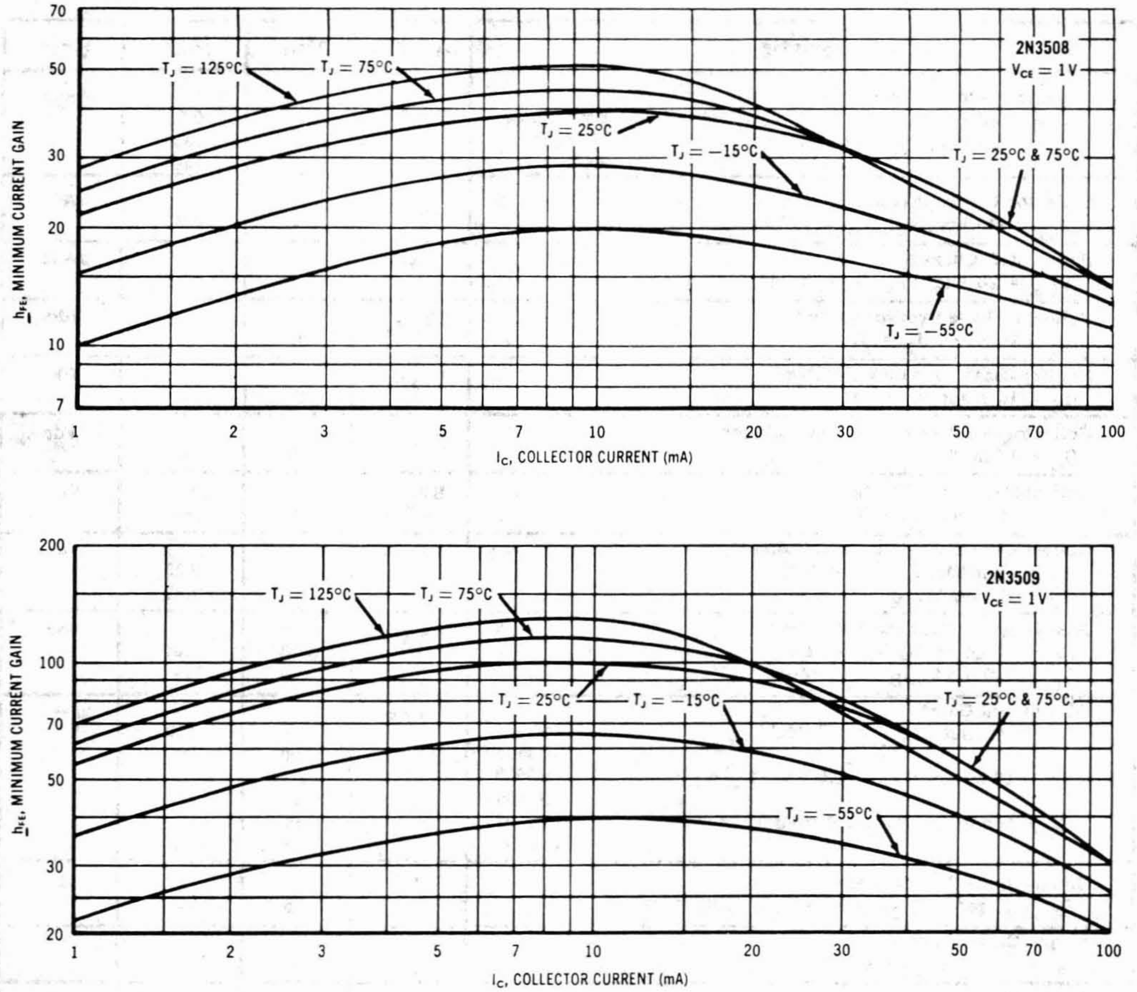
ELECTRICAL CHARACTERISTICS (at 25°C unless otherwise specified)

Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CB} = 20 Vdc) (V_{CB} = 20 Vdc, T_A = 150°C)	 Both Types 2N3508 2N3509	I_{CBO}	 — — —	 0.2 30 50	µAdc
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3 Vdc)		I_{CEX}	—	0.2	µAdc
Base Cutoff Current (V_{CE} = 20 Vdc, $V_{EB(off)}$ = 3 Vdc)		I_{BL}	—	0.5	µAdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_B = 0)		BV_{CBO}	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)		BV_{EBO}	6.0	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc)		BV_{CEO}*	20	—	Vdc
Collector-Emitter Voltage (I_C = 10 µAdc, I_B = 0)		BV_{CES}	40	—	Vdc
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)		$V_{CE(sat)}$*	 — —	 0.25 0.45	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)		$V_{BE(sat)}$*	 0.70 0.8	 0.85 1.4	Vdc
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	 2N3508 2N3509 2N3508 2N3509 2N3508 2N3509	h_{FE}*	 40 100 20 40 20 30	 120 300 — — — —	—
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		h_{fe}	5	—	—
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 140 kHz)		C_{ob}	—	4	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 140 kHz)		C_{ib}	—	4	pF
Storage Time (I_C = I_{B1} = I_{B2} = 10 mA)		$t_s(\tau_s)$	—	13	ns
Turn-On Time (I_C = 10 mA, I_{B1} = 3 mA, V_{CC} = 3 V, V_{OB} = 1.5 V)		t_{on}	—	12	ns
Turn-Off Time (I_C = 10 mA, I_{B1} = 3 mA, I_{B2} = 1.5 mA, V_{CC} = 3 V)		t_{off}	—	18	ns
Total Control Charge (I_C = 10 mA, I_B = 1 mA, V_{CC} = 3 V)		Q_T	—	50	pC
Delay Time	V_{CC} = 10 V, V_{EB} = 2 V, I_C = 100 mA, I_{B1} = 10 mA	t_d	—	5	ns
Rise Time		t_r	—	18	ns
Storage Time	V_{CC} = 10 V I_C = 100 mA, I_{B1} = I_{B2} = 10 mA	t_s	—	13	ns
Fall Time		t_f	—	15	ns

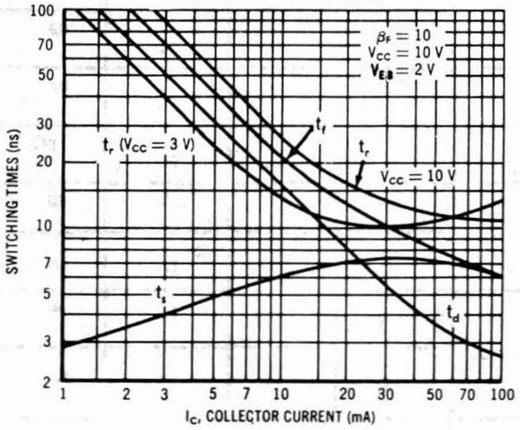
*Pulse Test: PW = 300µs, Duty Cycle ≤ 2%

2N3508, 2N3509 (continued)

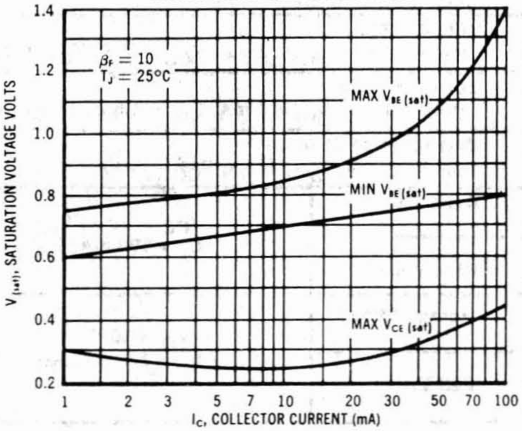
MINIMUM CURRENT GAIN CHARACTERISTICS



TYPICAL SWITCHING TIMES



LIMITS OF SATURATION VOLTAGE



2N3510 (SILICON)
2N3511
2N3647
2N3648

NPN silicon annular transistors for high-speed saturated switching applications to 500 mA.

2N3510
2N3511
CASE 27
(TO-52)

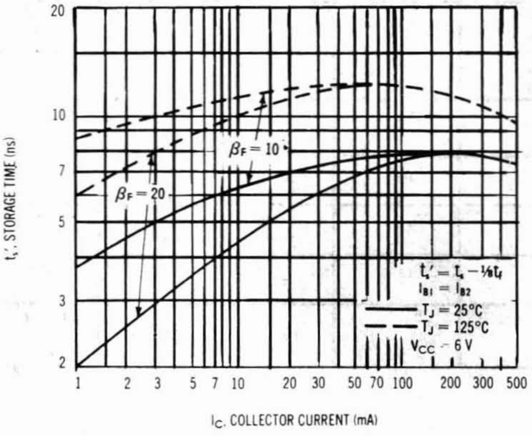
2N3647
2N3648
CASE 26
(TO-46)

Collector connected to case

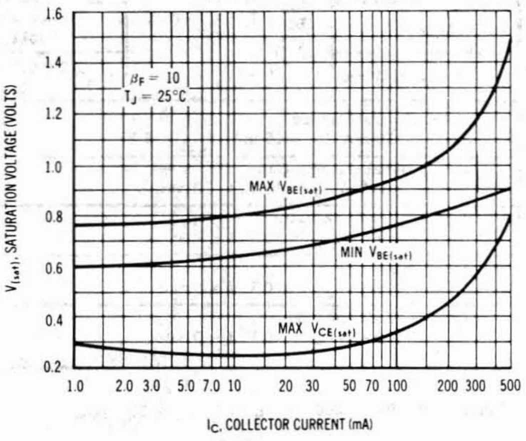
MAXIMUM RATINGS

Rating	Symbol	2N3510 2N3647	2N3511 2N3648	Unit
Collector-Base Voltage	V_{CB}	40	40	Vdc
Collector-Emitter Voltage	V_{CEO}	10	15	Vdc
Emitter-Base Voltage	V_{EB}	6		Vdc
Collector Current	I_C	500		mAdc
		TO-46 2N3647 2N3648	TO-52 2N3510 2N3511	
Total Device Dissipation @$T_A = 25^oC$ Derating Factor Above 25^oC	P_D	400 2.28	360 2.06	mW mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derating Factor Above 25^oC	P_D	2.0 11.43	1.2 6.9	Watts mW/^oC
Junction Temperature, Operating	T_J	+200		^oC
Storage Temperature Range	T_{stg}	-65 to +200		^oC

STORAGE TIME VARIATION



LIMITS OF SATURATION VOLTAGE

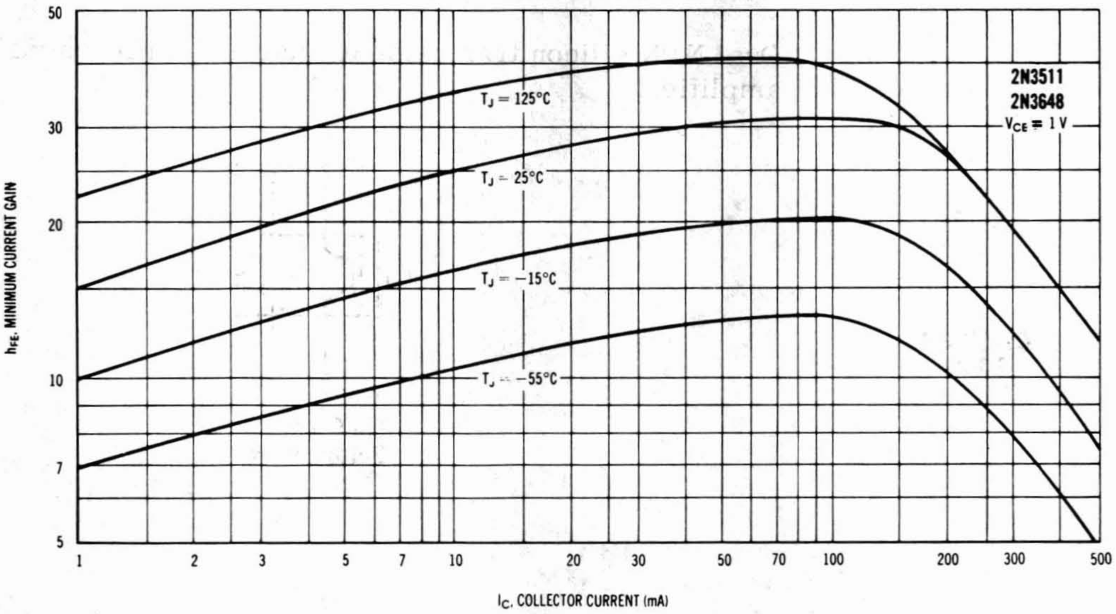


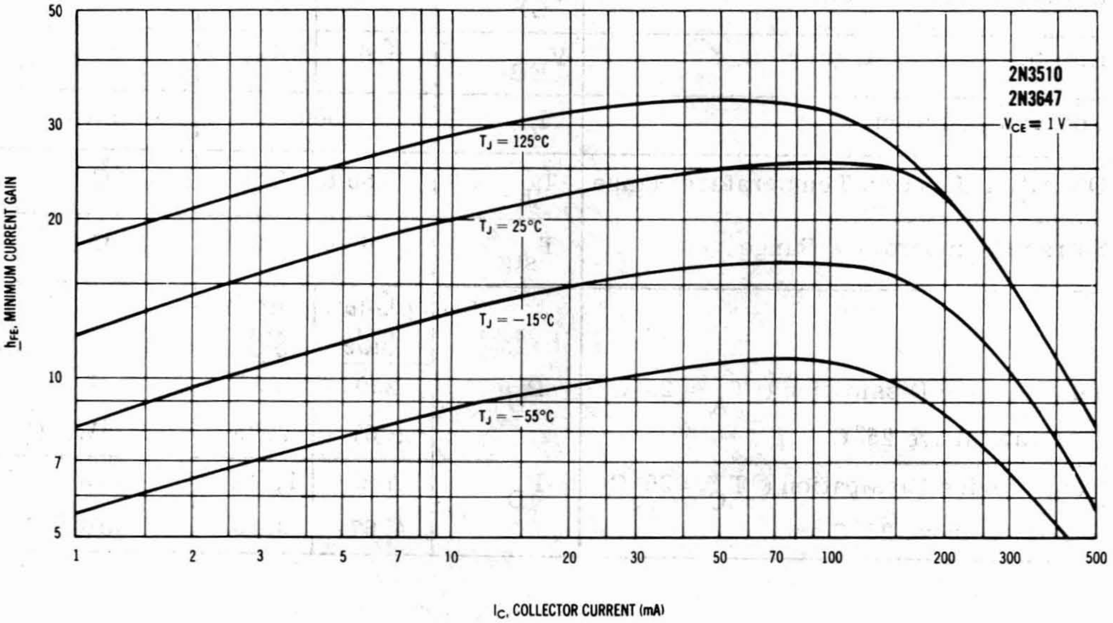
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise specified)

Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current		I_{CEX}			μAdc
(V_{CE} = 10 Vdc, $V_{EB(off)}$ = 1 Vdc)			—	.025	
(V_{CE} = 10 Vdc, $V_{EB(off)}$ = 1 Vdc, T_A = 150°C)			—	50	
Base Cutoff Current (V_{CE} = 10 Vdc, V_{OB} = 1 Vdc)		I_{BL}	—	.025	μAdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	40	—	Vdc
Collector-Emitter Breakdown Voltage*		BV_{CEO}*			Vdc
(I_C = 10 mAdc, I_B = 0)	2N3510, 2N3647		10	—	
	2N3511, 2N3648		15	—	
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	6	—	Vdc
Collector Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)	All Types		—	0.25	
(I_C = 150 mAdc, I_B = 15 mAdc)	All Types		—	0.4	
(I_C = 300 mAdc, I_B = 30 mAdc)	2N3510, 2N3647		—	0.6	
(I_C = 500 mAdc, I_B = 50 mAdc)	2N3511, 2N3648		—	0.8	
Base-Emitter Saturation Voltage*		$V_{BE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)	All Types		—	0.8	
(I_C = 150 mAdc, I_B = 15 mAdc)	All Types		0.8	1.0	
(I_C = 300 mAdc, I_B = 30 mAdc)	2N3510, 2N3647		—	1.15	
(I_C = 500 mAdc, I_B = 50 mAdc)	2N3511, 2N3648		—	1.5	
DC Current Gain*		h_{FE}*			—
(I_C = 1.0 mAdc, V_{CE} = 1 Vdc)	2N3510, 2N3647		12	—	
	2N3511, 2N3648		15	—	
(I_C = 10 mAdc, V_{CE} = 1 Vdc)	2N3510, 2N3647		20	—	
	2N3511, 2N3648		25	—	
(I_C = 150 mAdc, V_{CE} = 1 Vdc)	2N3510, 2N3647		25	150	
	2N3511, 2N3648		30	120	
(I_C = 150 mAdc, V_{CE} = 1 Vdc, TA = −55°C)	2N3511, 2N3648		12	—	
(I_C = 300 mAdc, V_{CE} = 1 Vdc)	2N3510, 2N3647		15	—	
(I_C = 500 mAdc, V_{CE} = 1 Vdc)	2N3511, 2N3648		12	—	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	4	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	8	pF
Small Signal Current Gain		h_{fe}			—
(I_C = 15 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3510, 2N3647		3.5	—	
	2N3511, 2N3648		4.5	—	
Delay Time (I_C = 150 mA, I_{B1} = 15 mA, V_{EB} = 0.5 V, V_{CC} = 6 V)	2N3510, 2N3647	t_d	—	10	ns
	2N3511, 2N3648		—	8	
Rise Time (I_C = 150 mA, I_{B1} = 15 mA, V_{EB} = 0.5 V, V_{CC} = 6 V)	2N3510, 2N3647	t_r	—	12	ns
	2N3511, 2N3648		—	10	
Turn-On Time (I_C = 150 mA, I_{B1} = 15 mA, V_{EB} = 0.5 V, V_{CC} = 6 V)	2N3510, 2N3647	t_{on}	—	20	ns
	2N3511, 2N3648		—	16	
Storage Time (I_C = 150 mA, I_{B1} = $-I_{B2}$ = 15 mA, V_{CC} = 6 V)	2N3510, 2N3647	t_s	—	16	ns
	2N3511, 2N3648		—	12	
Fall Time (I_C = 150 mA, I_{B1} = $-I_{B2}$ = 15 mA, V_{CC} = 6 V)	2N3510, 2N3647	t_f	—	12	ns
	2N3511, 2N3648		—	8	
Turn-Off Time (I_C = 150 mA, I_{B1} = $-I_{B2}$ = 15 mA, V_{CC} = 6 V)	2N3510, 2N3647	t_{off}	—	25	ns
	2N3511, 2N3648		—	18	
Total Control Charge (I_C = 150 mA, I_B = 15 mA, V_{CC} = 6 V)		Q_T	—	300	pC
Small Signal Current Gain (I_C = 1 mA, V_{CE} = 10 V, f = 1 kHz)		h_{fe}	20	150	—
Voltage Feedback Ratio (I_C = 1 mA, V_{CE} = 10 V, f = 1 kHz)		h_{re}	—	25	$X10^{-4}$
Input Impedance (I_C = 1 mA, V_{CE} = 10 V, f = 1 kHz)		h_{ie}	0.6	4.5	kohms
Output Admittance (I_C = 1 mA, V_{CE} = 10 V, f = 1 kHz)		h_{oe}	10	100	μmhos

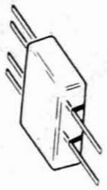
* Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2%

MINIMUM CURRENT GAIN CHARACTERISTICS



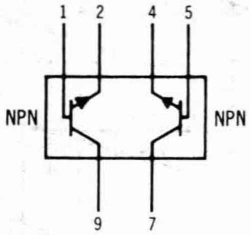


2N3515 (SILICON)
2N3518



CASE 33
(TO-89)

Dual NPN silicon transistor for use as a differential amplifier.



Pin Connections, Bottom View

MAXIMUM RATINGS (each side) (T_A = 25°C)

Rating	Symbol	2N3515	2N3518	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	Vdc
Collector-Base Voltage	V_{CB}	80	100	Vdc
Emitter-Base Voltage	V_{EB}	5.0	7.0	Vdc
Collector Current	I_C	500		mAdc
Operating Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	250 1.67	350 2.33	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	700 4.67	1,400 9.33	mW mW/°C

2N3515, 2N3518 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 20 mAdc, I_B = 0) 2N3515	BV_{CEO}*	40	-	Vdc
2N3518		60	-	
Collector-Base Breakdown Voltage (I_C = 50 nAdc, I_E = 0) 2N3515	BV_{CBO}	80	-	Vdc
(I_C = 100 μAdc, I_E = 0) 2N3518		100	-	
Emitter-Base Breakdown Voltage (I_E = 50 nAdc, I_C = 0) 2N3515	BV_{EBO}	5.0	-	Vdc
(I_E = 100 μAdc, I_C = 0) 2N3518		7.0	-	
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) 2N3515	I_{CBO}	-	0.02	μAdc
(V_{CB} = 30 Vdc, I_E = 0, T_A = 150°C) 2N3515		-	15	
(V_{CB} = 50 Vdc, I_E = 0) 2N3518			0.002	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C) 2N3518		-	10	
Emitter-Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0) 2N3515	I_{EBO}	-	20	nAdc
2N3518		-	2.0	
ON CHARACTERISTICS				
DC Current Gain (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	h_{FE}	35	-	-
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		50	200	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, T_A = -55°C) 2N3518		15	-	
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$	-	1.2	Vdc
Base-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 20 MHz) 2N3515	f_T	50	-	MHz
2N3518		60	-	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz) 2N3515	C_{ob}	-	18	pF
2N3518		-	15	
Input Capacitance (V_{BE} = 0, 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	-	85	pF
Input Impedance (I_C = 1.0 mAdc, V_{CB} = 5.0 Vdc, f = 1.0 kHz)	h_{ib}	20	35	ohms
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N3515	h_{ie}	1.0	5.0	k ohms
2N3518		1.0	10.5	
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}	50	300	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N3515	h_{oe}	4.0	16	μmhos
2N3518		4.0	50	
Noise Figure (I_C = 0.3 mAdc, V_{CE} = 10 Vdc, R_G = 510 ohms, B. W. = 1.0 Hz, f = 1.0 kHz)	NF	-	8.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N3515	h_{FE1}/h_{FE2}**	0.8	1.0	-
2N3518		0.9	1.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N3515		0.8	1.0	
2N3518		0.9	1.0	
Base Voltage Differential (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N3515	$\lvert V_{BE1}-V_{BE2}\rvert$	-	5.0	mVdc
2N3518		-	3.0	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N3515		-	5.0	
2N3518		-	3.0	
Base Voltage Differential Gradient (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55 to +125°C) 2N3515	$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$	-	15	μV/°C
2N3518		-	10	

* Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

** The lowest of the two h_{FE} readings is taken as h_{FE1} for the purpose of measurement.

2N3544 (SILICON)

CASE 22
(TO-18)

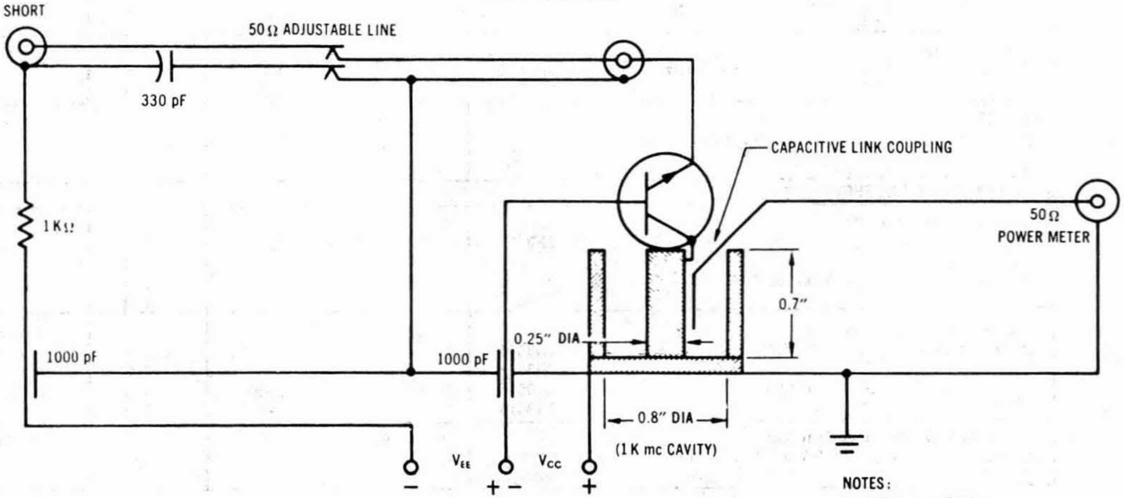
NPN silicon annular transistor for VHF and UHF oscillator applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Volts
Collector-Emitter Voltage	V_{CES}	25	Volts
Emitter-Base Voltage	V_{EB}	3.0	Volts
Collector Current	I_C	100	mA
Power Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	400 2.67	mW mW/°C
Power Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 2.0	mW mW/°C
Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

TEST CIRCUIT


SHORT
50Ω ADJUSTABLE LINE
330 pF
1KΩ
1000 pF
1000 pF
0.25" DIA
CAPACITIVE LINK COUPLING
0.7"
0.8" DIA
(1 K mc CAVITY)
50Ω
POWER METER
V_{EE}
V_{CC}
−
+ −
+

NOTES:
1. SET $V_{CC} = 12$ Vdc.
2. ADJUST V_{EE} FOR $I_C = 12$ mAdc.
3. SET ADJUSTABLE LINE FOR MAXIMUM POWER OUTPUT.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Conditions	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	$I_C = 10\ \mu$Adc, $I_E = 0$	25	30	--	Vdc
Collector-Emitter Breakdown Voltage	BV_{CES}	$I_C = 10\ \mu$A, $V_{BE} = 0$	25	30	--	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 15 Vdc, $I_E = 0$	--	0.01	0.1	µAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 3 Vdc, $I_C = 0$	--	0.1	10	µAdc
DC Current Gain	h_{FE}	V_{CE} = 10 Vdc, I_C=10 mAdc	25	50	--	--

AC Current Gain	$\|h_{fe}\|$	V_{CE} = 10 Vdc, I_C =10 mAdc, f = 100 MHz	6	9	15	--
Collector Output Capacitance	C_{ob}	V_{CB} = 15 Vdc, I_E = 0, f = 100 kHz	--	--	2.5	pF
Collector-Base Time Constant	$r_b'C_c$	V_{CB} = 10 Vdc, I_C = 10 mAdc, f =31.8 MHz	--	--	10	ps

Oscillator Power Output	P_{out}	f = 1.0 GHz , V_C = 12 Vdc, I_C=12 mAdc	10	16	--	mW

2N3546 (SILICON)

CASE 22
(TO-18)

PNP silicon annular transistor for low-level, high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	15	Vdc
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.9	Watts mW/°C
Operating Junction Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Thermal Resistance, Junction to Ambient	θ_{JA}	0.49	°C/mW
Thermal Resistance, Junction to Case	θ_{JC}	0.15	°C/mW

2N3546 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CB} = 10 Vdc) (V_{CB} = 10 Vdc, T_A = 150°C)		I_{CBO}	-- --	0.010 10	μAdc
Collector Cutoff Current (V_{CE} = 10 Vdc, $V_{BE(off)}$ = 3 Vdc)		I_{CEX}	--	0.010	μAdc
Base Cutoff Current (V_{CE} = 10 Vdc, $V_{BE(off)}$ = 3 Vdc)		I_{BL}	--	0.10	μAdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	15	--	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	4.5	--	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)		BV_{CEO}*	12	--	Vdc
Collector Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)		$V_{CE(sat)}$*	-- -- --	0.15 0.25 0.50	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)		$V_{BE(sat)}$*	0.7 0.8 --	0.9 1.3 1.6	Vdc
DC Current Gain* (I_C = 1.0 mAdc, V_{CE} = 1 Vdc) (I_C = 10 mAdc, V_{CE} = 1 Vdc) (I_C = 10 mAdc, V_{CE} = 1 Vdc, T_A = -55°C) (I_C = 50 mAdc, V_{CE} = 1 Vdc) (I_C = 100 mAdc, V_{CE} = 1Vdc)		h_{FE}*	20 30 15 25 15	-- 120 -- -- --	--
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)		C_{ob}	--	6	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1 MHz)		C_{ib}	--	5	pF
Current-Gain - Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	700	--	MHz
Total Control Charge (I_C = 50 mA, I_B = 5 mA, V_{CC} = 3 V)		Q_T	--	400	pC
Delay Time	I_C = 50 mA, I_{B1} = 5mA, V_{BE} = 2 V, V_{CC} = 3 V	t_d	--	10	ns
Rise Time		t_r	--	15	ns
Storage Time	I_C = 50 mA, I_{B1} = I_{B2} = 5 mA, V_{CC} = 3 V	t_s	--	20	ns
Fall Time		t_f	--	15	ns
Turn-On Time	(See Figure 3,4,5)	t_{on}	--	40	ns
Turn-Off Time		t_{off}	--	30	ns

*Pulse Test: PW = 300 μs, Duty Cycle ≤ 2%

2N3546 (continued)

FIGURE 1

LIMITS OF SATURATION VOLTAGES

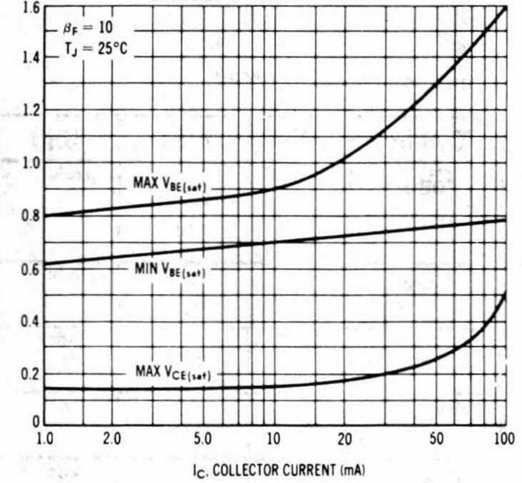


FIGURE 2

STORAGE TIME BEHAVIOR

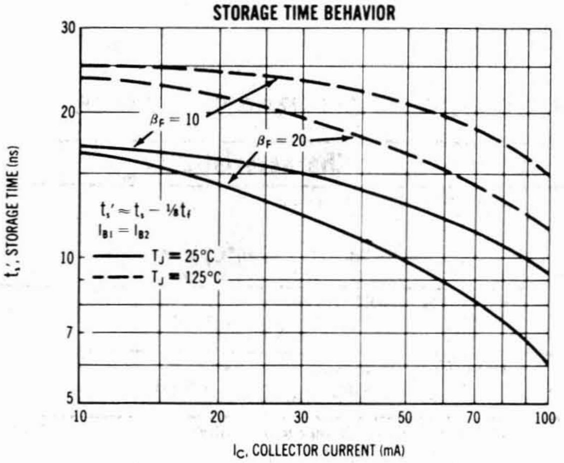
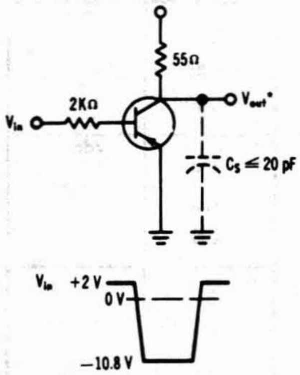


FIGURE 3

DELAY AND RISE TIME EQUIVALENT TEST CIRCUIT



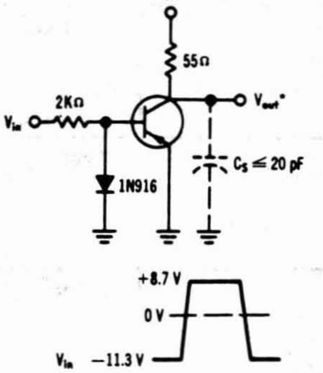
−3 V
55Ω
2KΩ
V_{in}
V_{out}*
$C_S \leq 20$ pF
V_{in}
+2 V
0 V
−10.8 V

PULSE WIDTH = 200 ns
RISE TIME ≤ 2 ns
DUTY CYCLE ≤ 10%

*OSCILLOSCOPE RISE TIME ≤ 1 ns

FIGURE 4

STORAGE AND FALL TIME EQUIVALENT TEST CIRCUIT

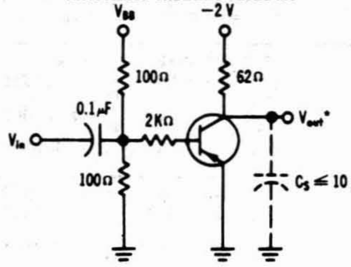


−3 V
55Ω
2KΩ
V_{in}
V_{out}*
1N916
$C_S \leq 20$ pF
+8.7 V
0 V
V_{in}
−11.3 V

PULSE WIDTH = 200 ns
RISE TIME ≤ 2 ns
DUTY CYCLE ≤ 10%

FIGURE 5

SWITCHING TIME TEST CIRCUIT



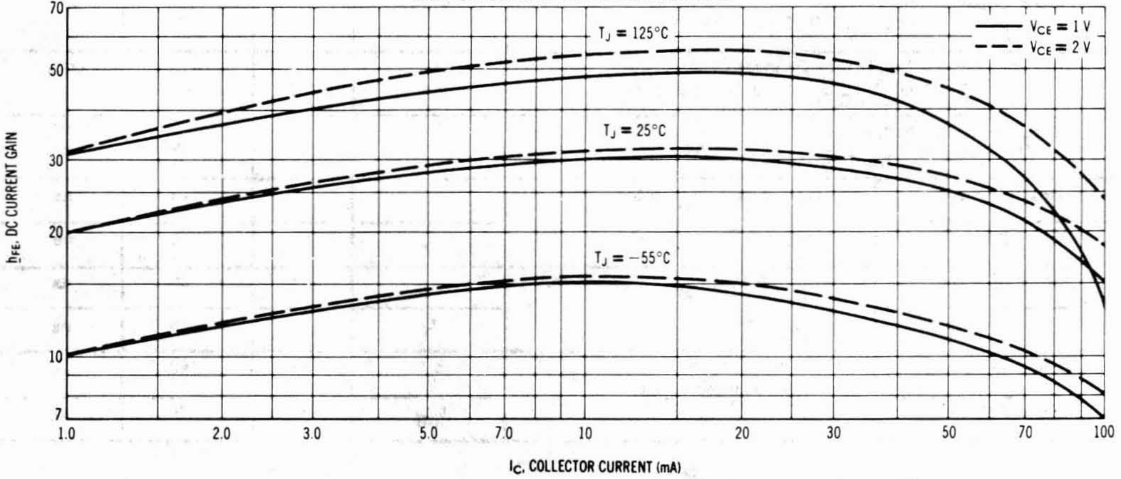
V_{BB}
−2 V
100Ω
62Ω
0.1μF
2KΩ
V_{in}
V_{out}*
100Ω
$C_S \leq 10$ pF

PULSE WIDTH > 200 ns
RISE TIME < 1 ns
$Z_{in} = 50\Omega$

t_{on} : $V_{BB} = +3$ V, $V_{in} = -7$ V
t_{off} : $V_{BB} = -4$ V, $V_{in} = +6$ V

FIGURE 6

MINIMUM CURRENT GAIN CHARACTERISTICS

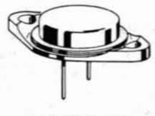


2N3553 (SILICON)

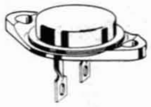
For Specifications, See 2N3375 Data.

2N3611 thru 2N3614 (GERMANIUM)

PNP germanium power transistors for switching and amplifier applications.



CASE 11
(TO-3)



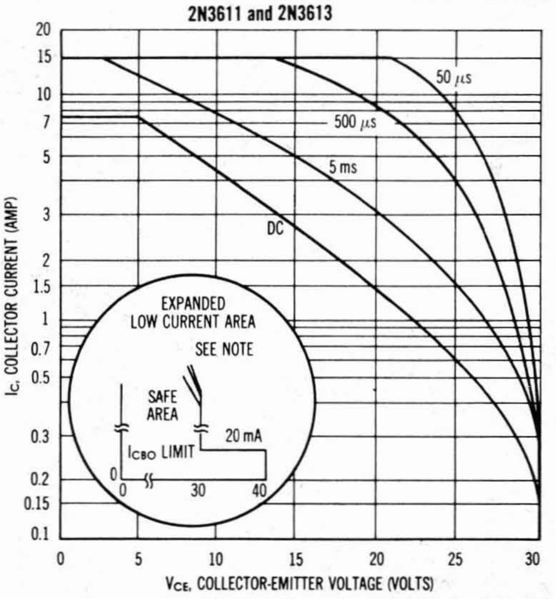
CASE 4-04
(TO-41)

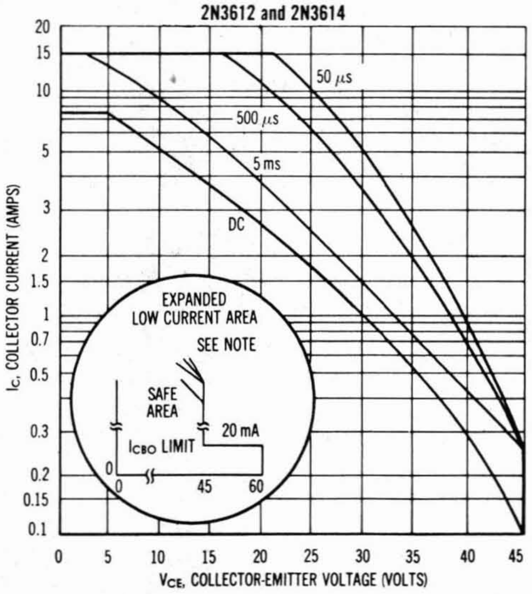
For units with solder lugs attached, specify device MP3611 etc. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N3611 2N3613	2N3612 2N3614	Unit
Collector-Emitter Voltage	V_{CES}	30	45	Vdc
Collector-Emitter Voltage (Open Base)	V_{CEO}	25	35	Vdc
Collector-Base Voltage	V_{CB}	40	60	Vdc
Emitter-Base Voltage	V_{EB}	20	30	Vdc
Collector Current (Continuous)	I_C	7		Adc
Peak Collector Current (PW ≦ 5 msec)	I_C	15		Adc
Base Current (Continuous)	I_B	2		Adc
Storage Temperature Range	T_{stg}	-65 to +110		°C
Operating Case Temperature Range	T_C	-65 to +110		°C
Total Device Dissipation @ $T_C = 25^oC$ Derate above $T_C = 25^oC$	P_D	77 1		Watts W/°C
Thermal Resistance, Junction to Case	θ_{JC}	1.1		°C/W
Thermal Resistance, Case to Ambient	θ_{CA}	32.7		°C/W

SAFE OPERATING AREAS





The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) The load line may exceed the BV_{CES} voltage limit only if the collector current has been reduced to 20 mA or less before or at the BV_{CES} limit; then and only then may the load line be extended to the absolute maximum voltage rating of BV_{CBO}. To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N3611 thru 2N3614 (continued)

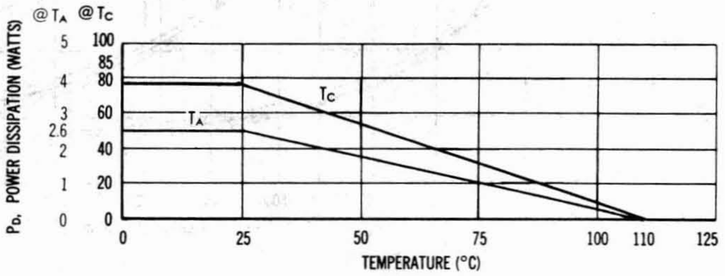
ELECTRICAL CHARACTERISTICS

Characteristics		Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage*		BV_{CES}*			Vdc
(I_C = 250 mAdc)	2N3611, 2N3613		30	–	
	2N3612, 2N3614		45	–	
Collector-Emitter Breakdown Voltage*		BV_{CEO}*			Vdc
(I_C = 500 mAdc)	2N3611, 2N3613		25	–	
	2N3612, 2N3614		35	–	
Floating Potential (V_{CB} = V_{CB} max)		V_{EBF}	–	1.0	Vdc
Collector-Emitter Leakage Current (V_{CE} = 1/2 V_{CEO} max)		I_{CEO}	–	30	mAdc
Collector-Emitter Leakage Current (V_{CE} = V_{CE} max, V_{BE} = 1.0 Vdc, T_C = +100°C)		I_{CEX}	–	10	mAdc
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 2 Vdc)			–	.040	
(V_{CB} = 25 Vdc)	2N3611, 2N3613		–	0.5	
(V_{CB} = 40 Vdc)	2N3612, 2N3614		–	0.5	
(V_{CB} = V_{CB} max)			–	5.0	
Emitter-Base Cutoff Current		I_{EBO}			μAdc
(V_{EB} = V_{EB} max)			–	500	
(V_{EB} = 12 Vdc)			–	100	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 3 Adc, I_B = 300 mAdc)			–	0.25	
(I_C = 7 Adc, I_B = 700 mAdc)			–	0.35	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 3 Adc, I_B = 300 mAdc)	2N3611, 2N3612		–	0.7	
	2N3613, 2N3614		–	0.6	
(I_C = 7 Adc, I_B = 700 mAdc)	2N3611, 2N3612		–	1.1	
	2N3613, 2N3614		–	0.9	
Transconductance		g_{FE}			mhos
(I_C = 3 Adc, V_{CE} = 2 Vdc)	2N3611, 2N3612		3.0	–	
	2N3613, 2N3614		3.5	–	
Small Signal Current Gain		h_{fe}			–
(I_C = 0.5 A, V_{CE} = 12 V, f = 20 kHz)			15	–	
(I_C = 0.5 A, V_{CE} = 2 V, f = 1 kHz)	2N3611, 2N3612		40	100	
	2N3613, 2N3614		60	150	
DC Current Gain		h_{FE}			–
(I_C = 3 Adc, V_{CE} = 2 Vdc)	2N3611, 2N3612		35	70	
	2N3613, 2N3614		60	120	
(I_C = 7 Adc, V_{CE} = 2 Vdc)	2N3611, 2N3612		20	–	
	2N3613, 2N3614		30	–	

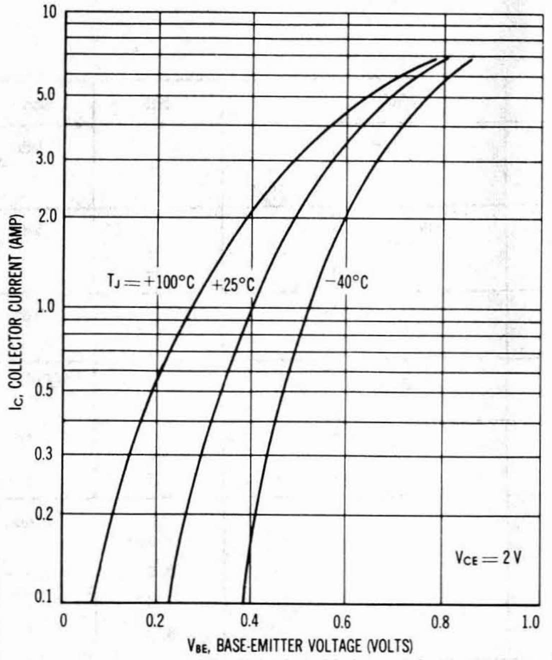
*Sweep Test: 1/2 sine wave, 60 Hz

POWER-TEMPERATURE DERATING CURVE

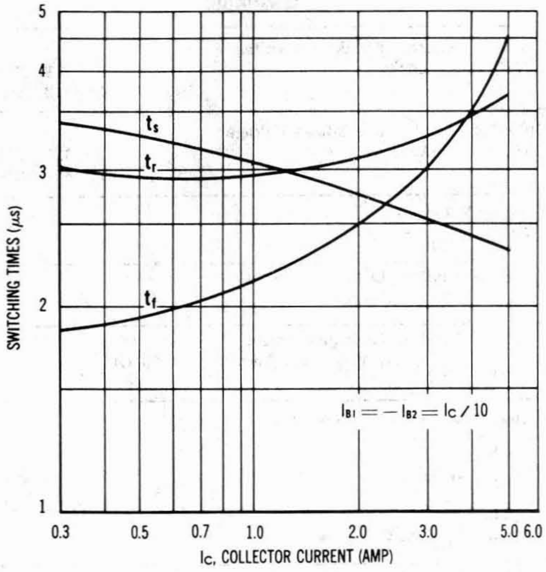
These transistors are also subject to safe area curves. Both limits are applicable and must be observed.



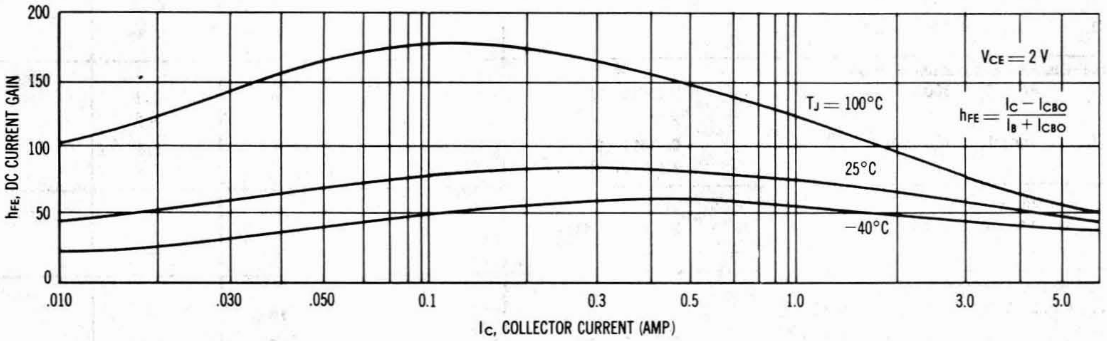
COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE



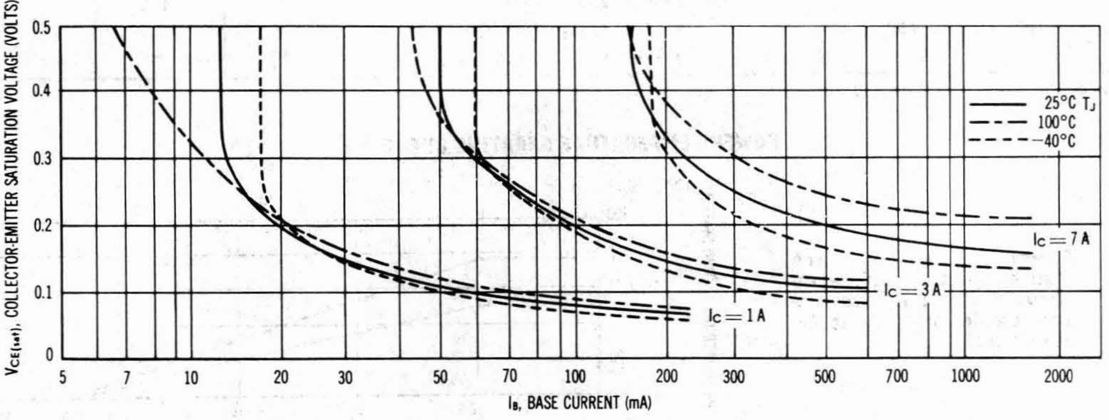
TYPICAL SWITCHING TIMES



DC CURRENT GAIN versus COLLECTOR CURRENT

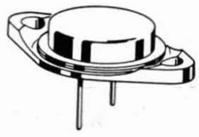


COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS

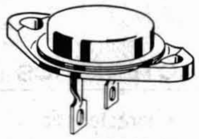


2N3615 thru 2N3618 (GERMANIUM)

PNP germanium power transistors for switching and amplifier applications.



CASE 11
(TO-3)



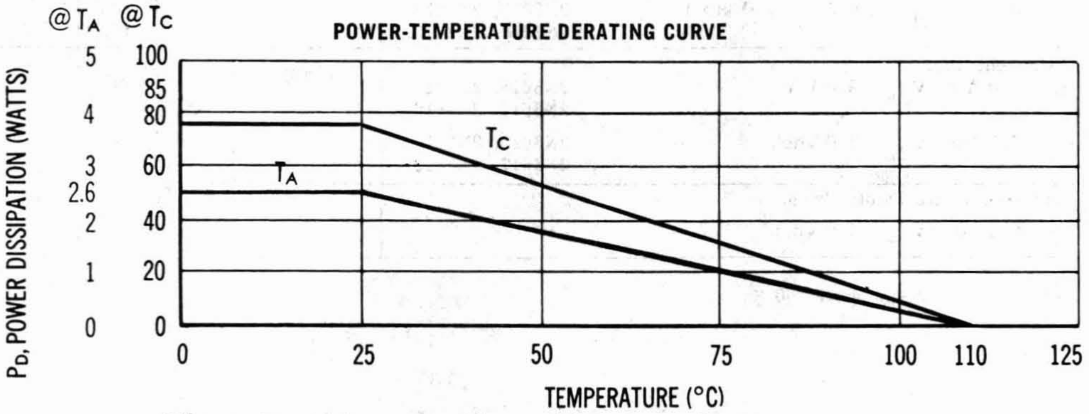
CASE 4-04
(TO-41)

For units with solder lugs attached, specify devices MP3615 etc. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N3615 2N3617	2N3616 2N3618	Unit
Collector-Emitter Voltage	V_{CES}	60	75	Vdc
Collector-Emitter Voltage (Open Base)	V_{CEO}	50	60	Vdc
Collector-Base Voltage	V_{CB}	80	100	Vdc
Emitter-Base Voltage	V_{EB}	40	50	Vdc
Collector Current (Continuous)	I_C	7		Adc
Peak Collector Current (PW ≦ 5 msec)	I_C	15		Adc
Base Current (Continuous)	I_B	2		Adc
Storage Temperature	T_{stg}	-65 to +110		°C
Operating Case Temperature	T_C	-65 to +110		°C
Total Device Dissipation @T_C = 25°C Derate above 25°C	P_D	77 1		Watts W/°C
Thermal Resistance, Junction to Case	θ_{JC}	1.0		°C/W
Thermal Resistance, Case to Ambient	θ_{CA}	32.7		°C/W

POWER-TEMPERATURE DERATING CURVE



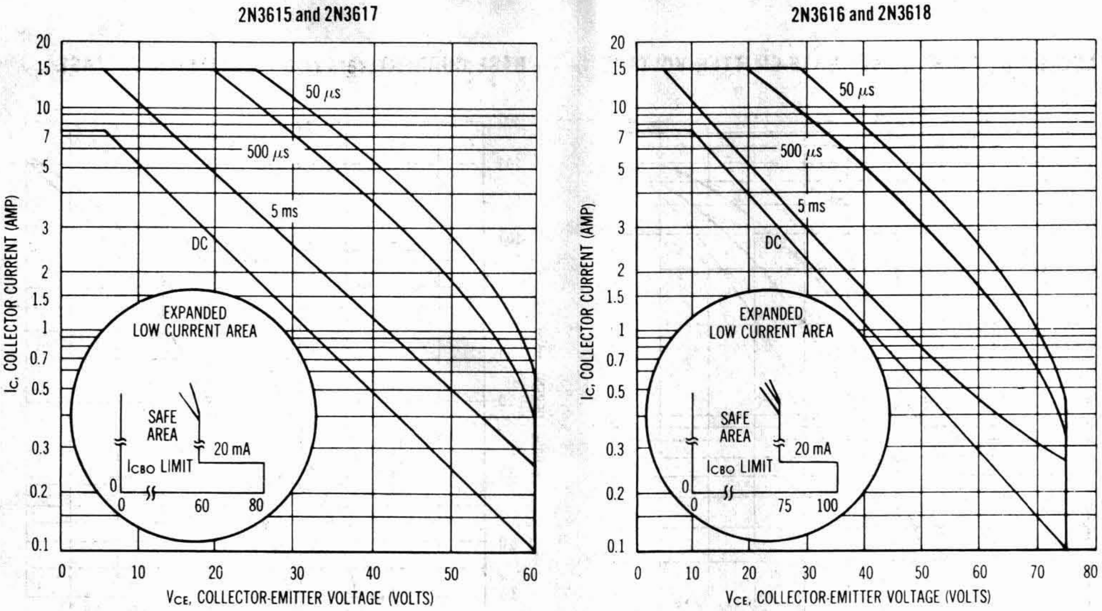
These transistors are also subject to safe area curves. Both limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage*	BV_{CES}*			Vdc
(I_C = 250 mAdc) 2N3615, 2N3617		60	-	
2N3616, 2N3618		75	-	
Collector-Emitter Breakdown Voltage*	BV_{CEO}*			Vdc
(I_C = 300 mAdc) 2N3615, 2N3617		50	-	
2N3616, 2N3618		60		
Floating Potential (V_{CB} = V_{CB} max)	V_{EBF}	-	1.0	Vdc
Collector-Emitter Leakage Current (V_{CE} = 1.2 V_{CEO} max)	I_{CEO}	-	30	mAdc
Collector-Emitter Leakage Current (V_{CE} = V_{CE} max, V_{BE} = 1.0 Vdc, T_C = +100°C)	I_{CEX}	-	10	mAdc
Collector-Base Cutoff Current	I_{CBO}			mAdc
(V_{CB} = 2.0 Vdc)		-	0.060	
(V_{CB} = 55 Vdc) 2N3615, 2N3617		-	1.0	
(V_{CB} = 65 Vdc) 2N3616, 2N3618		-	1.0	
(V_{CB} = V_{CB} max)		-	5.0	
Emitter-Base Cutoff Current	I_{EBO}			µAdc
(V_{EB} = V_{EB} max)			500	
(V_{EB} = 12 Vdc)		-		
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 3.0 Adc, I_B = 300 mAdc)		-	0.25	
(I_C = 7.0 Adc, I_B = 700 mAdc)		-	0.35	
Base Emitter Saturation Voltage	$V_{BE(sat)}$			Vdc
(I_C = 3.0 Adc, I_B = 300 mAdc) 2N3615, 2N3616		-	0.7	
2N3617, 2N3618		-	0.6	
(I_C = 7.0 Adc, I_B = 700 mAdc) 2N3615, 2N3616		-	1.1	
2N3617, 2N3618		-	0.9	
Transconductance	g_{FE}			mhos
(I_C = 3.0 A, V_{CE} = 2.0 V) 2N3615, 2N3616		3.0	-	
2N3617, 2N3618		3.5	-	
Small Signal Current Gain	h_{fe}			-
(I_C = 0.5 A, V_{CE} = 12 V, f = 20 kHz)		15	-	
(I_C = 0.5 A, V_{CE} = 2.0 V, f = 1.0 kHz) 2N3615, 2N3616		40	100	
2N3617, 2N3618		60	150	
DC Current Gain	h_{FE}			-
(I_C = 3.0 Adc, V_{CE} = 2.0 Vdc) 2N3615, 2N3616		30	60	
2N3617, 2N3618		45	90	
(I_C = 7.0 Adc, V_{CE} = 2.0 Vdc) 2N3615, 2N3616		20	-	
2N3617, 2N3618		30	-	
Current-Gain-Bandwidth Product	f_T	Typ		kHz
(I_C = 0.5 Adc, V_{CE} = 2.0 Vdc)		600		

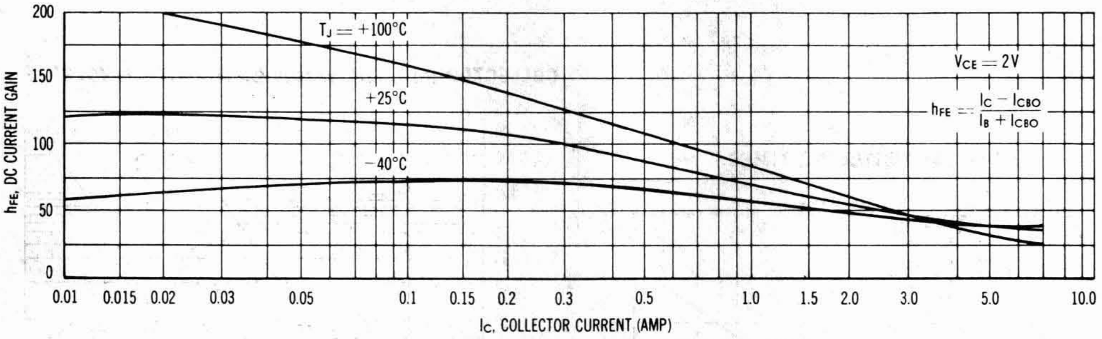
*Sweep Test: 1/2 sine wave, 60 Hz

SAFE OPERATING AREAS

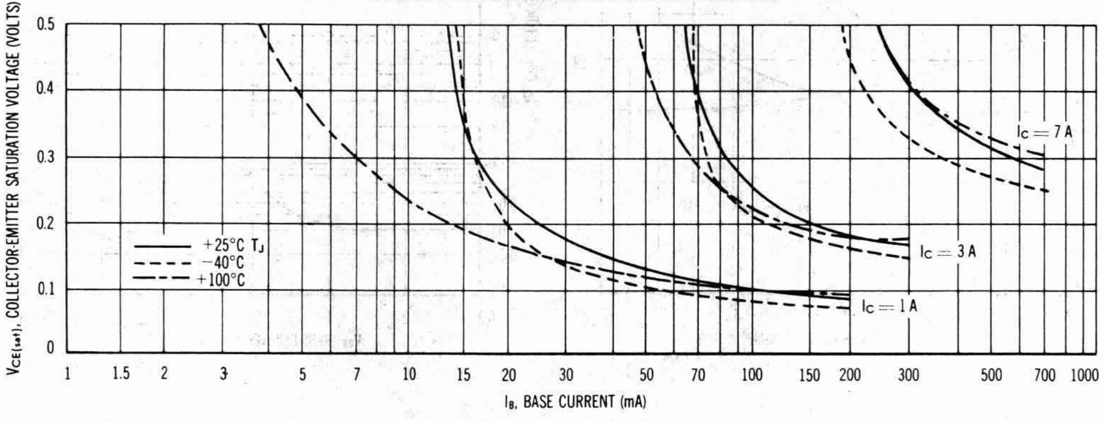


NOTE The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) The load line may exceed the BV_{CES} voltage limit only if the collector current has been reduced to 20 mA or less before or at the BV_{CES} limit; then and only then may the load line be extended to the absolute maximum voltage rating of BV_{CBO}. To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

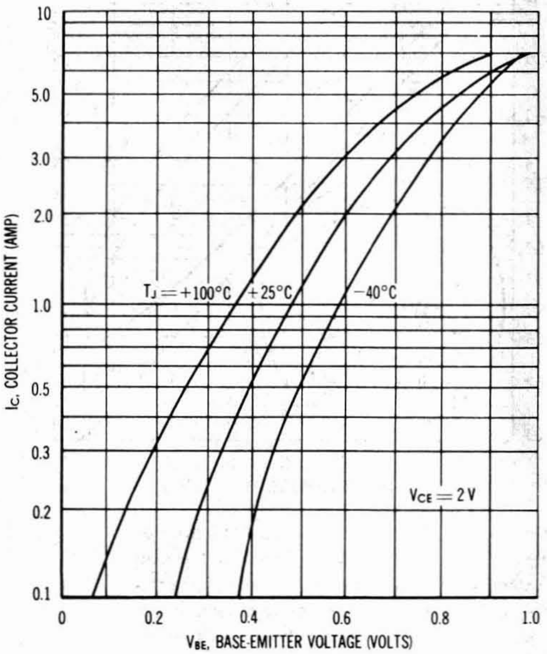
DC CURRENT GAIN versus COLLECTOR CURRENT



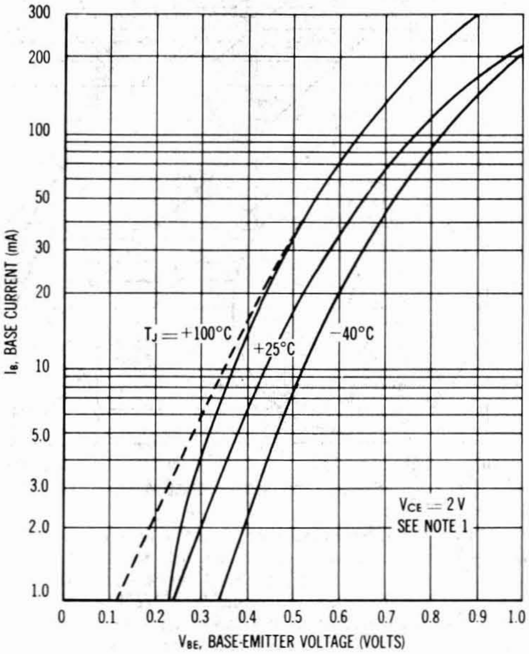
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS



COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE

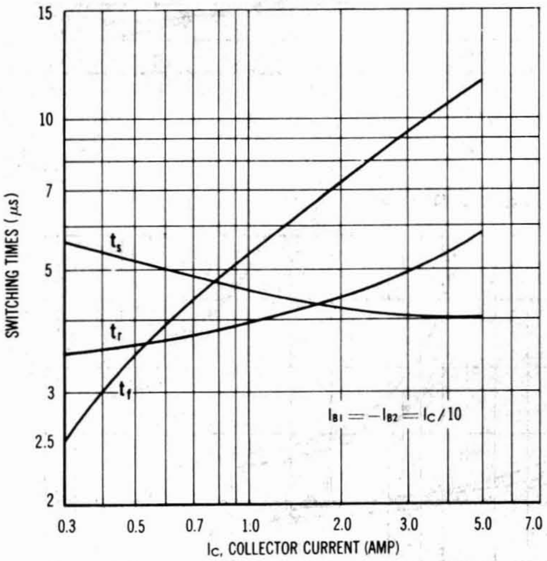


BASE CURRENT versus BASE-EMITTER VOLTAGE

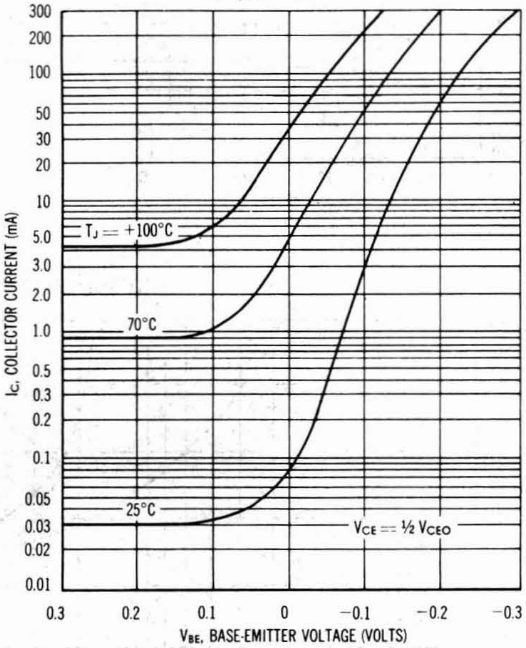


NOTE 1 — Dotted line indicates Metered Base Current plus the I_{CBO} of the transistor at 100°C.

TYPICAL SWITCHING TIMES



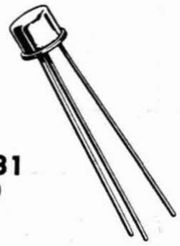
COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE



2N3632

For Specifications, See 2N3375 Data.

2N3634 thru 2N3637 (SILICON)



CASE 31
(TO-5)

Collector connected to case

PNP silicon annular transistors for high-voltage switching and low-power amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3634 2N3635	2N3636 2N3637	Unit
Collector-Emitter Voltage	V_{CEO}	140	175	Vdc
Collector-Base Voltage	V_{CB}	140	175	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	1.0		Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 5.71		Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	5.0 28.6		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

FIGURE 1 — JUNCTION CAPACITANCE VARIATIONS

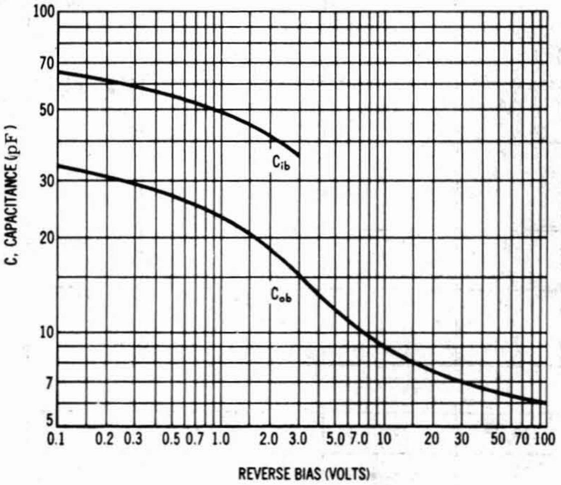
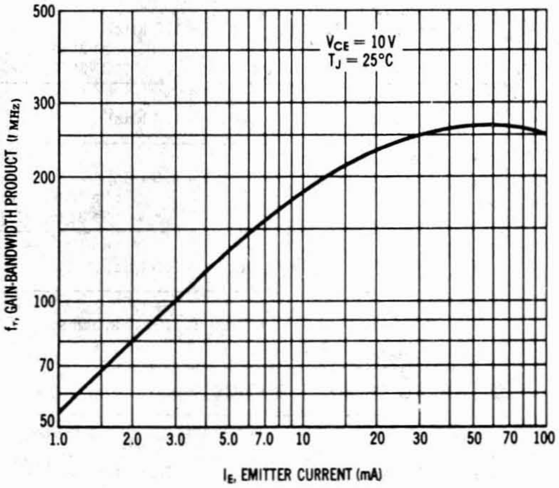


FIGURE 2 — GAIN-BANDWIDTH PRODUCT



2N3634 thru 2N3637 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0) 2N3634, 2N3635 2N3636, 2N3637	-	BV_{CEO}*	140 175	- -	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0) 2N3634, 2N3635 2N3636, 2N3637	-	BV_{CBO}	140 175	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	-	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 100 Vdc, I_E = 0)	-	I_{CBO}	-	100	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	-	I_{EBO}	-	50	nAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) 2N3634, 2N3636 2N3635, 2N3637 (I_C = 1.0 mAdc, V_{CE} = 10 Vdc) 2N3634, 2N3636 2N3635, 2N3637 (I_C = 10 mAdc, V_{CE} = 10 Vdc) 2N3634, 2N3636 2N3635, 2N3637 (I_C = 50 mAdc, V_{CE} = 10 Vdc) 2N3634, 2N3636 2N3635, 2N3637 (I_C = 150 mAdc, V_{CE} = 10 Vdc) 2N3634, 2N3636 2N3635, 2N3637	3, 4, 5, 6	h_{FE}*	40 80 45 90 50 100 50 100 25 50	- - - - - - 150 300 - -	-
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	11, 12	$V_{CE(sat)}$*	- -	0.3 0.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	11, 12	$V_{BE(sat)}$*	- 0.65	0.8 0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (V_{CE} = 30 Vdc, I_C = 30 mAdc, f = 100 MHz) 2N3634, 2N3636 2N3635, 2N3637	2	f_T	150 200	- -	MHz
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	1	C_{ob}	-	10	pF
Input Capacitance (V_{BE} = 1.0 Vdc, I_C = 0, f = 100 kHz)	1	C_{ib}	-	75	pF
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3634, 2N3636 2N3635, 2N3637	7	h_{ie}	100 200	600 1200	ohms
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	10	h_{re}	-	3.0	X 10^{-4}
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3634, 2N3636 2N3635, 2N3637	9	h_{fe}	40 80	160 320	-
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	8	h_{oe}	-	200	μmhos
Noise Figure (I_C = 0.5 mAdc, V_{CE} = 10 Vdc, R_S = 1.0 k ohms, f = 1.0 kHz)	-	NF	-	3.0	dB
SWITCHING CHARACTERISTICS					
Turn-On Time (V_{CC} = 100 Vdc, V_{BE} = 4.0 Vdc, I_C = 50 mAdc, I_{B1} = I_{B2} = 5.0 mAdc)	13, 14	t_{on}	-	400	ns
Turn-Off Time	13, 15	t_{off}	-	600	ns

* Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

FIGURE 3 — CURRENT GAIN CHARACTERISTICS versus JUNCTION TEMPERATURE

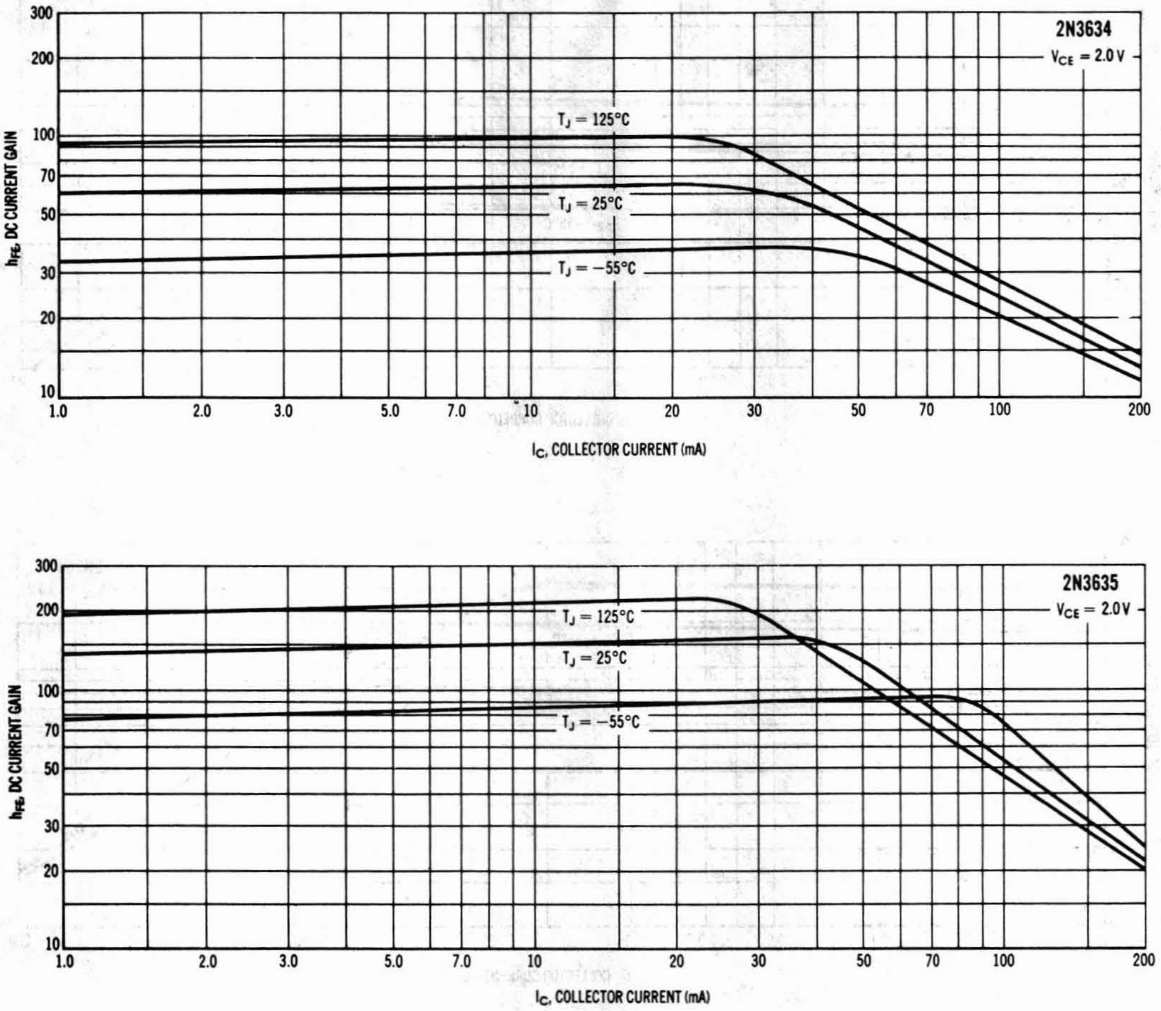


FIGURE 4 — CURRENT GAIN CHARACTERISTICS versus COLLECTOR EMITTER VOLTAGE

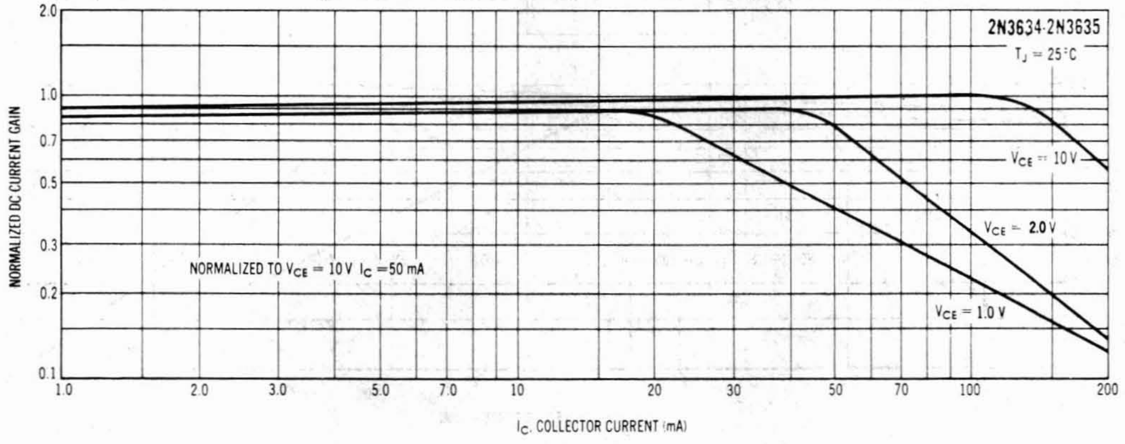


FIGURE 5 — CURRENT GAIN CHARACTERISTICS versus JUNCTION TEMPERATURE

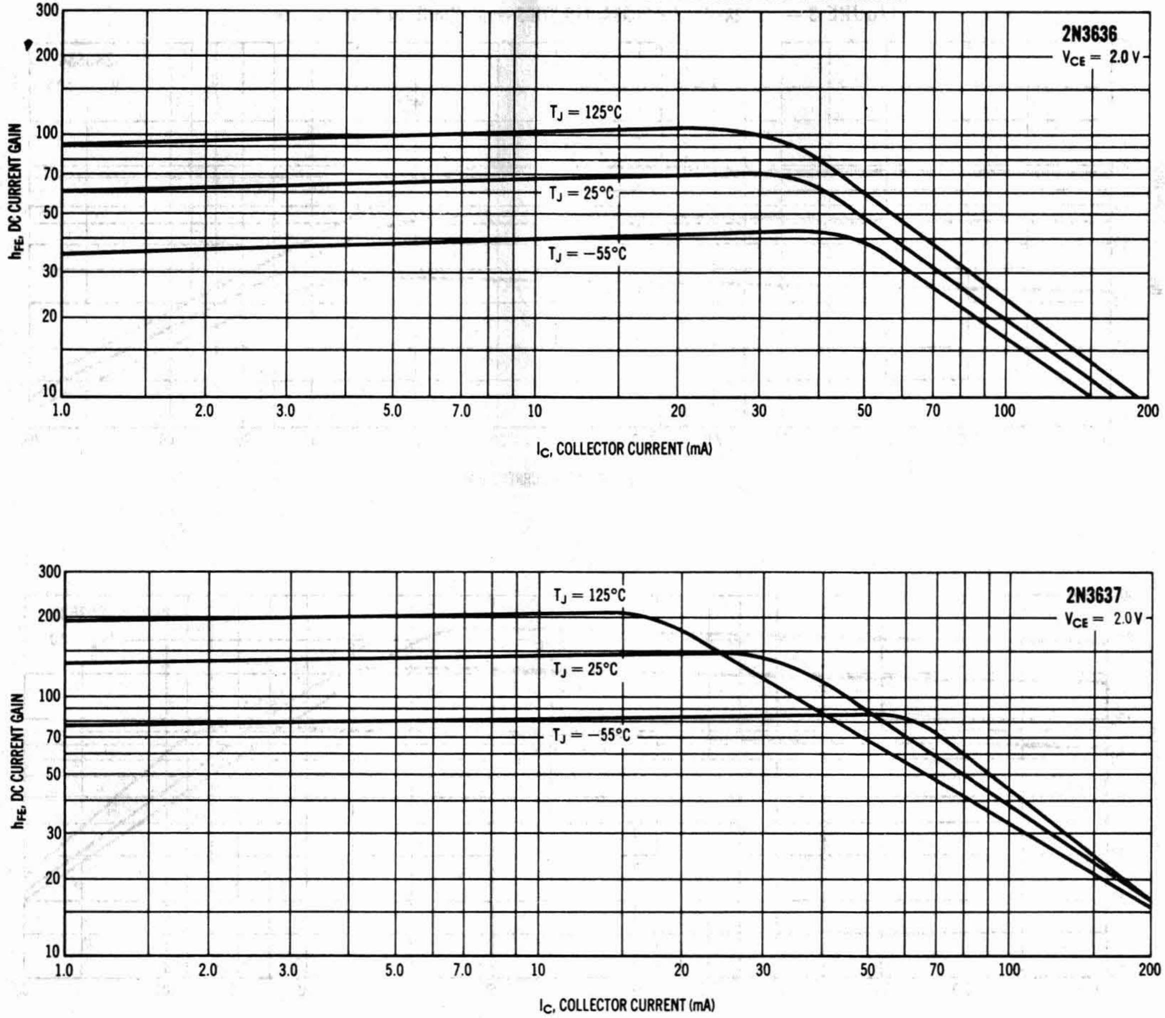


FIGURE 6 — CURRENT GAIN CHARACTERISTICS versus COLLECTOR EMITTER VOLTAGE

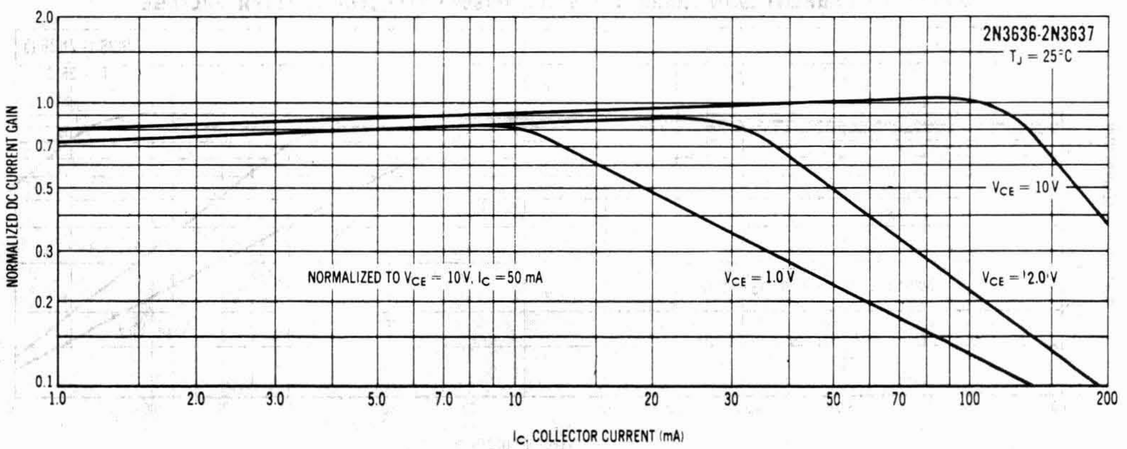


FIGURE 7 — INPUT IMPEDANCE

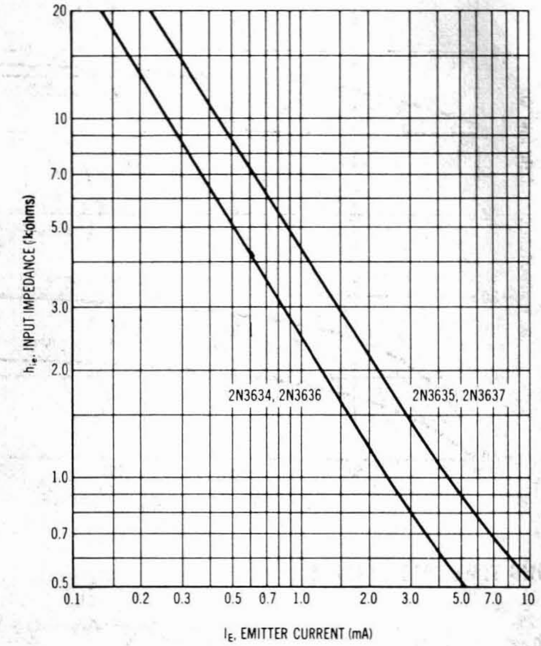


FIGURE 8 — OUTPUT IMPEDANCE

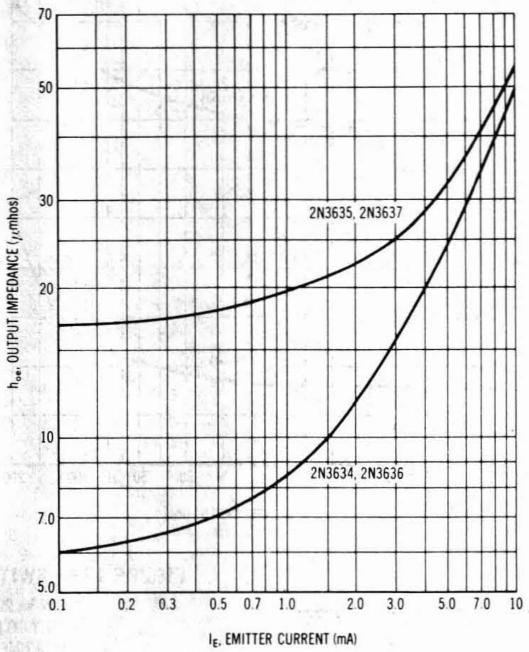


FIGURE 9 — CURRENT GAIN

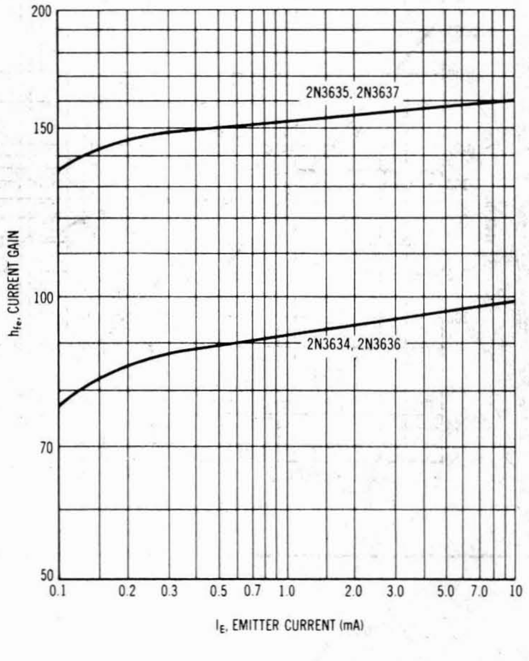


FIGURE 10 — VOLTAGE FEEDBACK RATIO

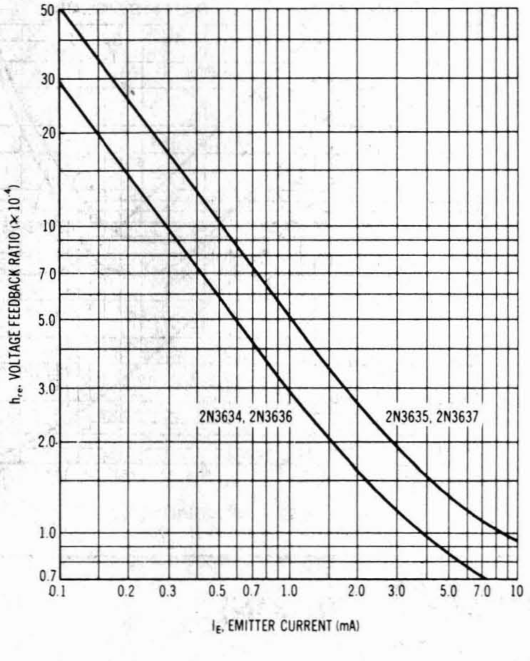


FIGURE 11 — SATURATION VOLTAGES

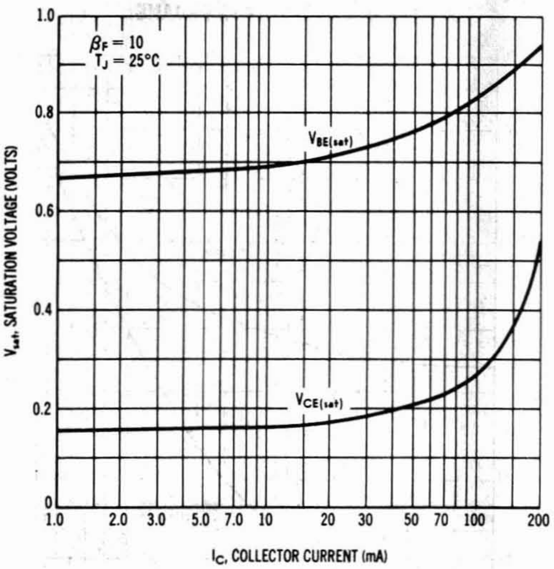


FIGURE 12 — TEMPERATURE COEFFICIENTS

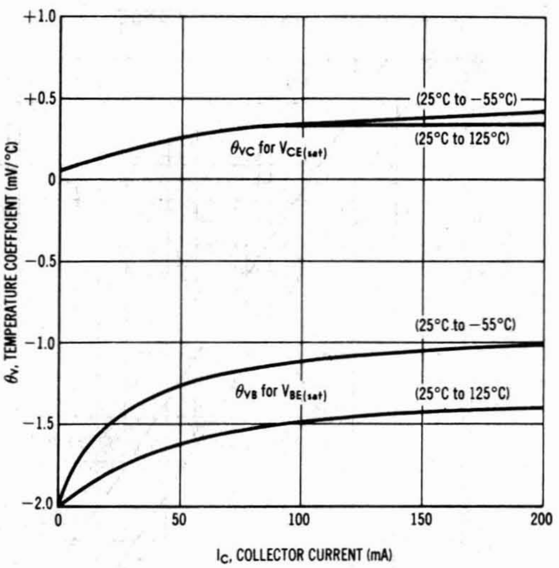
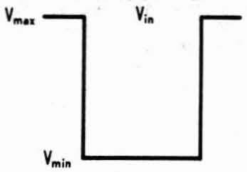


FIGURE 13 — SWITCHING TIME TEST CIRCUIT



P.W. ≅ 20 μs
DUTY CYCLE ≤ 2%
RISE TIME ≤ 20 ns

	V_{max}	V_{min}
TURN-ON	+4.0 V	−5.65 V
TURN-OFF	+4.1 V	−5.9 V

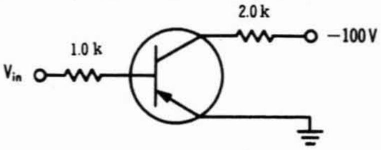


FIGURE 14 — TURN-ON TIME VARIATIONS WITH VOLTAGE

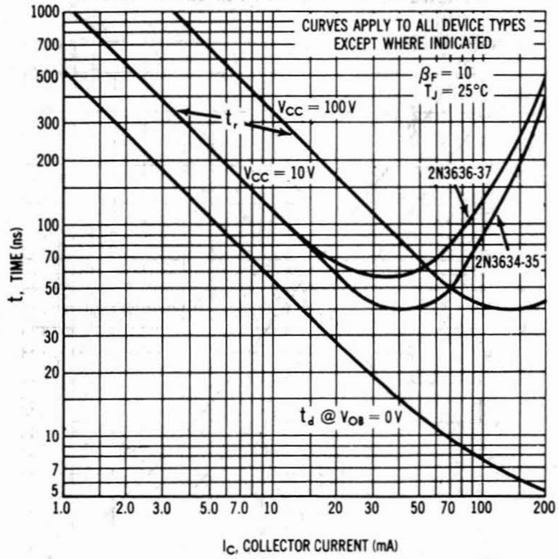
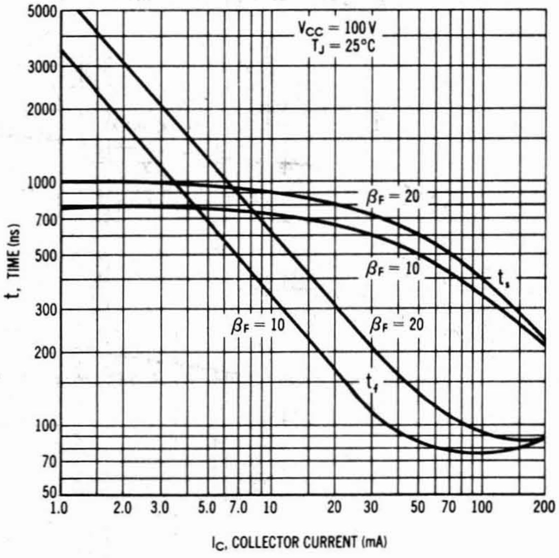


FIGURE 15 — TURN-OFF TIME VARIATIONS WITH CIRCUIT GAIN



2N3647 (SILICON)
2N3648

For Specifications, See 2N3510 Data.

2N3664 (SILICON)

CASE 24
(TO-102)

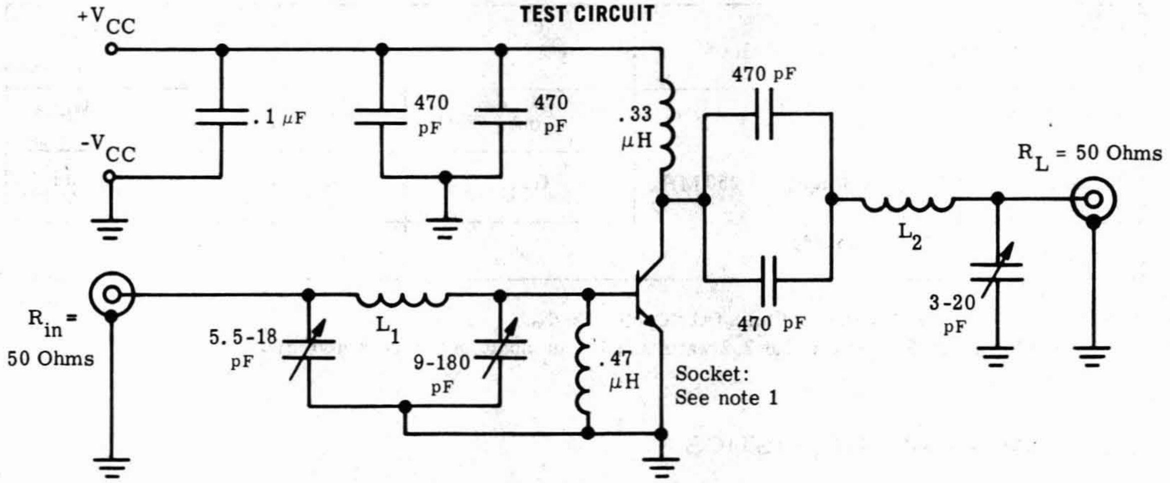
NPN silicon annular transistor for power amplifier and driver applications to 500 MHz.

Collector connected to case; stud isolated from case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector Base Voltage	V_{CB}	60	Vdc
Collector Emitter Voltage	V_{CES}	60	Vdc
Collector Emitter Voltage	V_{CEO}	40	Vdc
Emitter Base Voltage	V_{EB}	4	Vdc
Collector Current (Continuous)	I_C	0.5	Adc
Base Current (Continuous)	I_B	0.1	Adc
Power Dissipation @ 25°C Case Temperature @ 25°C Ambient Temperature	P_D	 5.0 1.0	 Watts Watts
Operating Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +200	°C

TEST CIRCUIT



$+V_{CC}$
$-V_{CC}$
.1 μF
470 pF
470 pF
.33 μH
470 pF
R_L = 50 Ohms
L_2
470 pF
3-20 pF
R_{in} = 50 Ohms
5.5-18 pF
L_1
9-180 pF
.47 μH
Socket: See note 1

L_1: 2T No. 14 tinned wire 5/16" ID, 1/4" long
L_2: 2T No. 14 tinned wire 3/8" ID, 3/16" long

Note 1: Use a 0.100" pin circle teflon socket with the emitter grounded to the chassis at the top of the socket.

When making RF power test, the device must be provided with an adequate heat sink.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise specified)

Characteristic	Symbol	Min	Max	Unit
Collector-Emitter Sustain Voltage* I_C = 30mAdc, R_{BE} = 0 ohms	$V_{CES\,(sus)}$*	60		Vdc
Collector-Emitter Open Base Sustain Voltage* I_C = 30mAdc, I_B = 0	$V_{CEO\,(sus)}$*	40		Vdc
Collector-Emitter Cutoff Current V_{CE} = 25Vdc, V_{BE} = 0, T_C = +150°C	I_{CES}		50	μAdc
Collector-Emitter Cutoff Current V_{CE} = 25Vdc, V_{BE} = 0	I_{CES}		0.05	μAdc
Collector-Emitter Cutoff Current V_{CE} = 50Vdc, V_{BE} = 0	I_{CES}		10	μAdc
Emitter Cutoff Current V_{EB} = 4Vdc, I_C = 0	I_{EBO}		100	μAdc
DC Current Gain V_{CE} = 2Vdc, I_C = 250mAdc V_{CE} = 2Vdc, I_C = 50mAdc	h_{FE}	 8 8	 80	
Collector-Emitter Saturation Voltage I_C = 250mAdc, I_B = 50mAdc	$V_{CE\,(sat)}$		0.75	Vdc
Base-Emitter Saturation Voltage I_C = 250mAdc, I_B = 50mAdc	$V_{BE\,(sat)}$		1.2	Vdc
Small Signal Current Gain V_{CE} = 15Vdc, I_C = 100mAdc, f = 100 MHz	$\lvert h_{fe} \rvert$	3		
Common Base Output Capacitance V_{CB} = 15Vdc, I_E = 0, f = 100kHz	C_{ob}		6.0	pF
Power Output** P_{in} = 400 mW, f = 250 MHz V_{CE} = 25 Vdc	P_{out}**	2.2		Watts
Power Gain	G_{PE}	7.4		dB
Efficiency	η	50		%

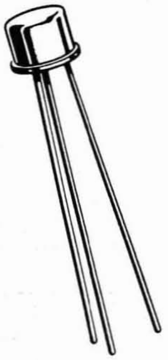
* Pulse Test: Pulse Width ≤ 200 μs, Duty Cycle ≤ 2.0%.

**In functional test P_{out} is fixed at 2.2 watts and P_{in} is monitored to be ≤ 400 mW.

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance - Junction to Case	θ_{JC}	35	°C/W
Thermal Resistance - Junction to Ambient	θ_{JA}	175	°C/W

2N3712 (SILICON)



CASE 31
(TO-5)

NPN silicon annular transistor designed for high-voltage DC to VHF amplifier applications.

Collector connected to case

MAXIMUM RATINGS

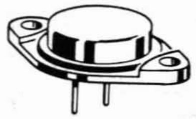
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	150	Vdc
Collector-Base Voltage	V_{CB}	150	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	1.0 5.71	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	5.0 28.6	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 30 mAdc, I_B = 0)	BV_{CEO}*	150	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	150	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 75 Vdc, I_E = 0) (V_{CB} = 75 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.1 50	μAdc
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	0.1	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 30 mAdc, V_{CE} = 10 Vdc)	h_{FE}*	25 30	- 150	-
Collector-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$*	-	2.0	Vdc
Base-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{BE(sat)}$*	-	0.9	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 30 mAdc, V_{CE} = 10 Vdc, f = 20 MHz)	f_T	40	240	MHz
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	1.0	9.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	-	80	pF
Small-Signal Current Gain (I_C = 30 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	25	-	-
Collector-Base Time Constant (I_E = 30 mAdc, V_{CB} = 10 Vdc, f = 31.9 MHz)	$r_b'C_c$	-	100	ps

*Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

2N3713 thru 2N3716 (SILICON)



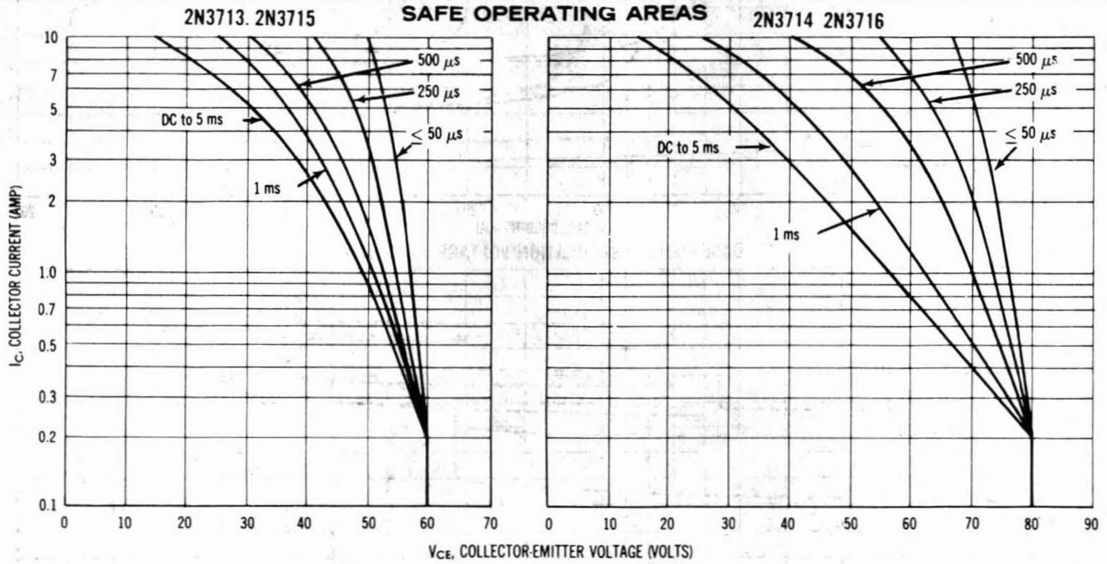
NPN silicon power transistors for medium-speed switching and amplifier applications. Complement to PNP types 2N3789 thru 2N3792.

CASE 11
(TO-3)

MAXIMUM RATINGS

Rating	Symbol	2N3713 2N3715	2N3714 2N3716	Unit
Collector-Base Voltage	V_{CB}	80	100	Volts
Collector-Emitter Voltage	V_{CEO}	60	80	Volts
Emitter-Base Voltage	V_{EB}	7	7	Volts
Collector Current	I_C	10	10	Amp
Base Current	I_B	4.0	4.0	Amp
Power Dissipation	P_D	150	150	Watts
Thermal Resistance	θ_{JC}	1.17	1.17	°C/W
Operating Junction and Storage Temperature Range	T_J and T_{stg}	-65 to +200		°C

SAFE OPERATING AREAS



The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

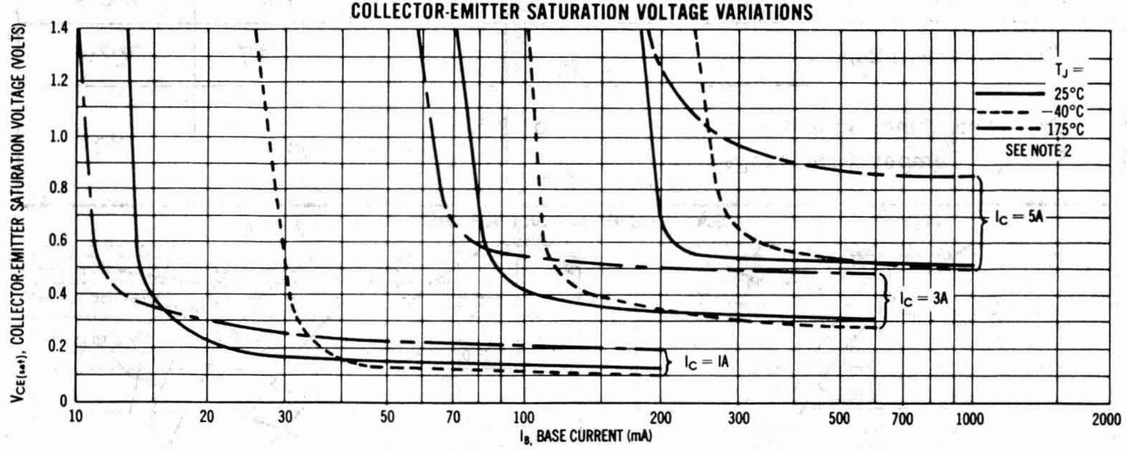
2N3713 thru 2N3716 (continued)

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

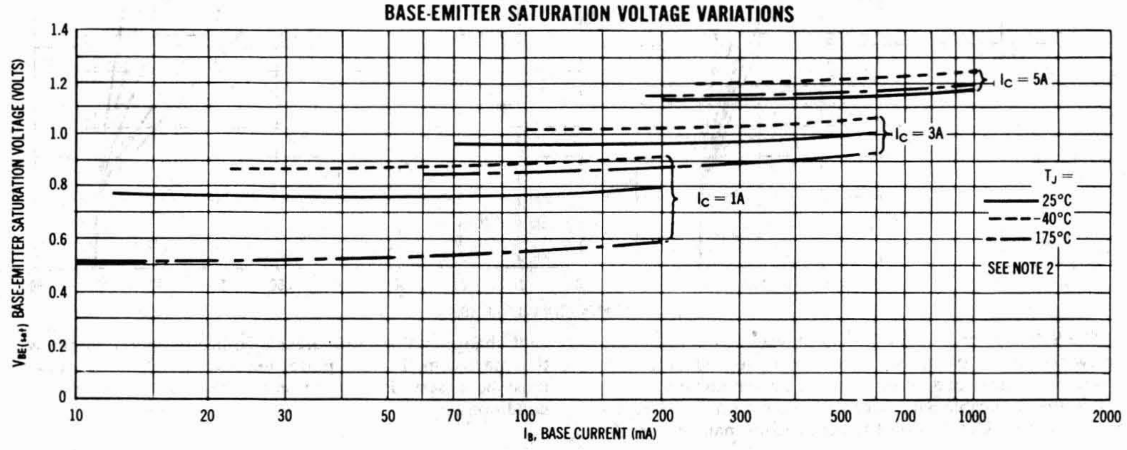
Characteristic	Types	Symbol	Min	Max	Unit
Emitter-Base Cutoff Current (V_{EB} = 7 Vdc)		I_{EBO}	—	5	mAdc
Collector-Emitter Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 80 Vdc, V_{BE} = -1.5 Vdc)	2N3713, 2N3715		—	1	
(V_{CE} = 100 Vdc, V_{BE} = -1.5 Vdc)	2N3714, 2N3716		—	1	
(V_{CE} = 60 Vdc, V_{BE} = -1.5 Vdc, T_C = 150°C)	2N3713, 2N3715		—	10	
(V_{CE} = 80 Vdc, V_{BE} = -1.5 Vdc, T_C = 150°C)	2N3714, 2N3716		—	10	
Collector-Emitter Sustaining Voltage* (I_C = 200 mAdc, I_B = 0)	2N3713, 2N3715	$V_{CEO(sus)}$*	60	—	Vdc
	2N3714, 2N3716		80	—	
DC Current Gain*		h_{FE}*			—
(I_C = 1 Adc, V_{CE} = 2 Vdc)	2N3713, 2N3714		25	90	
	2N3715, 2N3716		50	150	
(I_C = 3 Adc, V_{CE} = 2 Vdc)	2N3713, 2N3714		15	—	
	2N3715, 2N3716		30	—	
Collector-Emitter Saturation Voltage* (I_C = 5 Adc, I_B = 0.5 Adc)	2N3713, 2N3714	$V_{CE(sat)}$*	—	1.0	Vdc
	2N3715, 2N3716		—	0.8	
Base-Emitter Saturation Voltage* (I_C = 5 Adc, I_B = 0.5 Adc)	2N3713, 2N3714	$V_{BE(sat)}$*	—	2.0	Vdc
	2N3715, 2N3716		—	1.5	
Base-Emitter Voltage* (I_C = 3 Adc, V_{CE} = 2 Vdc)		V_{BE}*	—	1.5	Vdc
Small Signal Current Gain (V_{CE} = 10 Vdc, I_C = 0.5 Adc, f = 1 MHz)		h_{fe}	2.5	—	—
Switching Times (I_C = 5 A, I_{B1} = I_{B2} = 0.5 A)			Typ		μs
Rise Time		t_r	0.45		
Storage Time		t_s	0.3		
Fall Time		t_f	0.4		

*Use sweep test to prevent overheating

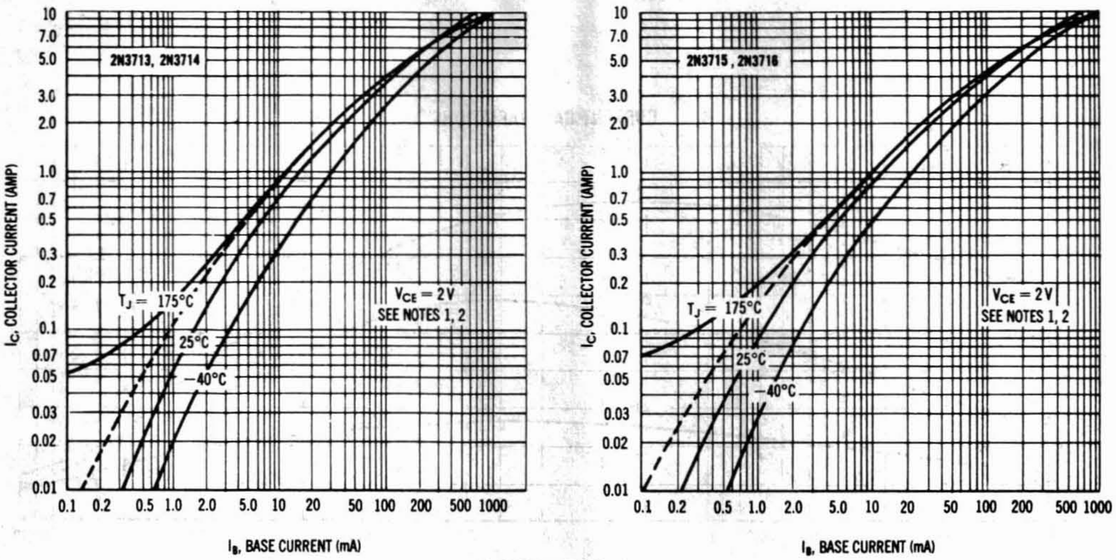
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS



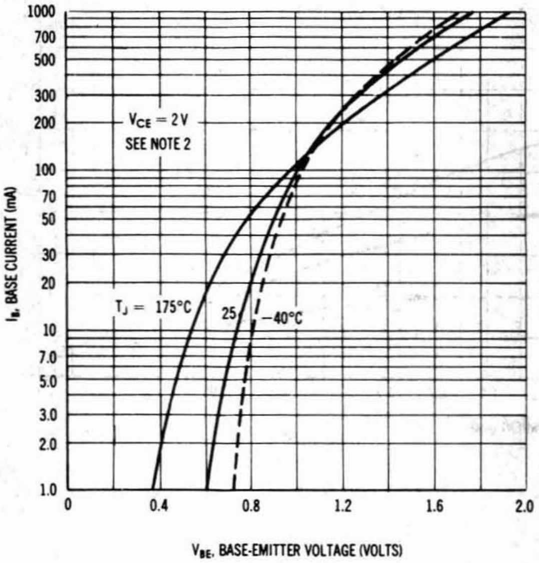
BASE-EMITTER SATURATION VOLTAGE VARIATIONS



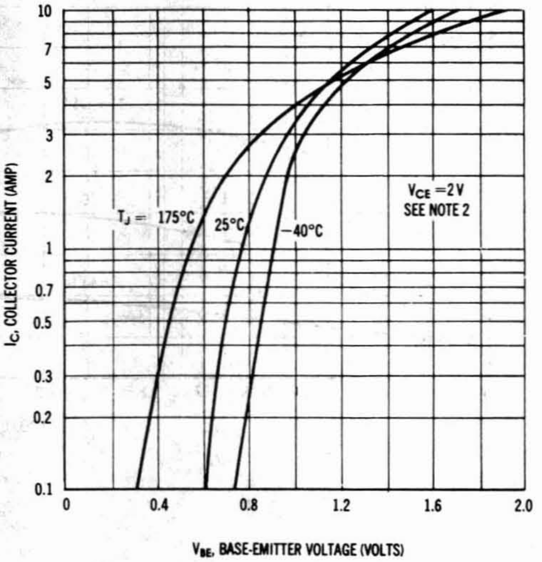
COLLECTOR CURRENT versus BASE CURRENT



BASE CURRENT-VOLTAGE VARIATIONS

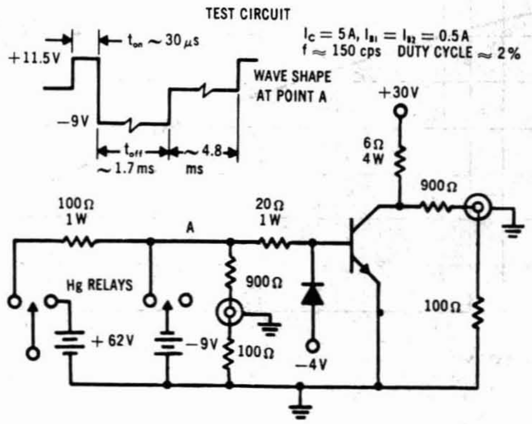


COLLECTOR CURRENT-VOLTAGE VARIATIONS

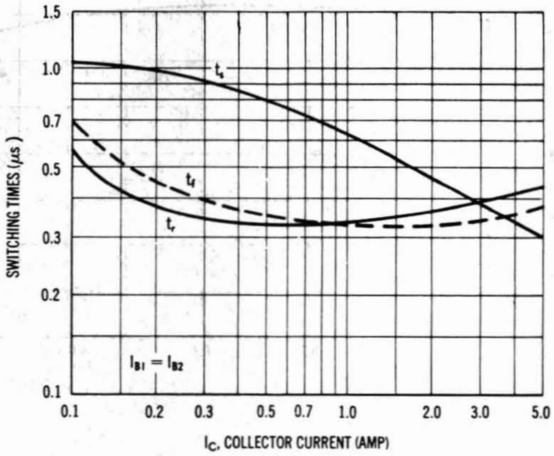


NOTE 1. Dotted line indicates metered base current plus the I_{CBO} of the transistor at 175°C.

NOTE 2. Pulse test: pulse width ≈ 200 μs, duty cycle ≈ 1.5%

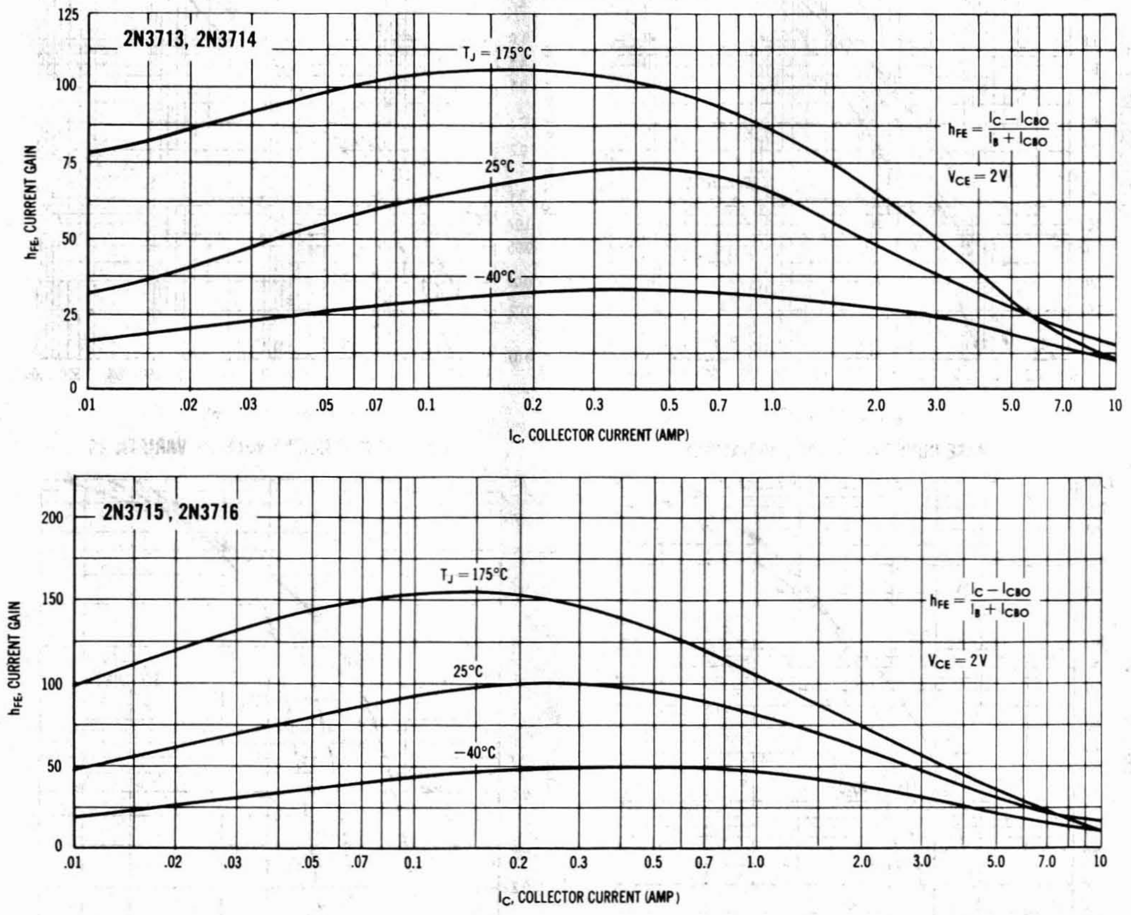

TEST CIRCUIT
I_C = 5 A, I_{B1} = I_{B2} = 0.5 A
f ≈ 150 cps DUTY CYCLE ≈ 2%
t_{on} ~ 30 μs
+11.5 V
−9 V
WAVE SHAPE AT POINT A
t_{off}
~1.7 ms
~4.8 ms
+30 V
6 Ω 4 W
900 Ω
100 Ω 1 W
A
20 Ω 1 W
Hg RELAYS
+62 V
−9 V
900 Ω
100 Ω
−4 V
100 Ω

TYPICAL SWITCHING TIMES

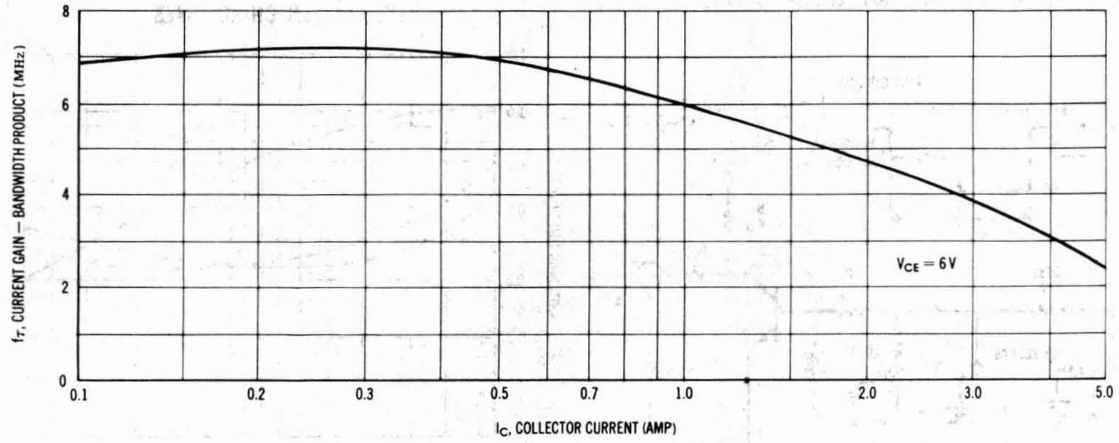


2N3713 thru 2N3716 (continued)

CURRENT GAIN VARIATIONS



CURRENT-GAIN—BANDWIDTH PRODUCT versus COLLECTOR CURRENT



2N3719 (SILICON)
2N3720

CASE 31
(TO-5)

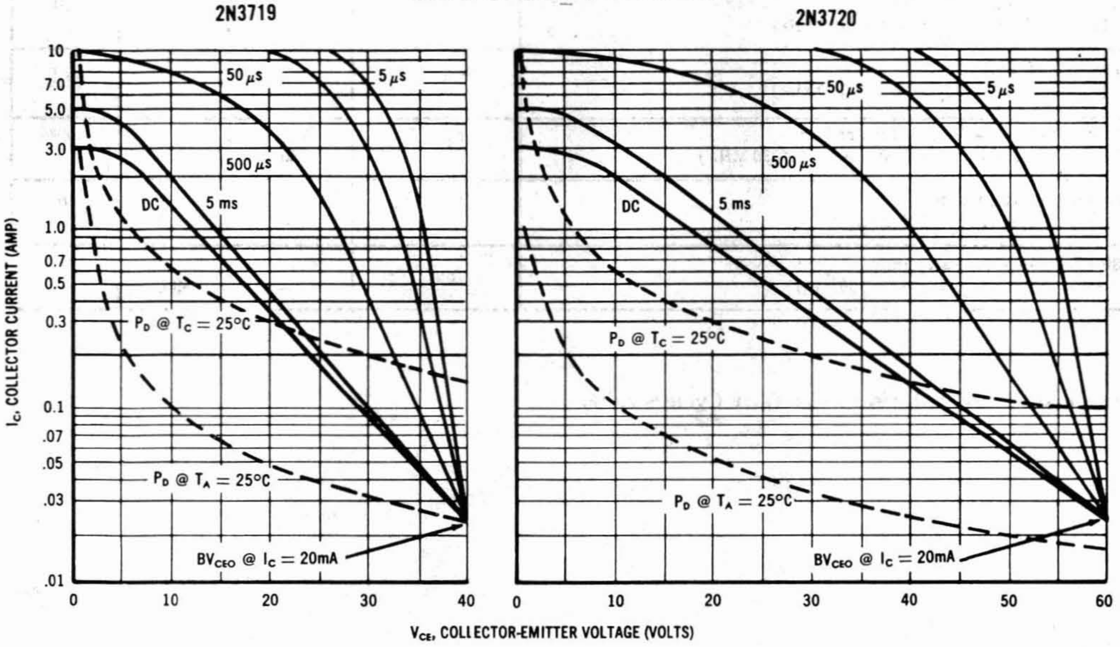
PNP silicon annular power transistors for high-speed, high-current switching in core, driver and Class C power applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N3719	2N3720	Unit
Collector-Base Voltage	V_{CB}	40	60	Volts
Collector-Emitter Voltage	V_{CEO}	40	60	Volts
Emitter-Base Voltage	V_{EB}	4	4	Volts
Collector Current—Continuous Collector Current—Peak	I_C	3 10	3 10	Amp Amp
Base Current	I_B	0.5	0.5	Amp
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 5.72		Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	6 34.3		Watts mW/°C
Operating Junction and Storage Temperature Range	T_J and T_{stg}	-65 to +200		°C

SAFE OPERATING AREAS



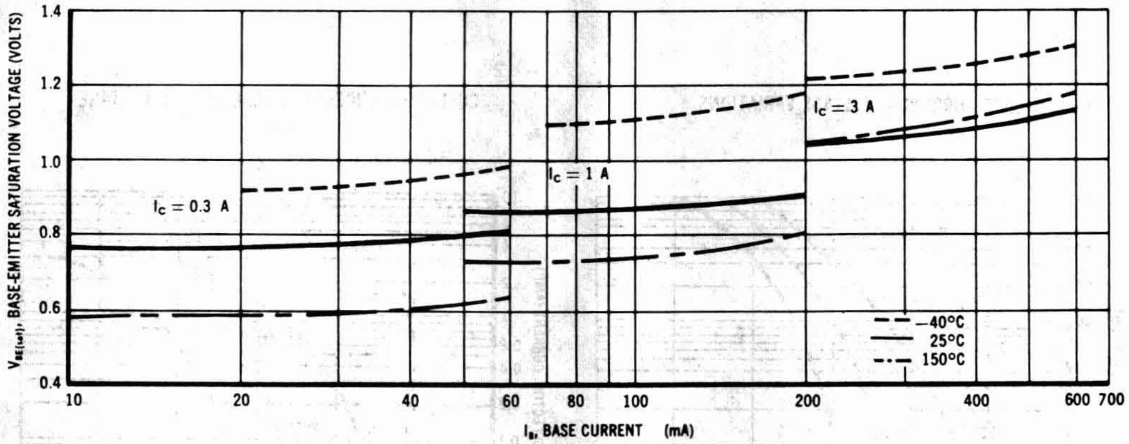
2N3719 and 2N3720 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

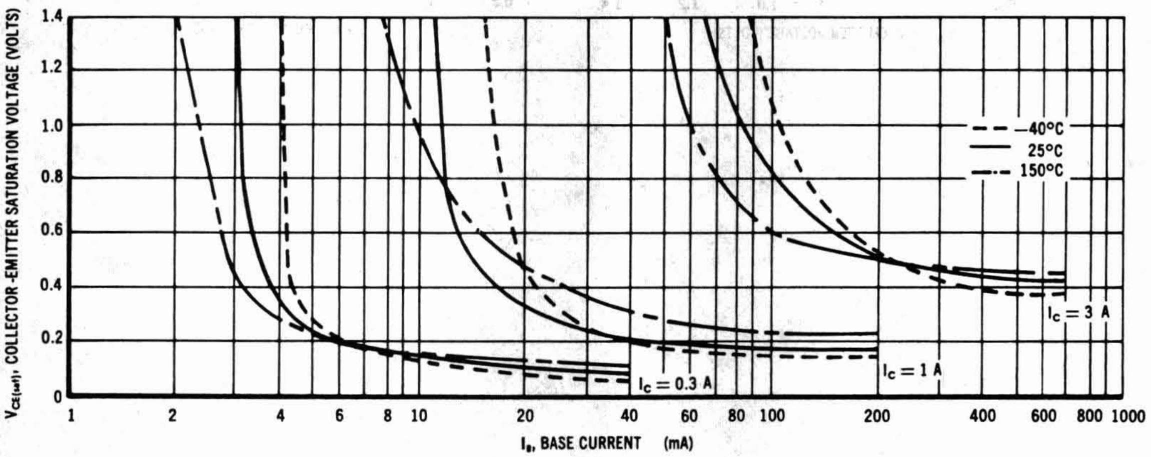
Characteristic		Symbol	Min	Max	Unit
Collector Leakage Current		I_{CEX}			μAdc
(V_{CE} = 40 Vdc, V_{BE} = 2 Vdc)	2N3719		—	10	
(V_{CE} = 60 Vdc, V_{BE} = 2 Vdc)	2N3720		—	10	
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 40 Vdc, I_E = 0, T_A = 25°C)	2N3719		—	0.010	
(V_{CB} = 40 Vdc, I_E = 0, T_A = 150°C)	2N3719		—	1	
(V_{CB} = 60 Vdc, I_E = 0, T_A = 25°C)	2N3720		—	0.010	
(V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)	2N3720		—	1	
Emitter-Base Cutoff Current (V_{BE} = 4 Vdc, I_C = 0)		I_{EBO}	—	1	mAdc
DC Current Gain*		h_{FE}*			—
(I_C = 500 mA, V_{CE} = 1.5 V, T_A = 25°C)			20	—	
(I_C = 1 A, V_{CE} = 1.5 V, T_A = 25°C)			25	180	
(I_C = 1 A, V_{CE} = 1.5 V, T_A = -40°C)			15	—	
Collector-Emitter Saturation Voltage*		$V_{CE(sat)}$*			Volts
(I_C = 1 A, I_B = 100 mA, T_A = -40 to +100°C			—	0.75	
(I_C = 3 A, I_B = 300 mA, T_A = 25°C)			—	1.5	
Base-Emitter Saturation Voltage*		$V_{BE(sat)}$*			Volts
(I_C = 1 A, I_B = 100 mA)			—	1.5	
(I_C = 3 A, I_B = 300 mA)			—	2.3	
Collector-Emitter Breakdown Voltage*		BV_{CEO}*			Volts
(I_C = 20 mA, I_B = 0)	2N3719		40	—	
	2N3720		60	—	
Collector Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	120	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	1000	pF
Current-Gain — Bandwidth Product (V_{CE} = 10 Vdc, I_C = 500 mAdc, f = 30 MHz)		f_T	60	—	MHz
Delay Plus Rise Time (I_C = 1 Adc, I_{B1} = 100 mA)		t_{on}	—	100	ns
Storage Time and Fall Time (I_C = 1 Adc, I_{B1} = I_{B2} = 100 mA)		t_{off}	—	400	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

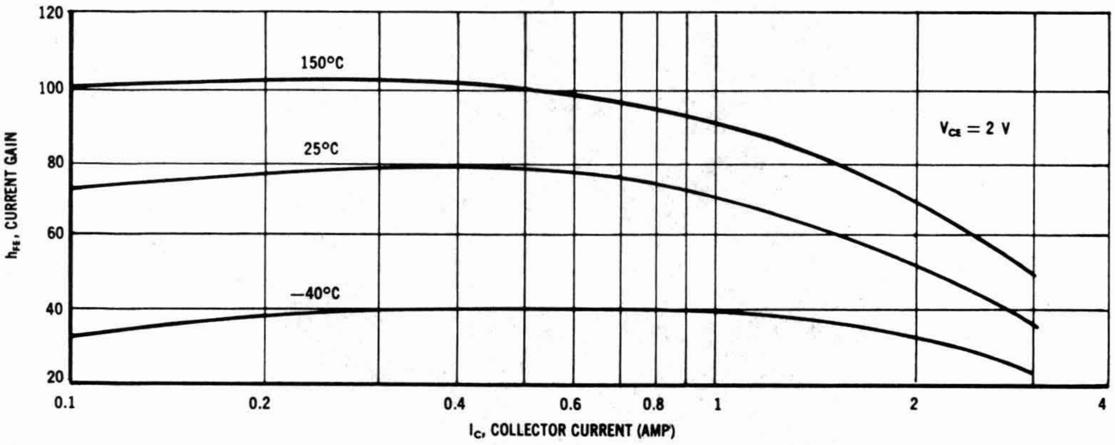
BASE EMITTER SATURATION VOLTAGE VARIATIONS



COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS

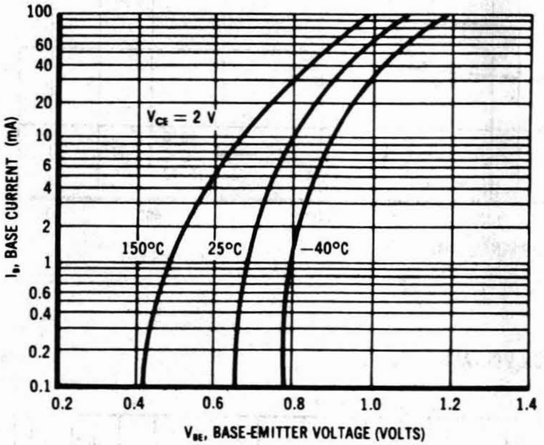


CURRENT GAIN VARIATIONS

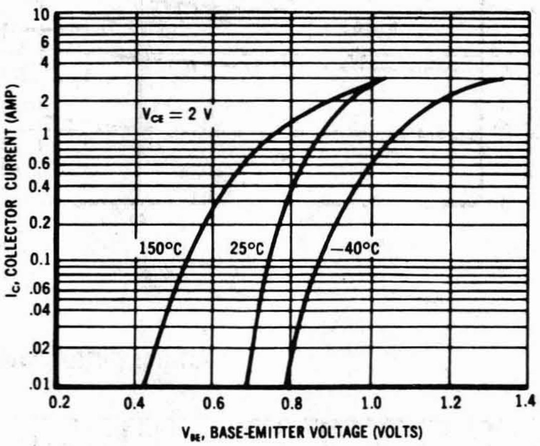


2N3719, 2N3720 (continued)

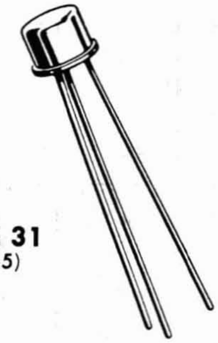
BASE CURRENT — VOLTAGE VARIATIONS



COLLECTOR CURRENT vs BASE-EMITTER VOLTAGE



2N3722 (SILICON)
2N3723



CASE 31
(TO-5)

NPN silicon annular transistors designed for medium-current, high-speed, high-voltage switching and driver applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N3722	2N3723	Unit
Collector-Emitter Voltage	V_{CEO}	60	80	Vdc
Collector-Base Voltage	V_{CB}	80	100	Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current — Continuous	I_C	500		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.8 4.56		Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	4.0 22.8		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	2N3722	BV_{CEO}*	60	-	Vdc
	2N3723		80	-	
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	2N3722	BV_{CES}	80	-	Vdc
	2N3723		100	-	
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N3722	BV_{CBO}	80	-	Vdc
	2N3723		100	-	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	6.0	-	Vdc
Collector Cutoff Current (V_{CE} = 40 Vdc, V_{BE} = 0)	2N3722	I_{CES}	-	0.5	μAdc
(V_{CE} = 50 Vdc, V_{BE} = 0)	2N3723		-	0.5	
(V_{CE} = 40 Vdc, V_{BE} = 0, T_A = +125°C)	2N3722		-	70	
(V_{CE} = 50 Vdc, V_{BE} = 0, T_A = +125°C)	2N3723		-	70	
Base Current (V_{CE} = 40 Vdc, V_{BE} = 0)	2N3722	I_B	-	0.5	μAdc
(V_{CE} = 50 Vdc, V_{BE} = 0)	2N3723		-	0.5	

* Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1.0%.

ELECTRICAL CHARACTERISTICS **(continued)**

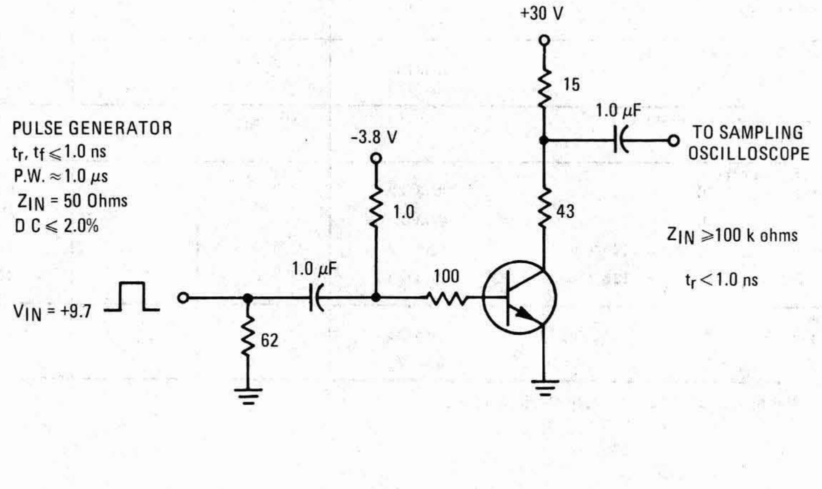
Characteristic		Symbol	Min	Max	Unit
ON CHARACTERISTICS					
DC Current Gain		h_{FE}*			-
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N3722, 2N3723		25	-	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	2N3722, 2N3723		40	150	
(I_C = 300 mAdc, V_{CE} = 2.0 Vdc)	2N3722		20	-	
	2N3723		15	-	
(I_C = 500 mAdc, V_{CE} = 2.0 Vdc)	2N3722		15	-	
(I_C = 500 mAdc, V_{CE} = 3.0 Vdc)	2N3723		15	-	
(I_C = 800 mAdc, V_{CE} = 5.0 Vdc)	2N3722, 2N3723		12	-	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)	2N3722, 2N3723		15	-	
(I_C = 200 mAdc, V_{CE} = 2.0 Vdc, T_A = -55°C)	2N3722, 2N3723		20	-	
Collector-Emitter Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)	2N3722		-	0.22	
	2N3723		-	0.25	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N3722		-	0.25	
	2N3723		-	0.28	
(I_C = 300 mAdc, I_B = 30 mAdc)	2N3722		-	0.37	
	2N3723		-	0.44	
(I_C = 500 mAdc, I_B = 50 mAdc)	2N3722		-	0.50	
	2N3723		-	0.75	
(I_C = 800 mAdc, I_B = 80 mAdc)	2N3722		-	2.0	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)	2N3722, 2N3723		-	0.75	
(I_C = 100 mAdc, I_B = 10 mAdc)	2N3722, 2N3723		-	0.85	
(I_C = 300 mAdc, I_B = 30 mAdc)	2N3722, 2N3723		-	1.1	
(I_C = 500 mAdc, I_B = 50 mAdc)	2N3722, 2N3723		0.86	1.2	
(I_C = 800 mAdc, I_B = 80 mAdc)	2N3722		-	1.5	
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	300	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	2N3722	C_{ob}	-	10	pF
	2N3723		-	9.0	
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	-	65	pF

SWITCHING CHARACTERISTICS

Characteristic	Conditions	Device	Symbol	Min	Max	Unit
Turn-On Time	(V_{CC} = 30 Vdc, $V_{BE(off)}$ = 3.8 Vdc, I_C = 500 mAdc, I_{B1} = 50 mAdc) (See Figure 1)	2N3722 2N3723	t_{on}	- -	50 70	ns
Delay Time		2N3722 2N3723	t_d	- -	12 15	ns
Rise Time		2N3722 2N3723	t_r	- -	50 70	ns
Turn-Off Time	(V_{CC} = 30 Vdc, I_C = 500 mAdc, I_{B1} = I_{B2} = 50 mAdc) (See Figure 1)	2N3722 2N3723	t_{off}	- -	100 130	ns
Storage Time		2N3722 2N3723	t_s	- -	85 110	ns
Fall Time		2N3722 2N3723	t_f	- -	45 50	ns

* Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1.0%.

FIGURE 1 — SWITCHING TIMES TEST CIRCUIT



2N3733 (SILICON)

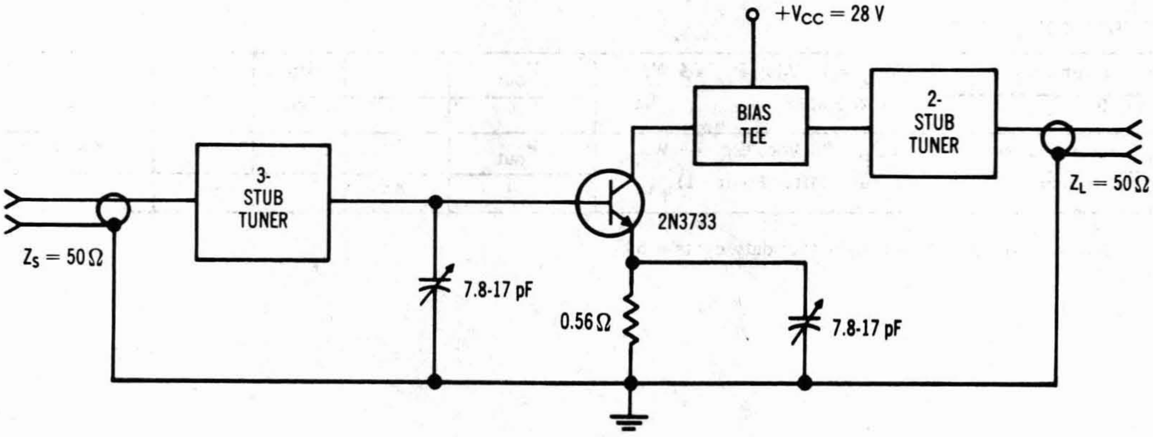
CASE 36
(TO-60)
stud isolated from case

NPN silicon transistor designed for amplifier, frequency multiplier, and oscillator applications.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Emitter Voltage ($V_{EB(off)} = 1.5$ Vdc)	V_{CEV}	65	Vdc
Collector-Base Voltage	V_{CB}	65	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector Current	I_C	3	Amps
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	23 0.13	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

FIGURE 1 — 400-MHz TEST CIRCUIT


+VCC = 28 V
BIAS TEE
2-STUB TUNER
3-STUB TUNER
2N3733
ZS = 50 Ω
ZL = 50 Ω
7.8-17 pF
0.56 Ω
7.8-17 pF

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

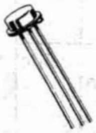
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 0 to 200 mAdc, I_B = 0)	BV_{CEO}*	40	-	-	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 0 to 200 mAdc, $V_{EB(off)}$ = 1.5 Vdc)	BV_{CEV}*	65	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 0.5 mAdc, I_E = 0)	BV_{CBO}	65	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.25 mAdc, I_C = 0)	BV_{EBO}	4	-	-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, I_B = 0)	I_{CEO}	-	-	0.25	mAdc
ON CHARACTERISTICS					
Collector-Emitter Saturation Voltage (I_C = 500 mAdc, I_B = 100 mAdc)	$V_{CE(sat)}$	-	-	1	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 150 mAdc, V_{CE} = 28 Vdc, f = 100 MHz)	f_T	-	400	-	MHz
Output Capacitance (V_{CB} = 30 Vdc, I_E = 0)	C_{ob}	-	-	20	pF
Collector-Case Capacitance	C_s	-	-	6	pF
Base-Spreading Resistance (I_C = 250 mAdc, V_{CE} = 28 Vdc, f = 200 MHz)	r_{bb}'	-	6.5	-	Ohms

FUNCTIONAL TEST

Power Output	V_{CE} = 28 Vdc, P_{in} = 4 W, f = 260 MHz	P_{out}	-	14.5	-	Watts
Efficiency		η	-	60	-	%
Power Output	V_{CE} = 28 Vdc, P_{in} = 4 W, f = 400 MHz (Figure 1)	P_{out}	10	-	-	Watts
Efficiency		η	45	-	-	%

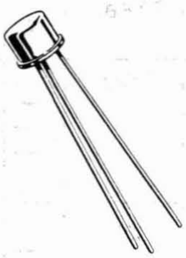
*Pulsed through a 25 mH inductor; duty cycle = 50%

2N3734 (SILICON)
2N3735
2N3736
2N3737



CASE 26
(TO-46)

2N3736
2N3737



CASE 31
(TO-5)

2N3734
2N3735

Medium current NPN silicon annular transistors designed for high-speed switching and driver applications.

Collector connected to case

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	2N3734 2N3736	2N3735 2N3737	Unit
Collector-Base Voltage	V_{CB}	50	75	Vdc
Collector-Emitter Voltage	V_{CEO}	30	50	Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	1.5		Adc
		TO-5 2N3734 2N3735	TO-46 2N3736 2N3737	
Total Device Dissipation @ T_A = 25°C Derating Factor Above 25°C	P_D	1.0 5.71	0.5 2.86	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derating Factor Above 25°C	P_D	4.0 22.8	2.0 11.4	Watts mW/°C
Thermal Resistance Junction to Ambient Junction to Case	 θ_{JA} θ_{JC}	 0.175 0.044	 0.35 0.088	°C/mW
Junction Temperature, Operating	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

2N3734, 2N3735, 2N3736, 2N3737 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

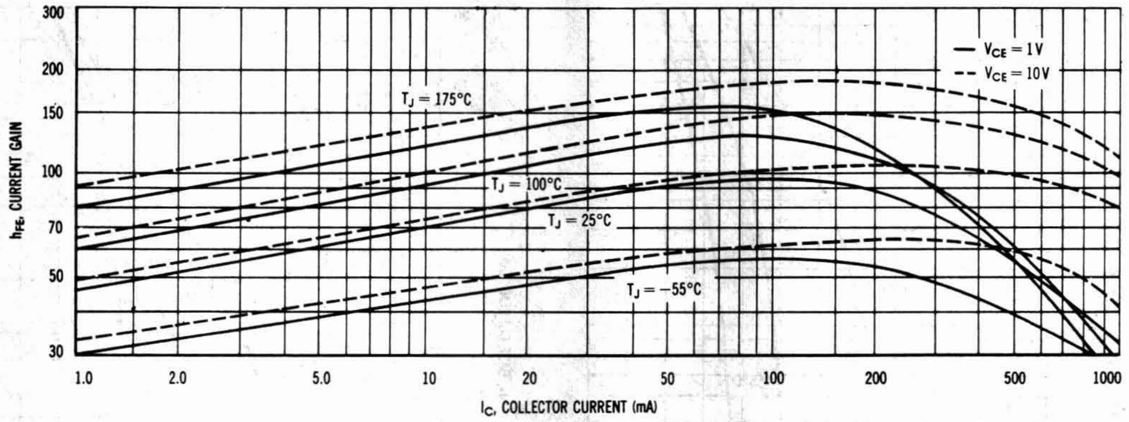
Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Base Breakdown Voltage		BV_{CBO}			Vdc
(I_C = 10 μAdc, I_E = 0)	2N3734, 2N3736		50	—	
	2N3735, 2N3737		75	—	
Collector-Emitter Breakdown Voltage*		BV_{CEO}*			Vdc
(I_C = 10 mAdc, I_B = 0)	2N3734, 2N3736		30	—	
	2N3735, 2N3737		50	—	
Emitter-Base Breakdown Voltage		BV_{EBO}			Vdc
(I_E = 10 μAdc, I_C = 0)			5	—	
Collector Cutoff Current		I_{CEX}			μAdc
(V_{CE} = 25 Vdc, V_{EB} = 2 Vdc)	2N3734, 2N3736		—	0.20	
(V_{CE} = 25 Vdc, V_{EB} = 2 Vdc, T_A = 100°C)			—	20	
(V_{CE} = 40 Vdc, V_{EB} = 2 Vdc)	2N3735, 2N3737		—	0.20	
(V_{CE} = 40 Vdc, V_{EB} = 2 Vdc, T_A = 100°C)			—	20	
Base Cutoff Current		I_{BL}			μAdc
(V_{CE} = 25 Vdc, V_{EB} = 2 Vdc)	2N3734, 2N3736		—	0.3	
(V_{CE} = 40 Vdc, V_{EB} = 2 Vdc)	2N3735, 2N3737		—	0.3	
ON CHARACTERISTICS					
DC Current Gain*		h_{FE}*			—
(I_C = 10 mAdc, V_{CE} = 1 Vdc)			35	—	
(I_C = 150 mAdc, V_{CE} = 1 Vdc)			40	—	
(I_C = 500 mAdc, V_{CE} = 1 Vdc)			35	—	
(I_C = 1 Adc, V_{CE} = 1.5 Vdc)	2N3734, 2N3736		30	120	
	2N3735, 2N3737		20	80	
(I_C = 1.5 Adc, V_{CE} = 5 Vdc)	2N3734, 2N3736		30	—	
	2N3735, 2N3737		20	—	
Collector Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			—	0.2	
(I_C = 150 mAdc, I_B = 15 mAdc)			—	0.3	
(I_C = 500 mAdc, I_B = 50 mAdc)			—	0.5	
(I_C = 1 Adc, I_B = 100 mAdc)			—	0.9	
Base-Emitter Saturation Voltage*		$V_{BE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			—	0.8	
(I_C = 150 mAdc, I_B = 15 mAdc)			—	1.0	
(I_C = 500 mAdc, I_B = 50 mAdc)			—	1.2	
(I_C = 1 Adc, I_B = 100 mAdc)			0.9	1.4	
DYNAMIC CHARACTERISTICS					
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	9	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	80	pF
High-Frequency Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		h_{fe}	2.5	—	—
Delay Time	(V_{CC} = 30 V, $V_{BE(off)}$ = 2 V, I_C = 1 Amp, I_{B1} = 100 mA)	t_d	—	8	ns
Rise Time		t_r	—	40	ns
Storage Time	(V_{CC} = 30 V, I_C = 1 Amp, I_{B1} = $-I_{B2}$ = 100 mA)	t_s	—	30	ns
Fall Time		t_f	—	30	ns
Total Control Charge (I_C = 1 Amp, I_B = 100 mA, V_{CC} = 30 V)		Q_T	—	10	nC

*Pulse Test: PW ≦ 300 μs, Duty Cycle ≦ 2%

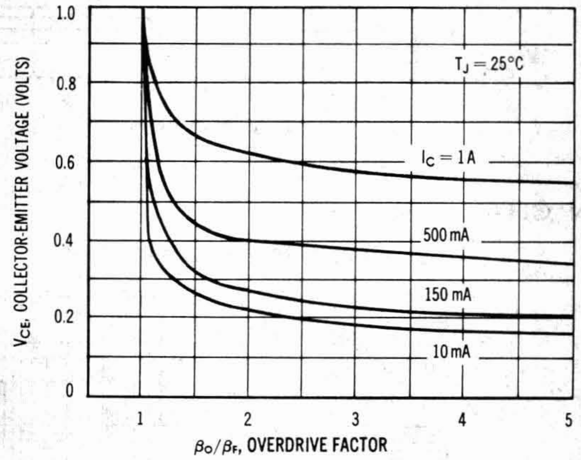
"ON" CONDITION CHARACTERISTICS

FIGURE 1

DC CURRENT GAIN



COLLECTOR SATURATION REGION

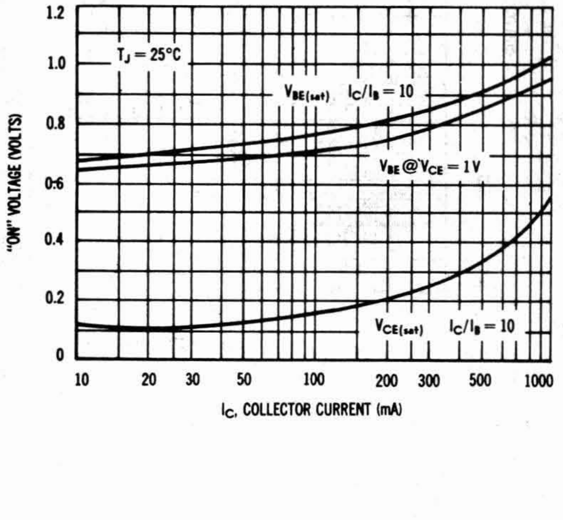


This graph shows the effect of base current on collector current. β_O (current gain at the edge of saturation) is the current gain of the transistor at 1 volt, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit. EXAMPLE: For type 2N3734, estimate a base current (I_{BF}) to insure saturation at a temperature of 25°C and a collector current of 500 mA.

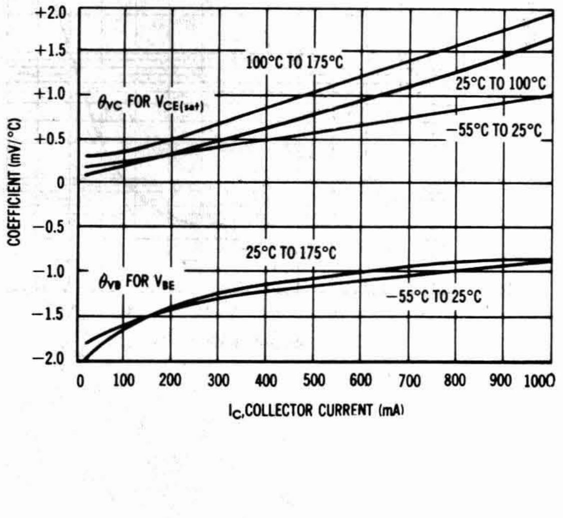
Observe that at $I_C = 500$ mA an overdrive factor of at least 2.0 is required to drive the transistor well into the saturation region. From Figure 1, it is seen that h_{FE} @ 1 volt is typically 54 (guaranteed limits from the Table of Characteristics can be used for "worst-case" design). $\therefore$

$$\frac{\beta_O}{\beta_F} = \frac{h_{FE} @ 1\text{ Volt}}{I_C/I_{BF}} \qquad 2 = \frac{54}{500\text{ mA}/I_{BF}} \qquad I_{BF} \approx 18.5\text{ mA typ}$$

"ON" VOLTAGES

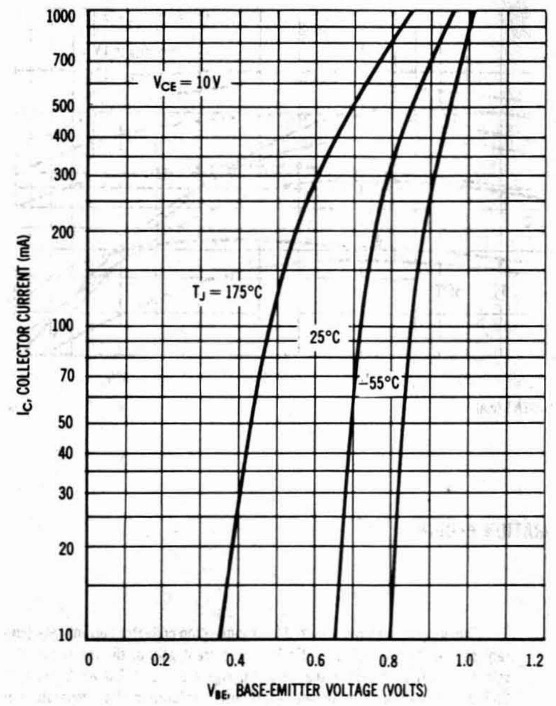


TEMPERATURE COEFFICIENTS

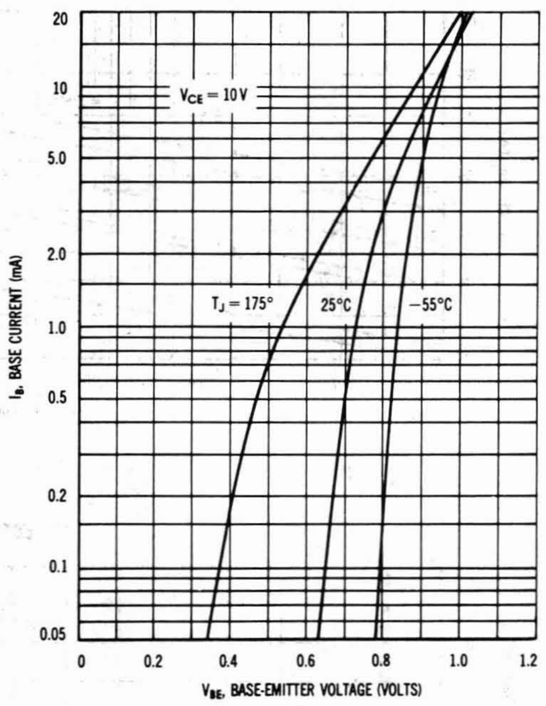


LARGE SIGNAL CHARACTERISTICS

TRANSCONDUCTANCE

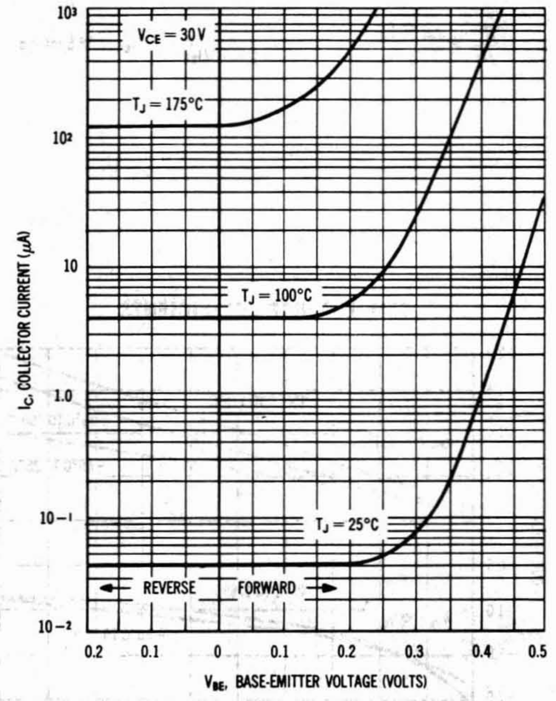


INPUT ADMITTANCE

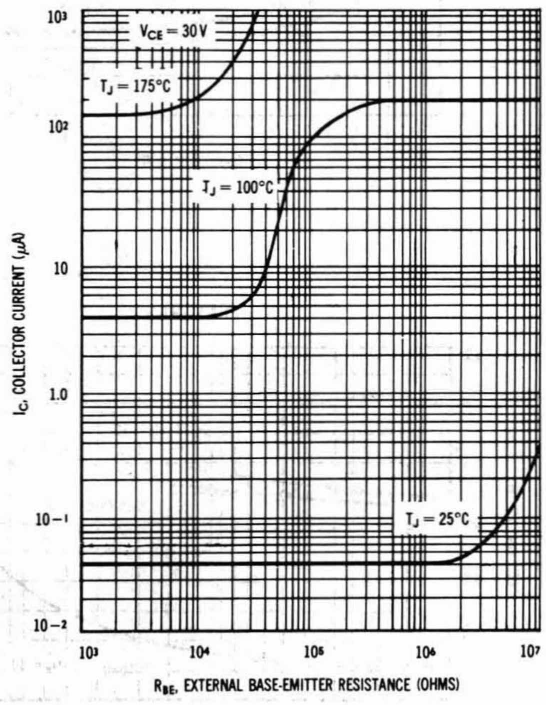


"OFF" CONDITION CHARACTERISTICS

TRANSCONDUCTANCE



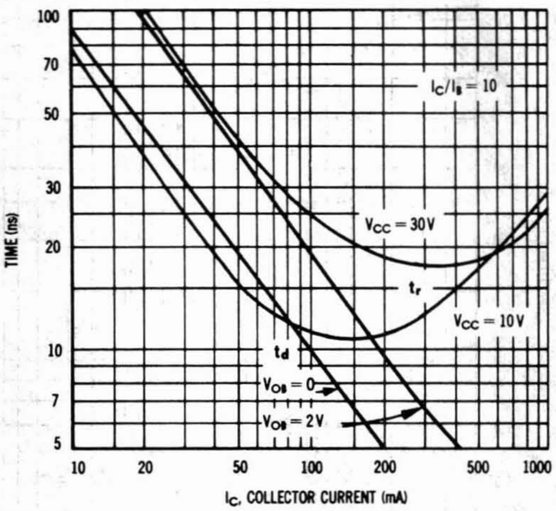
EFFECT OF BASE-EMITTER RESISTANCE



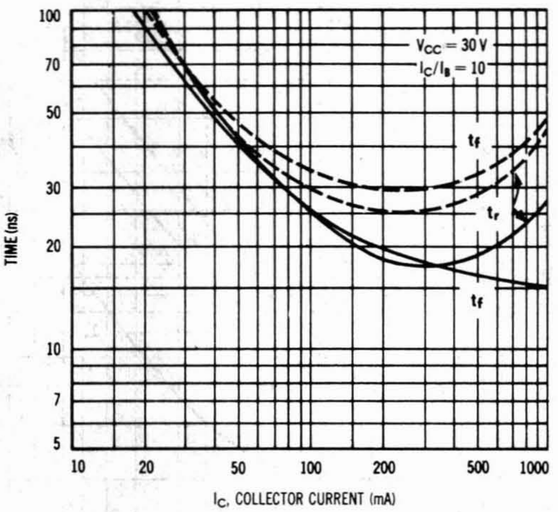
SWITCHING CHARACTERISTICS

— $T_J = 25°C$ -- $T_J = 150°C$

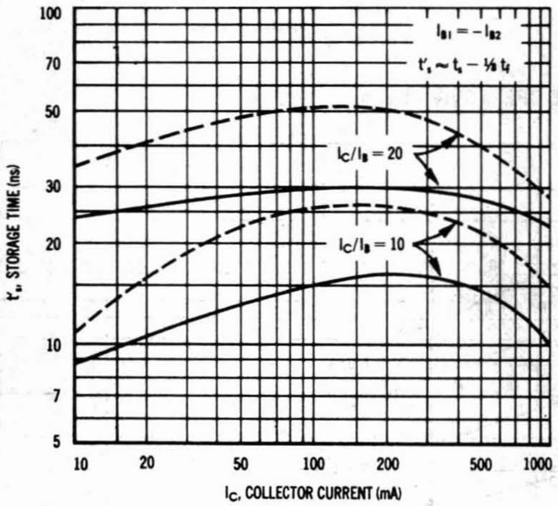
TURN-ON TIME



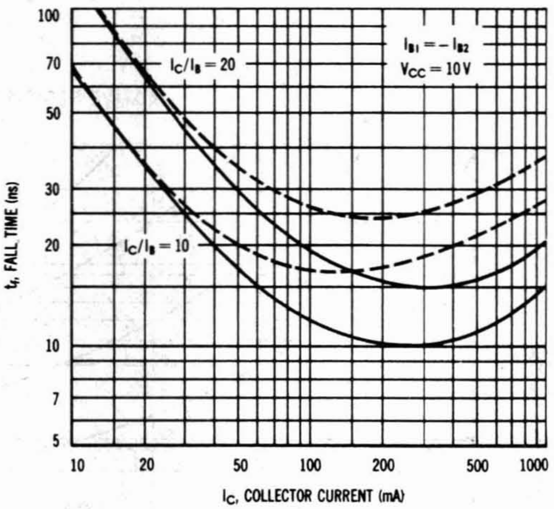
RISE AND FALL TIMES



STORAGE TIME

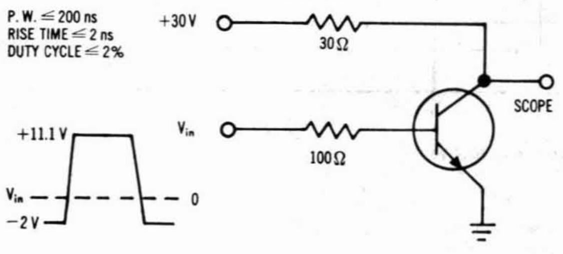


FALL TIME

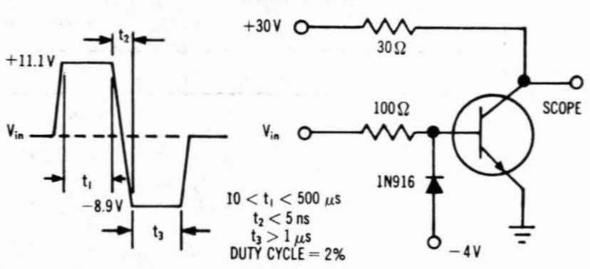


SWITCHING TIME EQUIVALENT TEST CIRCUITS

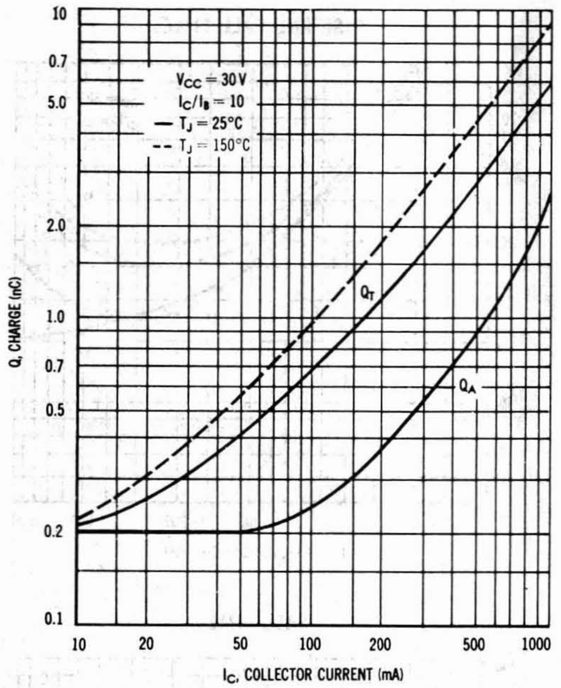
TURN-ON TIME


P. W. ≤ 200 ns
RISE TIME ≤ 2 ns
DUTY CYCLE ≤ 2%
+30 V
30 Ω
V_{in}
100 Ω
SCOPE
+11.1 V
V_{in}
0
−2 V

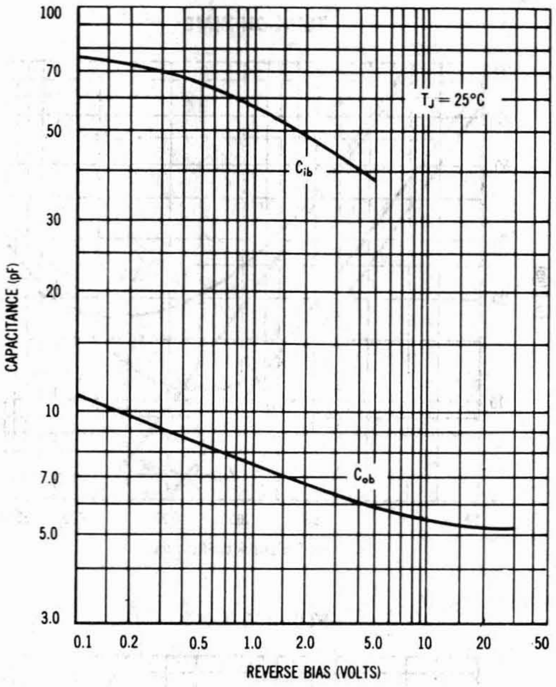
TURN-OFF TIME


t_2
+11.1 V
V_{in}
t_1
−8.9 V
t_3
$10 < t_1 < 500\ \mu s$
$t_2 < 5$ ns
$t_3 > 1\ \mu s$
DUTY CYCLE = 2%
+30 V
30 Ω
100 Ω
SCOPE
V_{in}
1N916
−4 V

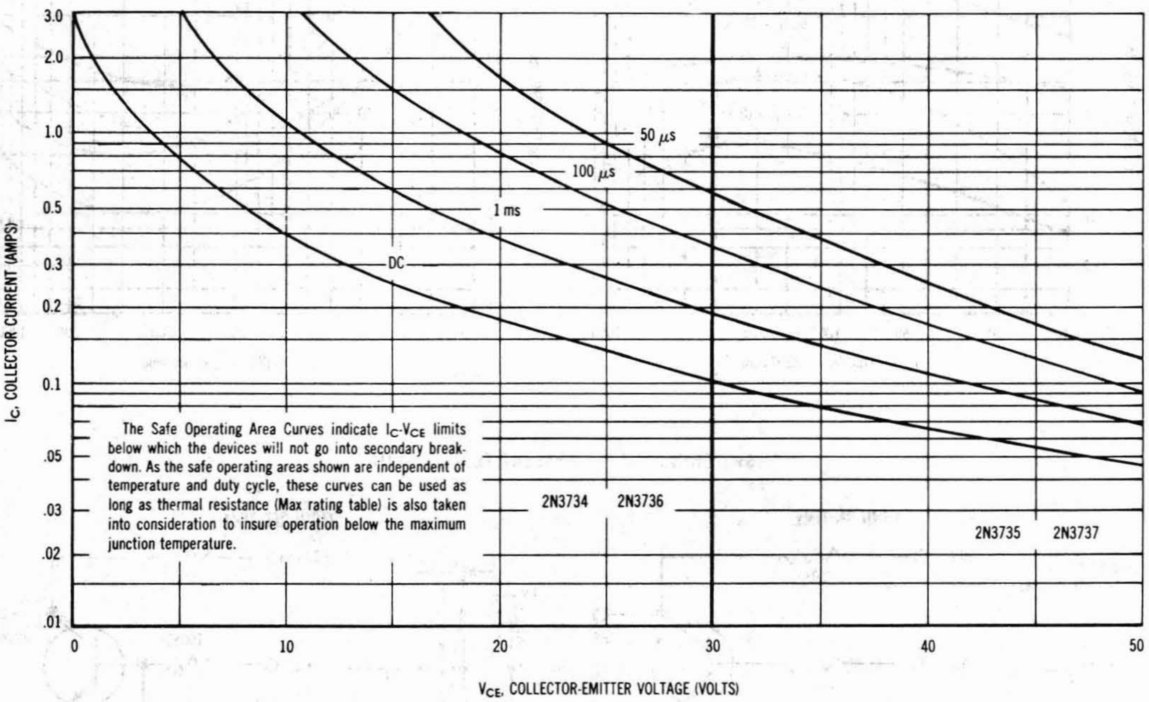
CHARGE DATA



CAPACITANCE

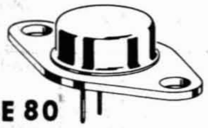


ACTIVE REGION SAFE OPERATING AREAS



The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the devices will not go into secondary breakdown. As the safe operating areas shown are independent of temperature and duty cycle, these curves can be used as long as thermal resistance (Max rating table) is also taken into consideration to insure operation below the maximum junction temperature.

2N3738 (SILICON)
2N3739



CASE 80
(TO-66)

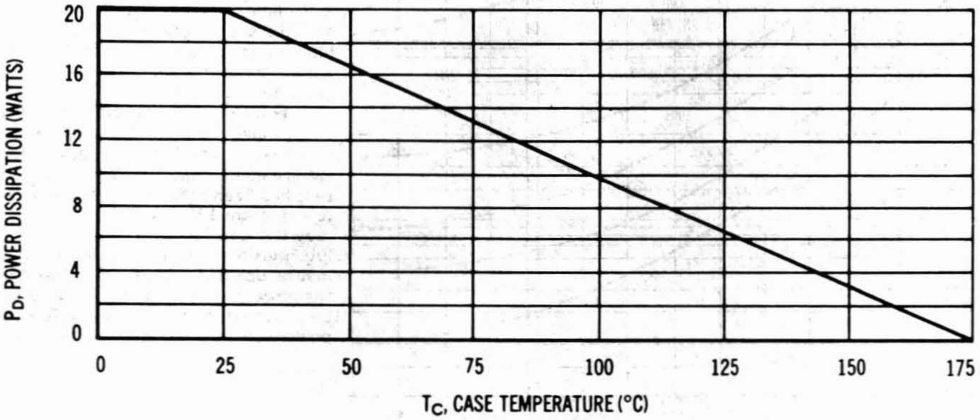
Collector connected to case

High-voltage NPN silicon power transistors, designed for use in line operated equipment such as audio output amplifiers; low-current, high-voltage converters; and AC line relays, featuring excellent dc gain.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	2N3738	2N3739	Unit
Collector-Base Voltage	V_{CB}	250	325	Vdc
Emitter-Base Voltage	V_{EB}	6	6	Vdc
Collector-Emitter Voltage	V_{CEO}	225	300	Vdc
Collector Current (Continuous)	I_C	3		Adc
Collector Current (Peak)	I_C	3		Amp
Base Current	I_B	1		Amp
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	20 0.133		Watts $W/^oC$
Thermal Resistance	θ_{JC}	7.5		$^oC/W$
Junction Operating and Storage Temperature Range	T_J, T_{stg}	-65 to +175		^oC

POWER-TEMPERATURE DERATING CURVE



2N3738, 2N3739 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Sustaining Voltage* (I_C = 5 mAdc, I_B = 0)	2N3738 2N3739	$V_{CEO(sus)}$*	225 300	— —	Vdc
Emitter-Base Cutoff Current (V_{EB} = 6 Vdc)		I_{EBO}	—	0.1	mAdc
Collector Cutoff Current (V_{CE} = 250 Vdc, V_{BE} = 1.5 Vdc) (V_{CE} = 300 Vdc, V_{BE} = 1.5 Vdc) (V_{CE} = 125 Vdc, V_{BE} = 1.5 Vdc, T_C = 100°C) (V_{CE} = 200 Vdc, V_{BE} = 1.5 Vdc, T_C = 100°C)	 2N3738 2N3739 2N3738 2N3739	I_{CEX}	 — — — —	 0.5 0.5 1.0 1.0	mAdc
Collector-Emitter Cutoff Current (V_{CE} = 125 Vdc, I_B = 0) (V_{CE} = 200 Vdc, I_B = 0)	 2N3738 2N3739	I_{CEO}	 — —	 0.25 0.25	mAdc
Collector-Base Cutoff Current (V_{CB} = 250 Vdc, I_E = 0) (V_{CB} = 325 Vdc, I_E = 0)	 2N3738 2N3739	I_{CBO}	 — —	 0.1 0.1	mAdc

ON CHARACTERISTICS

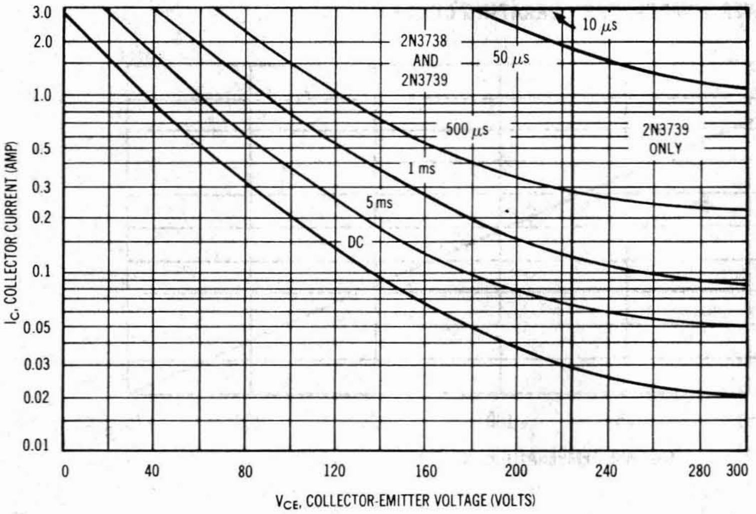
Characteristic	Symbol	Min	Max	Unit
DC Current Gain* (I_C = 50 mAdc, V_{CE} = 10 Vdc) (I_C = 100 mAdc, V_{CE} = 10 Vdc) (I_C = 250 mAdc, V_{CE} = 10 Vdc)	h_{FE}*	 30 40 25	 — 200 —	—
Collector-Emitter Saturation Voltage* (I_C = 250 mAdc, I_B = 25 mAdc)	$V_{CE(sat)}$*	—	2.5	Vdc
Base-Emitter Voltage* (I_C = 100 mAdc, V_{CE} = 10 Vdc)	V_{BE}*	—	1.0	Vdc

TRANSIENT CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Current-Gain — Bandwidth Product (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)	f_T	10	—	MHz
Common Base Output Capacitance (V_{CB} = 100 Vdc, I_C = 0, f = 100 kHz)	C_{ob}	—	20	pF
Small Signal Current Gain (I_C = 100 mAdc, V_{CE} = 20 Vdc, f = 1 kHz)	h_{fe}	35	—	—

*PULSE TEST: PW ≤ 300 μs, Duty Cycle ≤ 2%

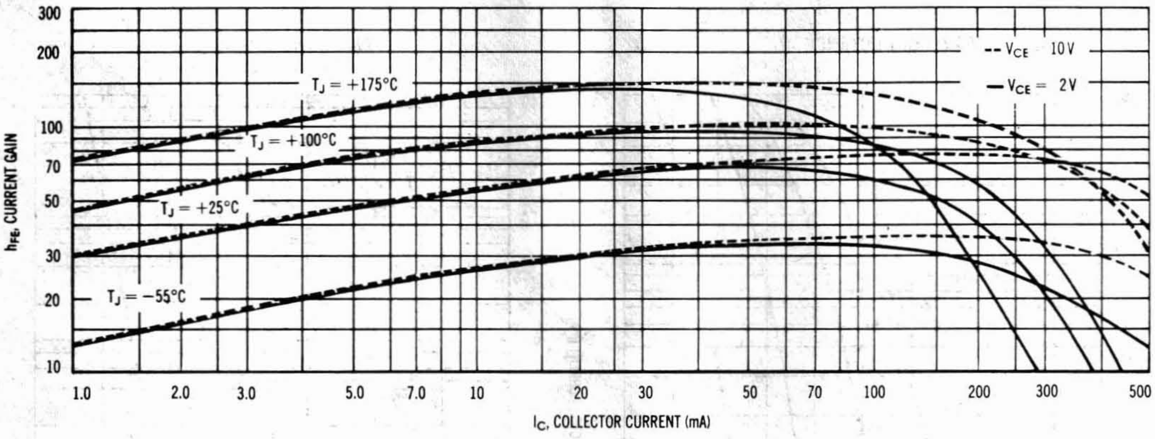
ACTIVE REGION SAFE AREAS



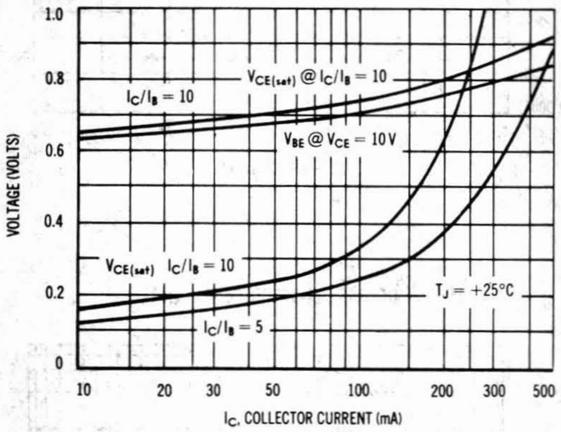
The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) The load line may exceed the BV_{CEO} voltage limit only if the collector current has been reduced to 20 mA or less before or at the BV_{CEO} limit; then and only then may the load line be extended to the absolute maximum voltage rating of BV_{CBO}. To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

2N3738, 2N3739 (continued)

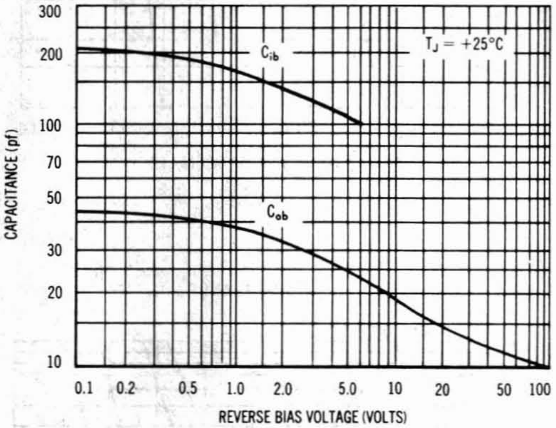
CURRENT GAIN



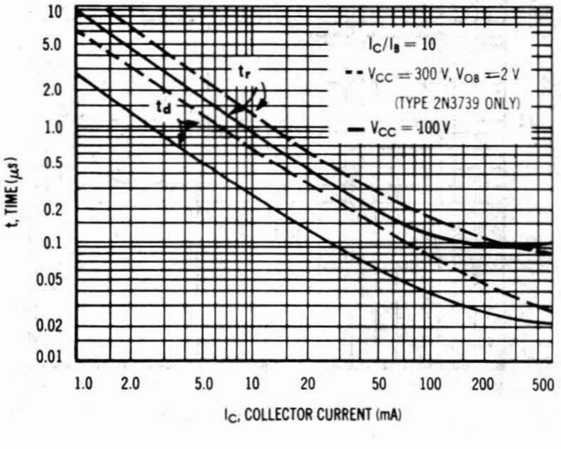
"ON" VOLTAGES



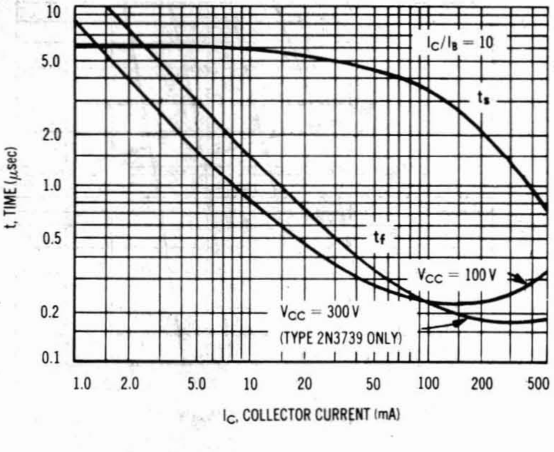
CAPACITANCE



TURN-ON TIME



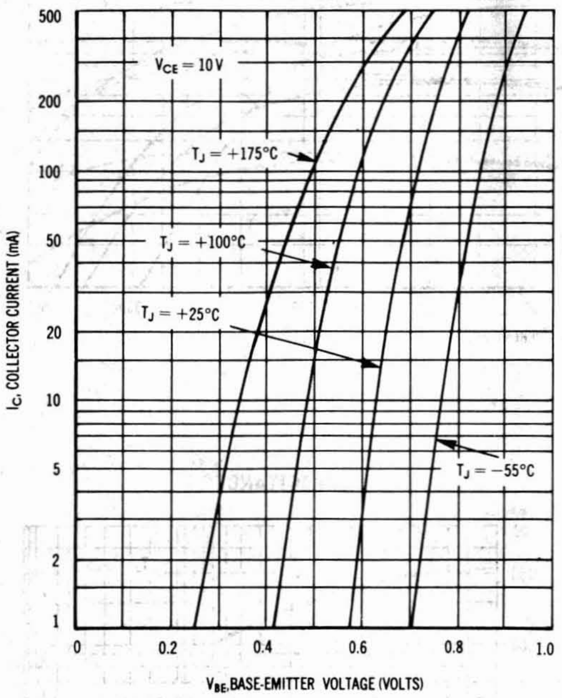
TURN-OFF TIME



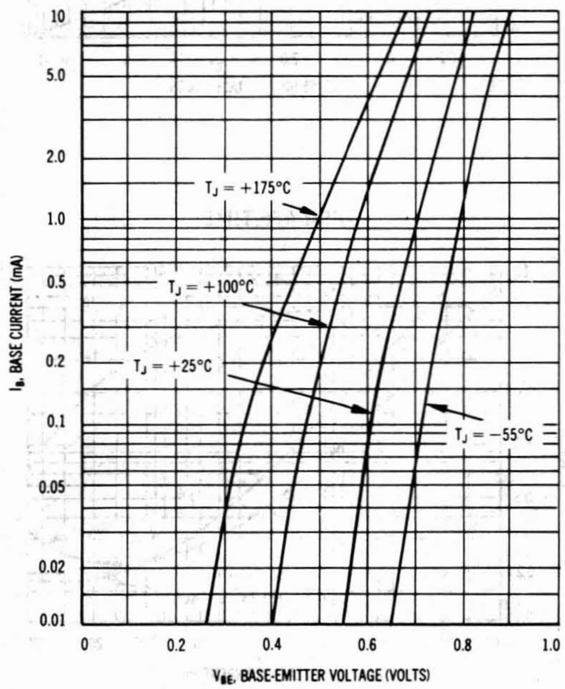
2N3738, 2N3739 (continued)

LARGE SIGNAL CHARACTERISTICS

TRANSCONDUCTANCE

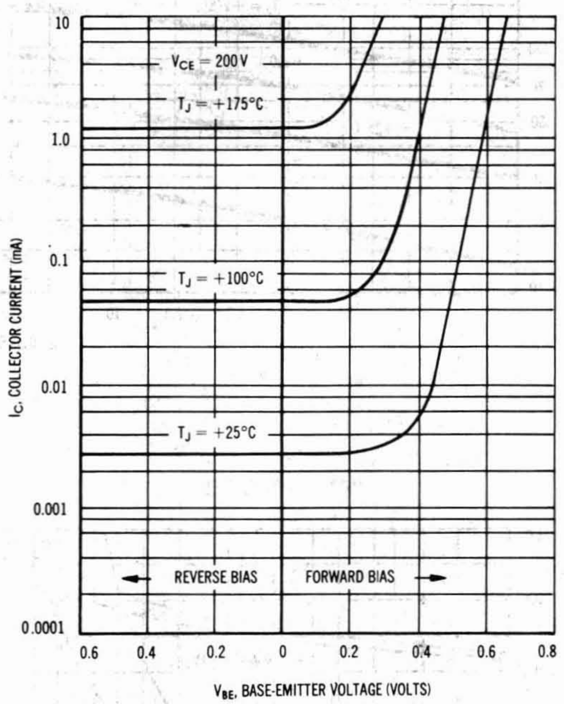


INPUT ADMITTANCE

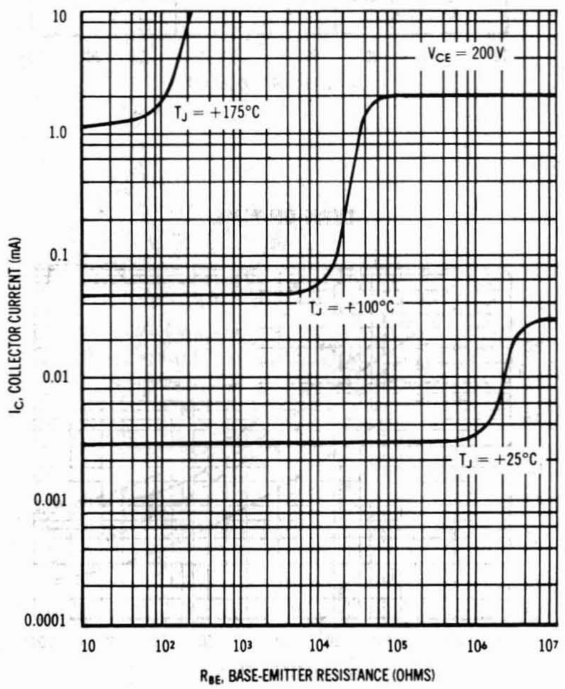


CUT-OFF CHARACTERISTICS

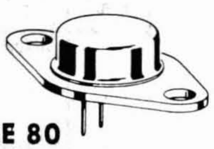
TRANSCONDUCTANCE



EFFECT OF BASE-EMITTER RESISTANCE



2N3740 (SILICON)
2N3741



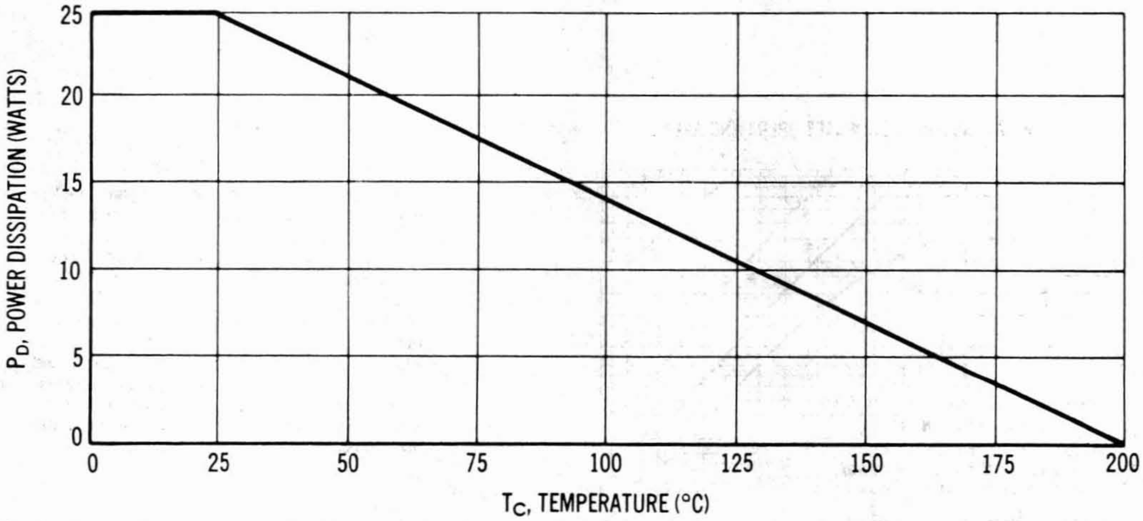
CASE 80
(TO-66)
Collector connected to case

Medium-power PNP transistors, ideal for use as drivers, switches and direct replacement of germanium medium-power devices, feature low saturation voltage and excellent safe area limits. Complement to NPN 2N3766 (2N3740) 2N3767 (2N3741)

MAXIMUM RATINGS

Rating	Symbol	2N3740	2N3741	Unit
Collector-Base Voltage	V_{CB}	60	80	Vdc
Emitter-Base Voltage	V_{EB}	7.0	7.0	Vdc
Collector-Emitter Voltage	V_{CEO}	60	80	Vdc
Collector Current (Continuous) See Figure 2	I_C	4.0		Adc
Collector Current (Peak) See Figure 2	I_C	10		Adc
Base Current	I_B	2.0		Adc
Total Device Dissipation @ T_C = 25 °C Derate Above 25 °C	P_D	25 0.143		Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

FIGURE 1 — POWER - TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 2.
Both limits are applicable and must be observed.

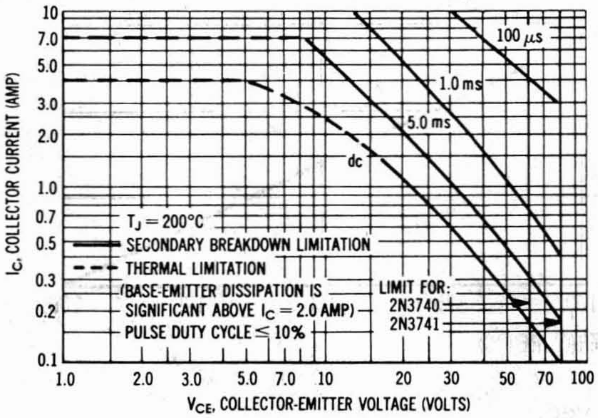
2N3740, 2N3741 (continued)

ELECTRICAL CHARACTERISTICS (At T_A = 25°C unless otherwise noted)

Characteristics	Figure No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, I_B = 0) 2N3740 2N3741	2	$V_{CEO(sus)}$*	60 80	— —	Vdc
Emitter Base Cutoff Current (V_{EB} = 7.0 Vdc)		I_{EBO}	—	0.5	mAdc
Collector Cutoff Current (V_{CE} = 60 Vdc, V_{BE} = 1.5 Vdc) 2N3740 (V_{CE} = 80 Vdc, V_{BE} = 1.5 Vdc) 2N3741 (V_{CE} = 40 Vdc, V_{BE} = 1.5 Vdc, T_C = 150 °C) 2N3740 (V_{CE} = 60 Vdc, V_{BE} = 1.5 Vdc, T_C = 150 °C) 2N3741	5, 6	I_{CEX}	— — — —	0.1 0.1 1.0 1.0	mAdc
Collector-Emitter Cutoff Current (V_{CE} = 40 Vdc, I_B = 0) 2N3740 (V_{CE} = 60 Vdc, I_B = 0) 2N3741	5, 6	I_{CEO}	— —	1.0 1.0	mAdc
Collector Base Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) 2N3740 (V_{CB} = 80 Vdc, I_E = 0) 2N3741	—	I_{CBO}	— —	0.1 0.1	mAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 100 mAdc, V_{CE} = 1.0 Vdc) (I_C = 250 mAdc, V_{CE} = 1.0 Vdc) (I_C = 500 mAdc, V_{CE} = 1.0 Vdc) (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	7	h_{FE}	40 30 20 10	— 100 — —	—
Collector-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 125 mAdc)	8, 9, 10	$V_{CE(sat)}$	—	0.6	Vdc
Base-Emitter Voltage (I_C = 250 mAdc, V_{CE} = 1.0 Vdc)	3, 4, 9, 10	V_{BE}	—	1.0	Vdc
TRANSIENT CHARACTERISTICS					
Current-Gain-Bandwidth Product (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)	—	f_T	4.0	—	MHz
Common Base Output Capacitance (V_{CB} = 10 Vdc, I_C = 0, f = 100 kHz)	13	C_{ob}	—	100	pF
Small-Signal Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	—	h_{fe}	25	—	—

*PULSE TEST: PW ≤ 300 µs, Duty Cycle ≤ 2.0%

FIGURE 2 — ACTIVE REGION SAFE OPERATING AREA



The safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor which must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

The data of Figure 2 is based upon $T_{J(pk)}$ = 200°C; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} \leq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 7. At high case temperatures, thermal limitations will reduce the power which can be handled to values less than the limitations imposed by secondary breakdown.

LARGE SIGNAL CHARACTERISTICS

FIGURE 3 — TRANSCONDUCTANCE

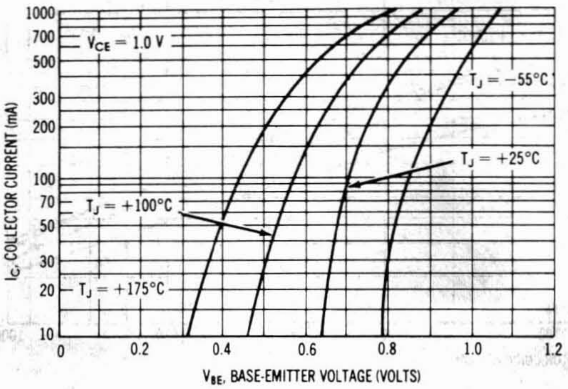
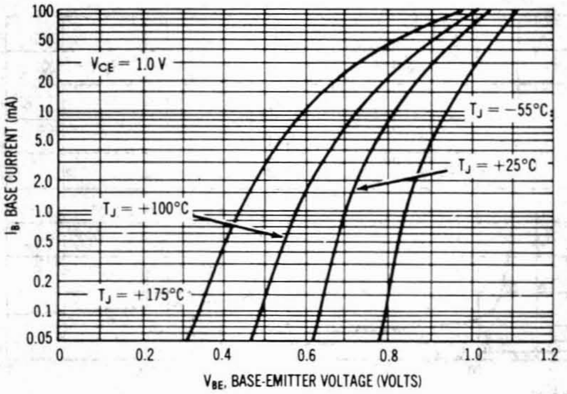


FIGURE 4 — INPUT ADMITTANCE



"OFF" REGION CHARACTERISTICS

FIGURE 5 — TRANSCONDUCTANCE

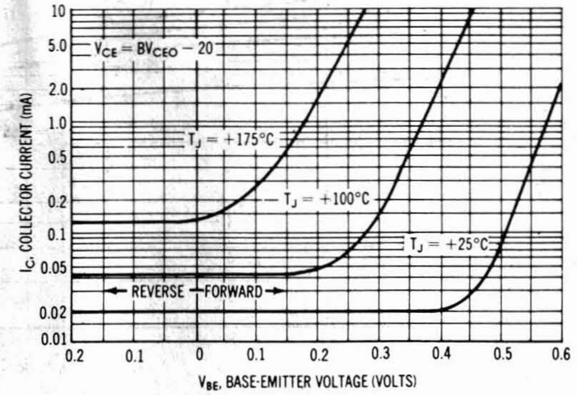


FIGURE 6 — EFFECTS OF BASE-EMITTER RESISTANCE

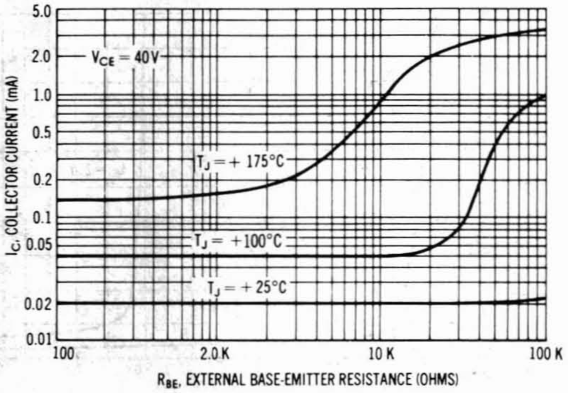


FIGURE 7 — THERMAL RESPONSE

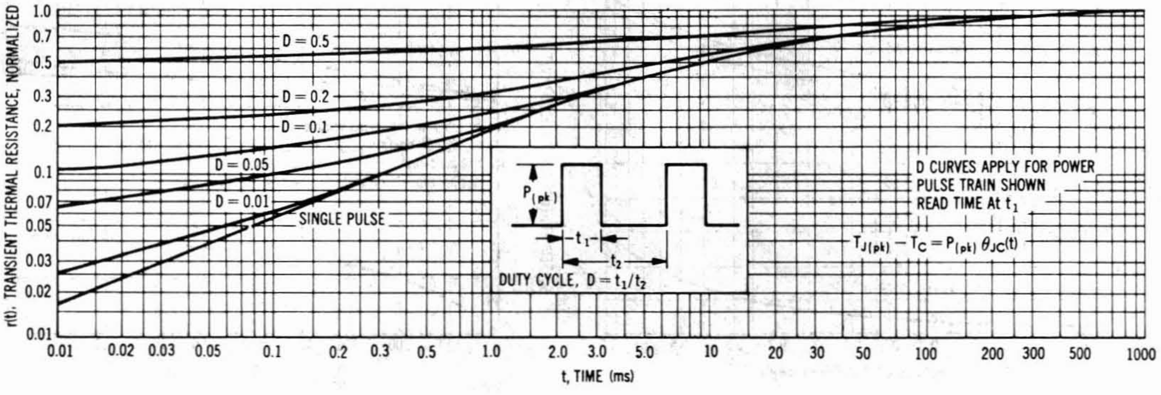
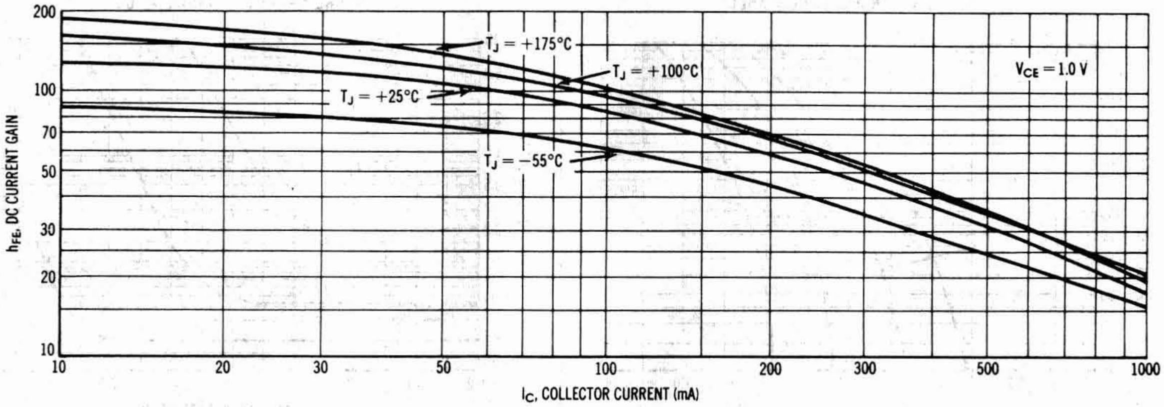


FIGURE 8 — CURRENT GAIN



SATURATION REGION CHARACTERISTICS

FIGURE 9 — COLLECTOR SATURATION REGION

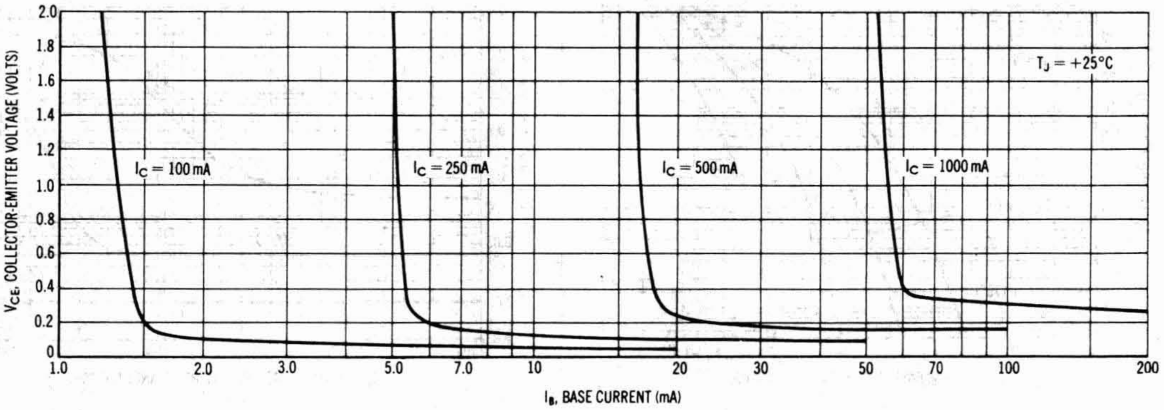


FIGURE 10 — "ON" VOLTAGES

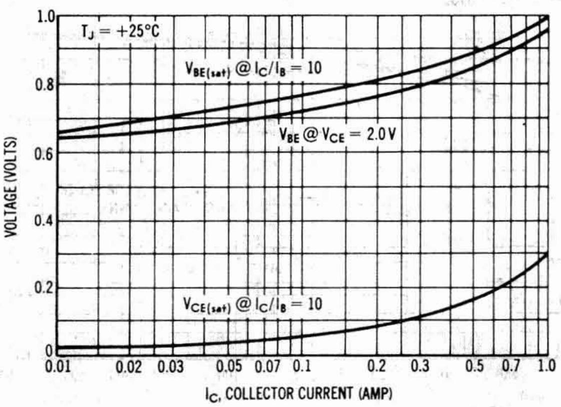
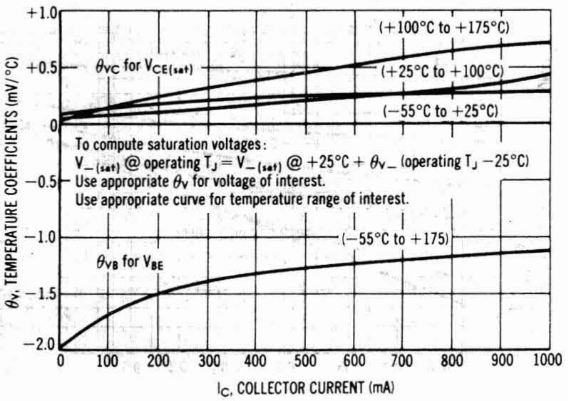


FIGURE 11 — TEMPERATURE COEFFICIENTS



To compute saturation voltages:
$V_{-(sat)}$ @ operating $T_J = V_{-(sat)}$ @ +25°C + θ_{V-} (operating T_J −25°C)
Use appropriate θ_V for voltage of interest.
Use appropriate curve for temperature range of interest.

DYNAMIC CHARACTERISTICS

FIGURE 12 — TURN-ON TIME

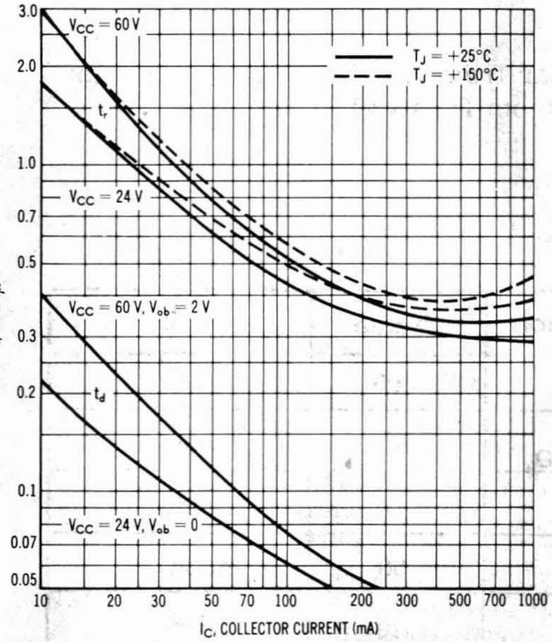


FIGURE 14 — CAPACITANCE

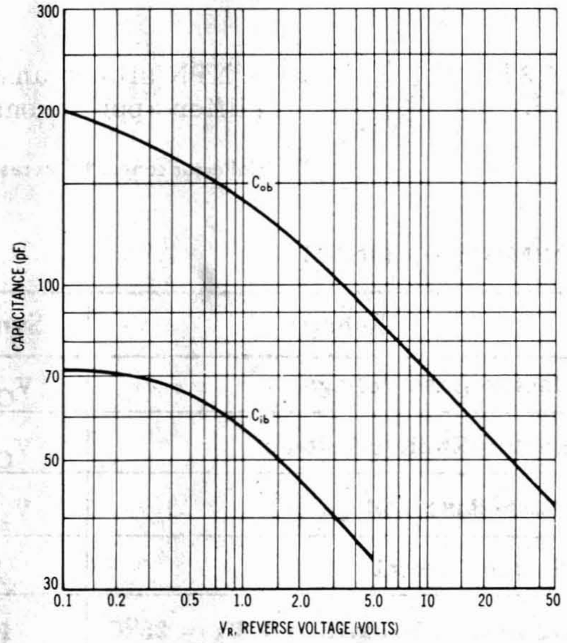


FIGURE 13 — STORAGE TIME

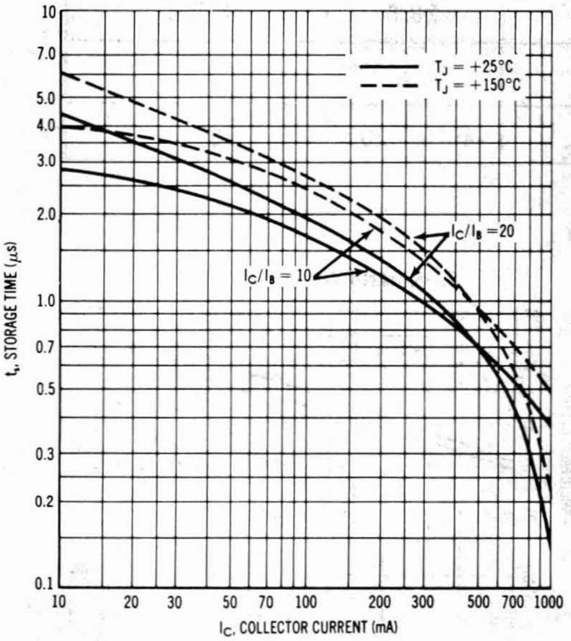
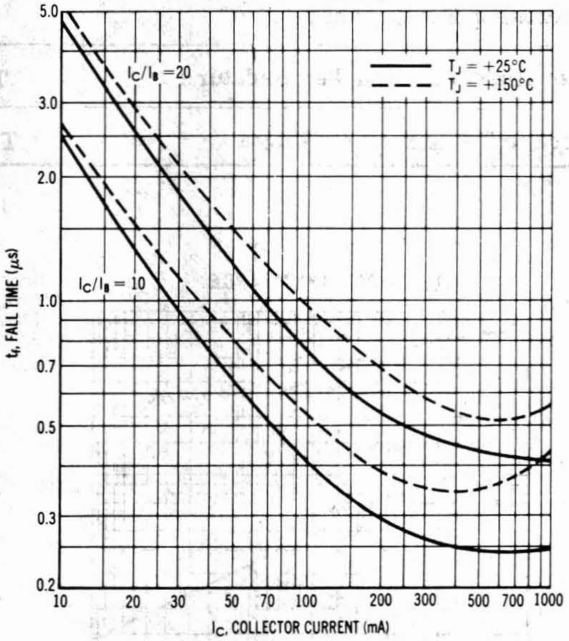


FIGURE 15 — FALL TIME



2N3742 (SILICON)

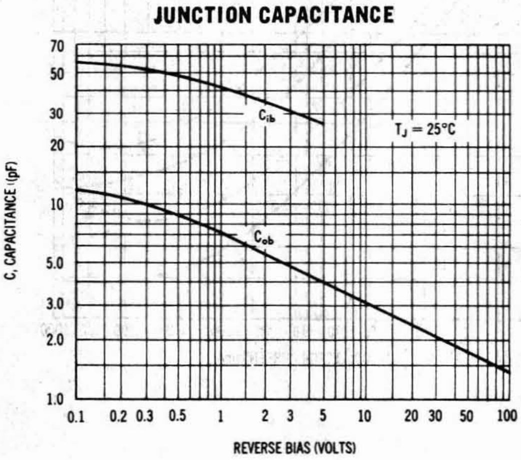
CASE 31
(TO-5)

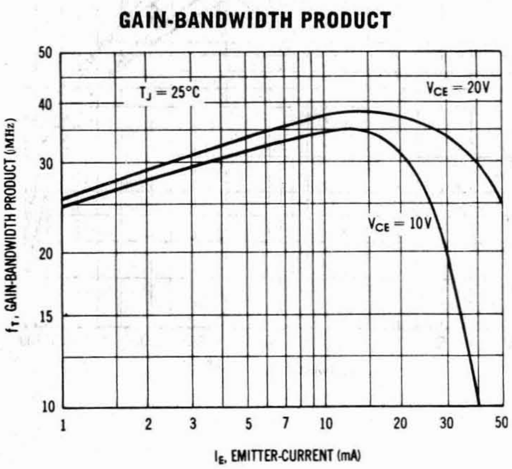
NPN silicon annular transistor for high-voltage amplifier applications from DC to VHF.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	**300**	**Vdc**
Collector-Emitter Voltage	V_{CEO}	**300**	**Vdc**
Emitter-Base Voltage	V_{EB}	**7**	**Vdc**
Collector Current	I_C	**50**	**mAdc**
Total Device Dissipation @ T_A = 25°C **Derating Factor Above 25°C**	P_D	**1.0** **5.71**	**Watt** **mW/°C**
Total Device Dissipation @ T_C = 25°C **Derating Factor Above 25°C**	P_D	**5** **28.6**	**Watts** **mW/°C**
Operating Junction Temperature	T_J	**+200**	**°C**
Storage Temperature Range	T_{stg}	**-65 to + 200**	**°C**


JUNCTION CAPACITANCE


GAIN-BANDWIDTH PRODUCT

2N3742 (continued)

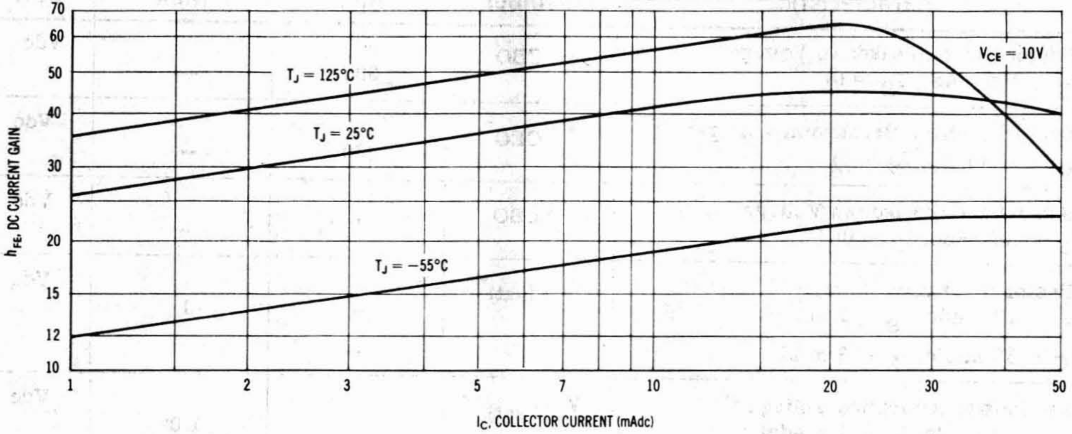
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 µAdc, I_E = 0)	BV_{CBO}	300	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	300	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100µAdc, I_C = 0)	BV_{EBO}	7	—	Vdc
Collector Saturation Voltage ** (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 30 mAdc, I_B = 3 mAdc)	$V_{CE(sat)}$**	— —	1 5	Vdc
Base-Emitter Saturation Voltage ** (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 30 mAdc, I_B = 3 mAdc)	$V_{BE(sat)}$**	— —	1.0 1.2	Vdc
DC Current Gain ** (I_C = 3 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 30 mAdc, V_{CE} = 10 Vdc) (I_C = 50 mAdc, V_{CE} = 20 Vdc)	h_{FE}**	10 15 20 20	— — 200 —	—
Collector Cutoff Current (V_{CB} = 200 Vdc, I_E = 0) (V_{CB} = 200 Vdc, I_E = 0, T_A = 100°C)	I_{CBO}	— —	0.2 20	µAdc
Emitter Cutoff Current V_{EB} = 6 Vdc, I_C = 0)	I_{EBO}	—	0.2	µAdc
Small Signal Current Gain (V_{CE} = 20 Vdc, I_C = 10 mAdc, f = 20 MHz)	$\|h_{fe}\|$	1.5	—	—
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	6	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	80	pF
Small Signal Current Gain (I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	h_{fe}	20	200	—
Voltage Feedback Ratio (I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	h_{re}	—	1.0	$X10^{-4}$
Input Impedance (I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	h_{ie}	—	0.5	Kohms
Output Admittance (I_C = 10 mA, V_{CE} = 10 V, f = 1 kHz)	h_{oe}	5	50	µmhos
Real Part of Input Impedance (I_C = 10 mA, V_{CE} = 10 V, f = 5 MHz)	$Re(h_{ie})$	—	40	ohms

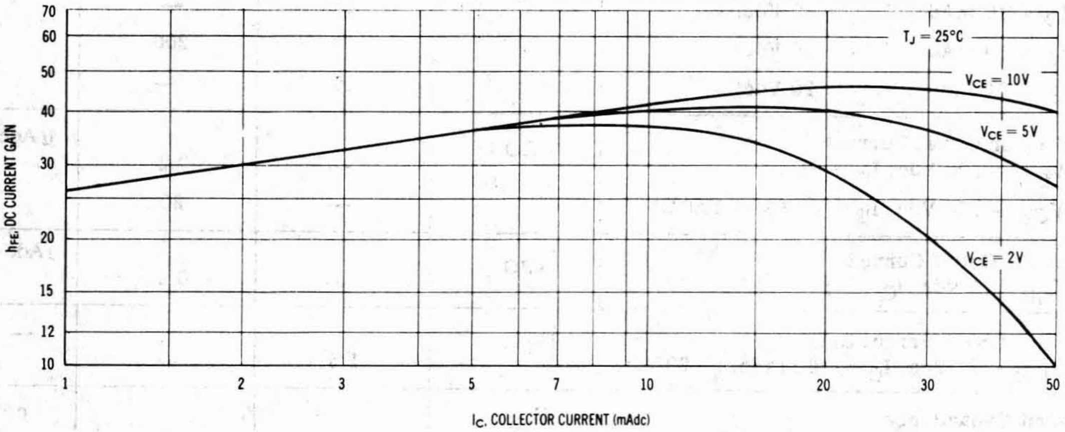
*PW $\leq$ 30 µs, Duty Cycle $\leq$ 1%

**PW $\leq$ 300 µs, Duty Cycle $\leq$ 2%

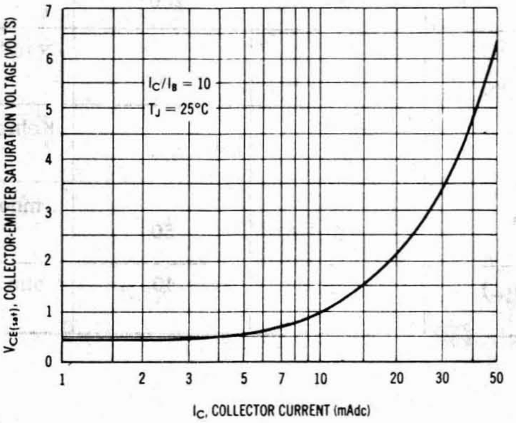
CURRENT GAIN CHARACTERISTICS versus JUNCTION TEMPERATURE



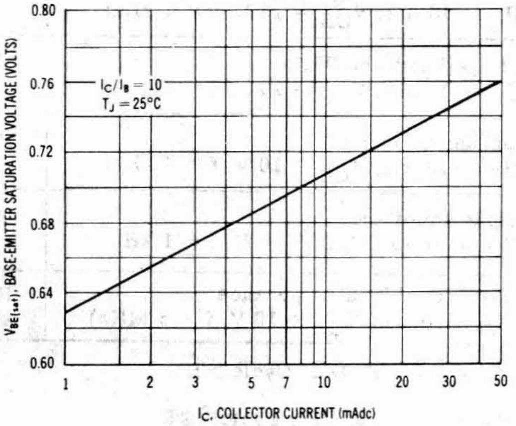
CURRENT GAIN CHARACTERISTICS versus COLLECTOR-EMITTER VOLTAGE



COLLECTOR-EMITTER SATURATION VOLTAGE

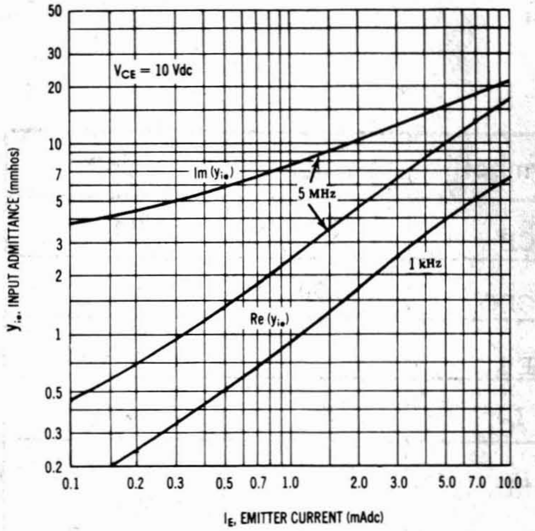


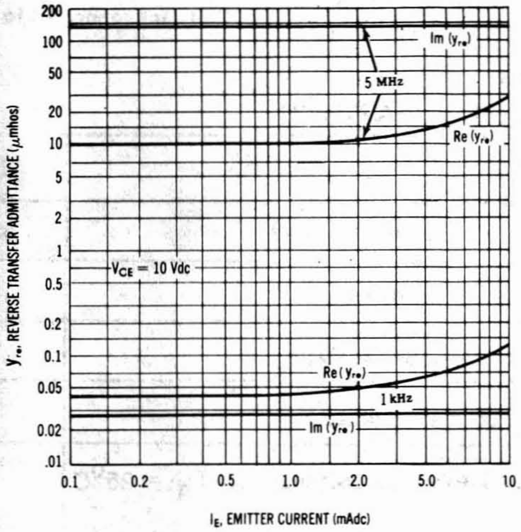
BASE -EMITTER SATURATION VOLTAGE

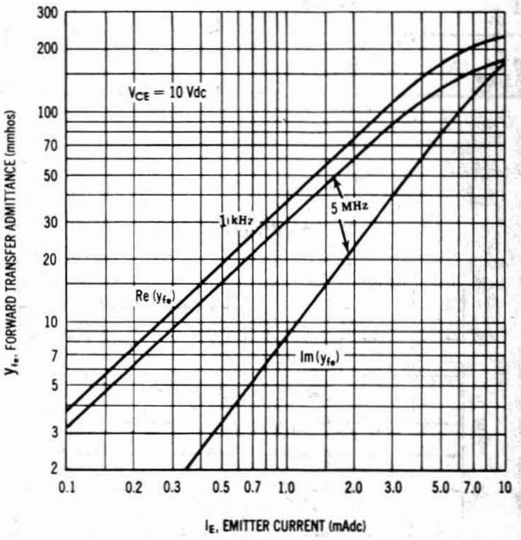


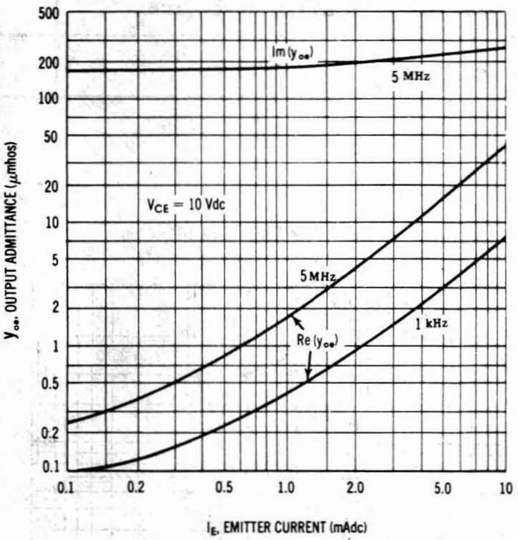
SMALL SIGNAL y PARAMETERS

$T_A = 25°C$


INPUT ADMITTANCE


REVERSE TRANSFER ADMITTANCE


FORWARD TRANSFER ADMITTANCE


OUTPUT ADMITTANCE

2N3743 (SILICON)

PNP silicon annular transistor for high-voltage amplifier applications from dc to VHF.

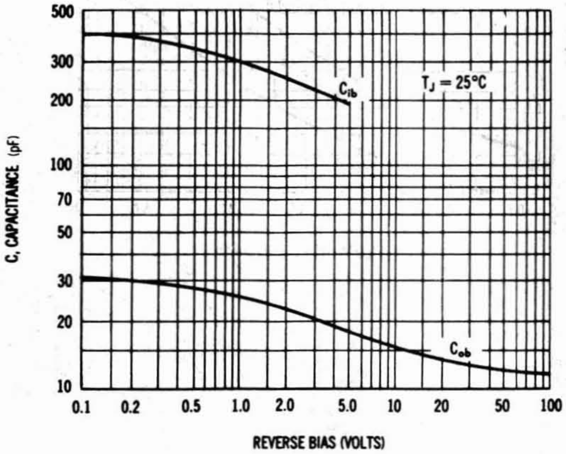
Collector connected to case

CASE 31
(TO-5)

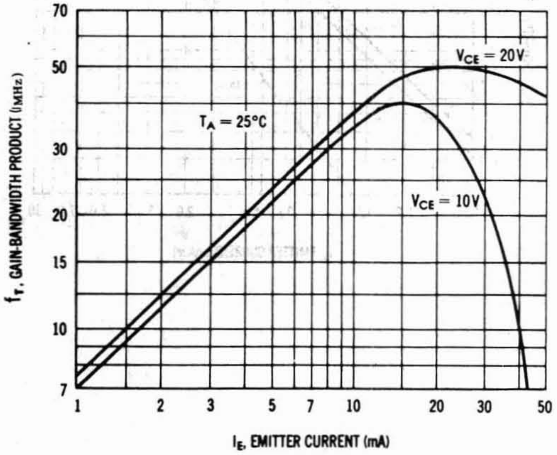
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	300	Vdc
Collector-Emitter Voltage	V_{CEO}	300	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ $T_A = 25^{o}C$ Derate Above 25°C	P_D	1.0 5.7	Watt mW/°C
Total Device Dissipation@ $T_C = 25^{o}C$ Derate Above 25°C	P_D	5.0 28.6	Watts mW/°C
Operating Junction Temperature	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

JUNCTION CAPACITANCE



GAIN-BANDWIDTH PRODUCT



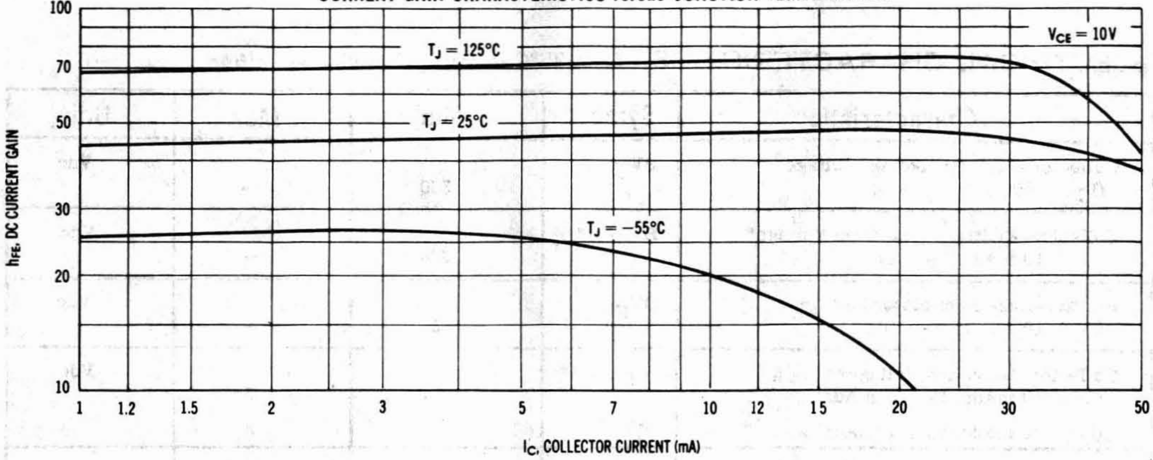
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise specified)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	300	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	300	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5	—	Vdc
Collector Saturation Voltage** (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 30 mAdc, I_B = 3 mAdc)	$V_{CE(sat)}$**	— —	5 8	Vdc
Base-Emitter Saturation Voltage** (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 30 mAdc, I_B = 3 mAdc)	$V_{BE(sat)}$**	— —	1.0 1.2	Vdc
DC Forward Current Gain** (I_C = 100 μAdc, V_{CE} = 10 Vdc) (I_C = 1 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 30 mAdc, V_{CE} = 10 Vdc) (I_C = 50 mAdc, V_{CE} = 20 Vdc)	h_{FE}**	20 25 25 25 25	— — — 250 —	—
Collector Cutoff Current (V_{CB} = 200 Vdc, I_E = 0) (V_{CB} = 200 Vdc, I_E = 0, T_A = 100°C)	I_{CBO}	— —	0.3 30	μAdc
Emitter-Base Leakage Current (V_{EB} = 3 Vdc, I_C = 0)	I_{EBO}	—	0.1	μAdc
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 20MHz)	$\lvert h_{fe} \rvert$	1.5	—	—
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	15	pF
Input Capacitance (V_{EB} = 1 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	400	pF
Small Signal Current Gain (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)	h_{fe}	30	300	—
Voltage Feedback Ratio (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)	h_{re}	—	4.0	$X10^{-4}$
Input Impedance (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)	h_{ie}	—	1.0	kohms
Output Admittance (V_{CE} = 10 V, I_C = 10 mA, f = 1 kHz)	h_{oe}	—	200	μmhos
Real Part of Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 5 MHz)	$Re(h_{ie})$	—	40	ohms

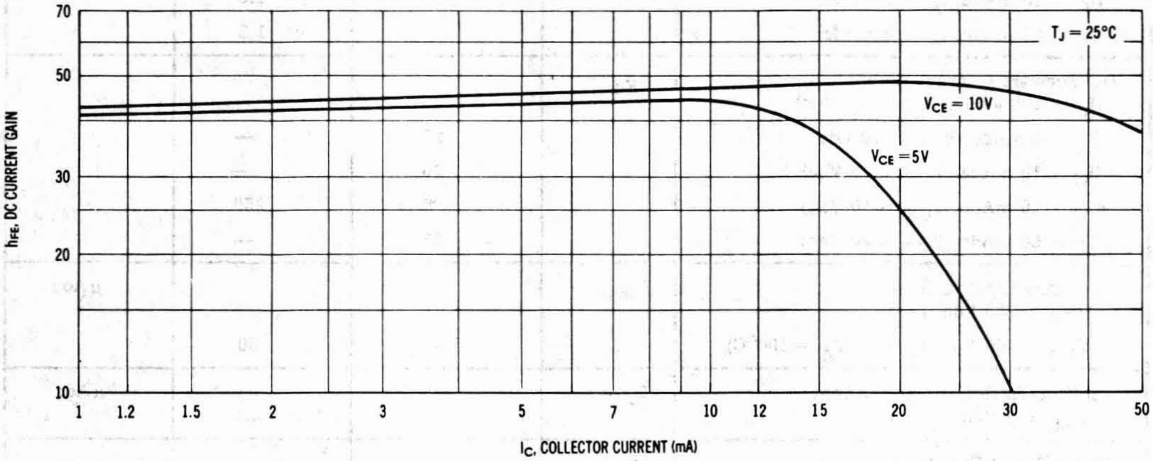
*PW $\leq$ 30 μs, Duty Cycle $\leq$ 1%

**PW $\leq$ 300 μs, Duty Cycle $\leq$ 2%

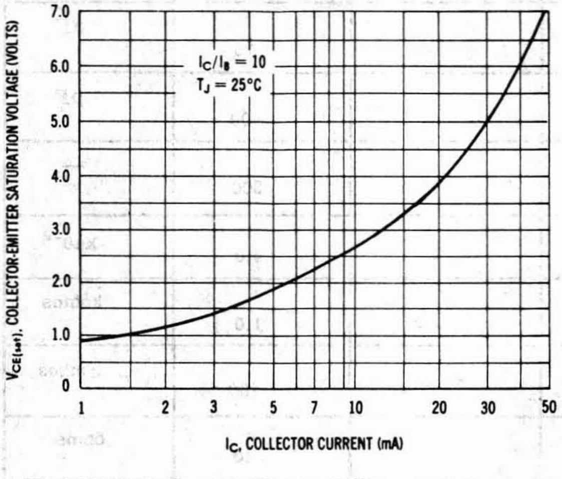
CURRENT GAIN CHARACTERISTICS versus JUNCTION TEMPERATURE



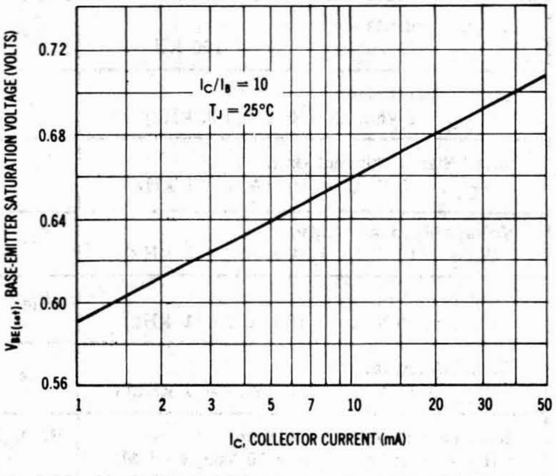
CURRENT GAIN CHARACTERISTICS versus COLLECTOR-EMITTER VOLTAGE



COLLECTOR-EMITTER SATURATION VOLTAGE



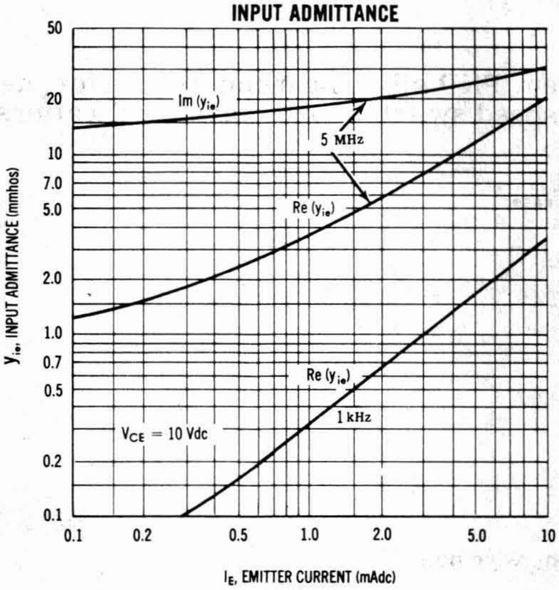
BASE-EMITTER SATURATION VOLTAGE



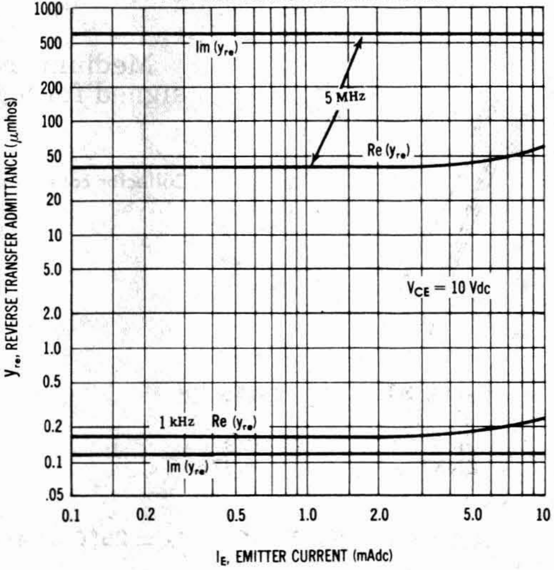
SMALL SIGNAL y PARAMETERS

$T_A = 25°C$

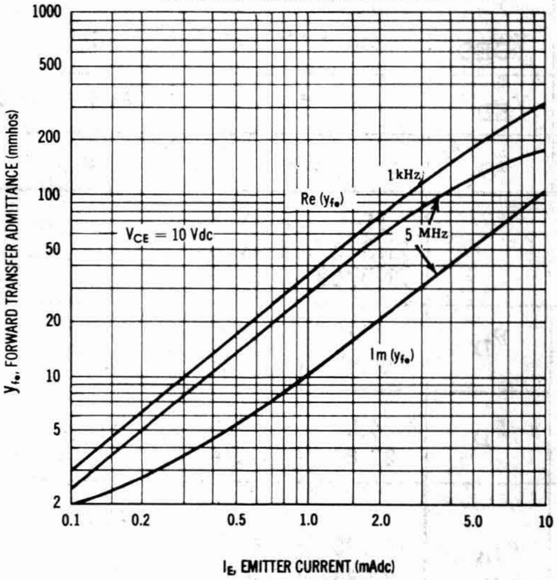
INPUT ADMITTANCE



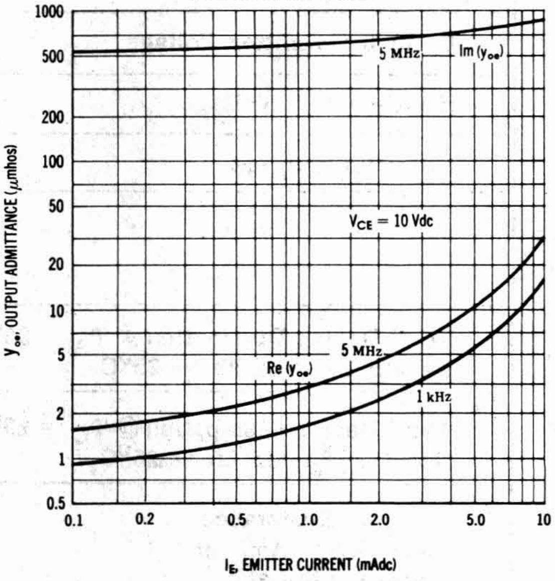
REVERSE TRANSFER ADMITTANCE



FORWARD TRANSFER ADMITTANCE



OUTPUT ADMITTANCE



2N3762 (SILICON)
2N3763
2N3764
2N3765

Medium-current PNP silicon annular transistor, designed for high-speed switching and driver applications.

Collector connected to case

CASE 31
(TO-5)
2N3762
2N3763

CASE 26
(TO-46)
2N3764
2N3765

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	2N3762 2N3764	2N3763 2N3765	Unit
Collector-Base Voltage	V_{CB}	40	60	Vdc
Collector-Emitter Voltage	V_{CEO}	40	60	Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	1.5		Adc
		TO-5 2N3762 2N3763	TO-46 2N3764 2N3765	
Total Device Dissipation @ T_A = 25°C Derating Factor Above 25°C	P_D	1.0 5.71	0.5 2.86	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derating Factor Above 25°C	P_D	4.0 22.8	2.0 11.4	Watts mW/°C
Thermal Resistance Junction to Ambient Junction to Case	θ_{JA} θ_{JC}	0.175 0.044	0.35 0.088	°C/mW
Junction Temperature, Operating	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

2N3762, 2N3763, 2N3764, 2N3765 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

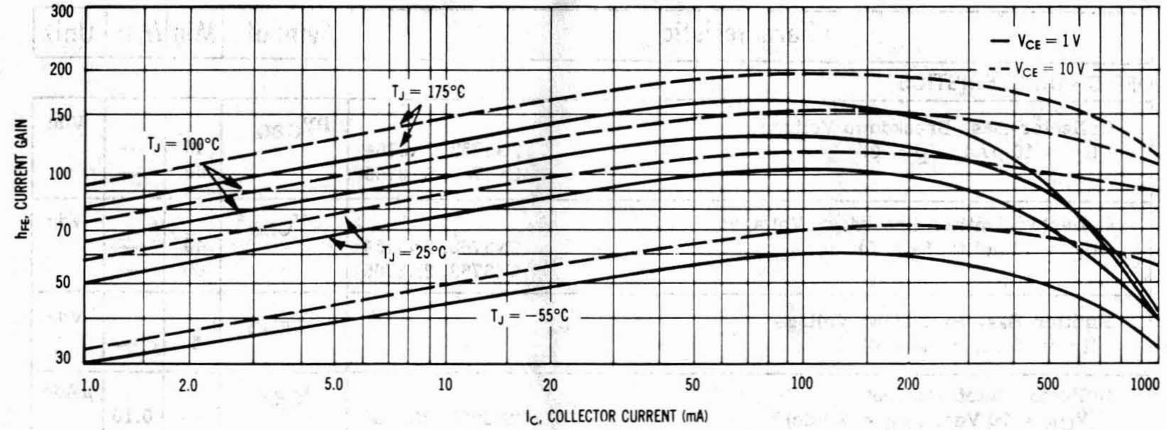
Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N3762, 2N3764 2N3763, 2N3765	BV_{CBO}	40 60	— —	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	2N3762, 2N3764 2N3763, 2N3765	BV_{CEO}*	40 60	— —	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, V_{EB} = 2 Vdc) (V_{CE} = 20 Vdc, V_{EB} = 2 Vdc, T_A = 100°C) (V_{CE} = 30 Vdc, V_{EB} = 2 Vdc) (V_{CE} = 30 Vdc, V_{EB} = 2 Vdc, T_A = 100°C)	2N3762, 2N3764 2N3763, 2N3765	I_{CEX}	— — — —	0.10 10 0.10 10	μAdc
Base Cutoff Current (V_{CE} = 20 Vdc, V_{EB} = 2 Vdc) (V_{CE} = 30 Vdc, V_{EB} = 2 Vdc)	2N3762, 2N3764 2N3763, 2N3765	I_{BL}	— —	0.2 0.2	μAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1 Vdc) (I_C = 150 mAdc, V_{CE} = 1 Vdc) (I_C = 500 mAdc, V_{CE} = 1 Vdc) (I_C = 1 Adc, V_{CE} = 1.5 Vdc) (I_C = 1.5 Adc, V_{CE} = 5 Vdc)	 2N3762, 2N3764 2N3763, 2N3765 2N3762, 2N3764 2N3763, 2N3765	h_{FE}*	35 40 35 30 20 30 20	— — — 120 80 — —	—
Collector Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1 Adc, I_B = 100 mAdc)		$V_{CE(sat)}$*	— — — —	0.1 0.22 0.5 0.9	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1 Adc, I_B = 100 mAdc)		$V_{BE(sat)}$*	— — — 0.9	0.8 1.0 1.2 1.4	Vdc
TRANSIENT CHARACTERISTICS					
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	15	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	80	pF
High Frequency Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	2N3762, 2N3764 2N3763, 2N3765	$\lvert h_{fe} \rvert$	1.8 1.5	— —	—
Delay Time	(V_{CC} = 30 V, $V_{BE(off)}$ = 2 V, I_C = 1 Amp, I_{B1} = 100 mA)	t_d	—	8	ns
Rise Time		t_r	—	35	ns
Storage Time	(V_{CC} = 30 V, I_C = 1 Amp, I_{B1} = $-I_{B2}$ = 100 mA)	t_s	—	80	ns
Fall Time		t_f	—	35	ns
Total Control Charge (I_C = 1 Amp, I_B = 100 mA, V_{CC} = 30 V)		Q_T	—	30	nC

*Pulse Test: PW ≦ 300 μs, Duty Cycle ≦ 2%

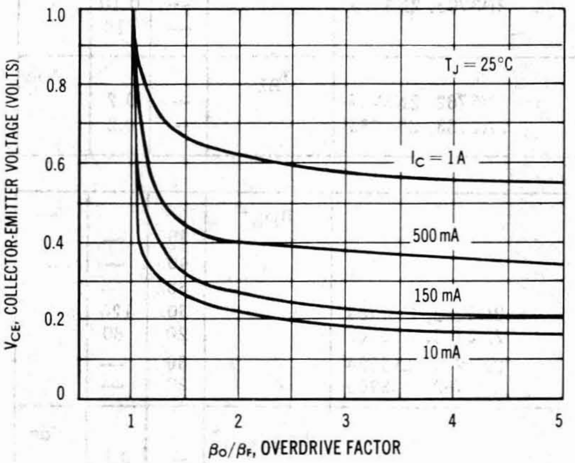
FIGURE 1

"ON" CONDITION CHARACTERISTICS

DC CURRENT GAIN



COLLECTOR SATURATION REGION

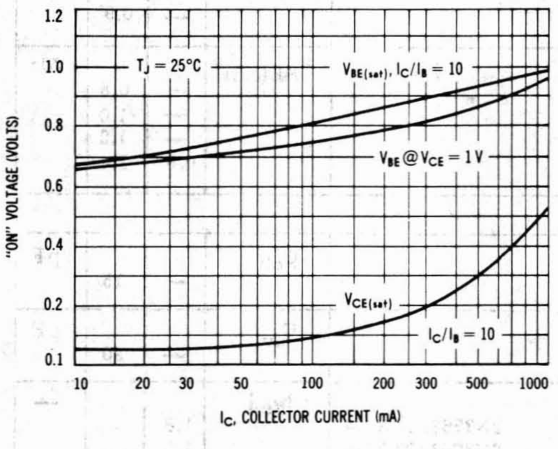


This graph shows the effect of base current on collector current. β_O (current gain at the edge of saturation) is the current gain of the transistor at 1 volt, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit. EXAMPLE: For type 2N3734, estimate a base current (I_{BF}) to ensure saturation at a temperature of 25°C and a collector of 500 mA.

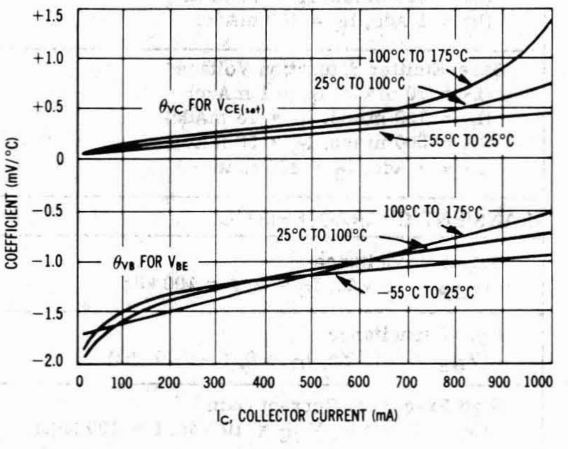
Observe that at $I_C = 500$ mA an overdrive factor of at least 2.0 is required to drive the transistor well into the saturation region. From Figure 1, it is seen that h_{FE} @ 1 volt is typically 54 (guaranteed limits from the Table of Characteristics can be used for "worst-case" design).

$$\frac{\beta_O}{\beta_F} = \frac{h_{FE} @ 1\text{ Volt}}{I_C/I_{BF}} \qquad 2 = \frac{54}{500\text{ mA}/I_{BF}} \qquad I_{BF} \approx 18.5\text{ mA typ}$$

"ON" VOLTAGES

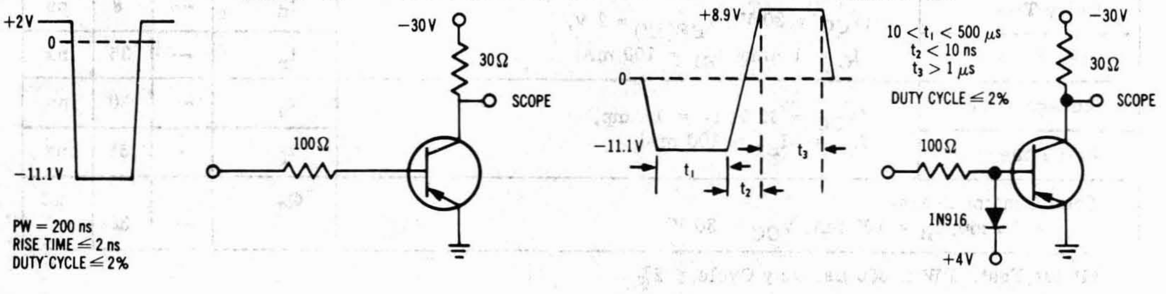


TEMPERATURE COEFFICIENTS



SWITCHING TIME EQUIVALENT TEST CIRCUITS

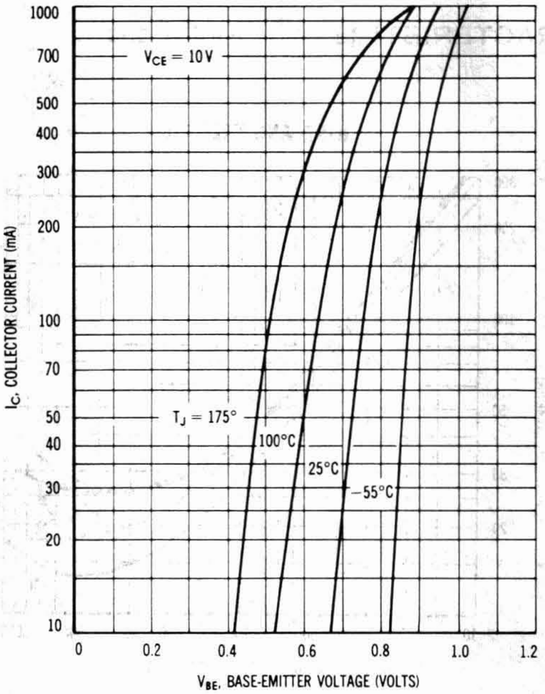
TURN-ON TIME **TURN-OFF TIME**



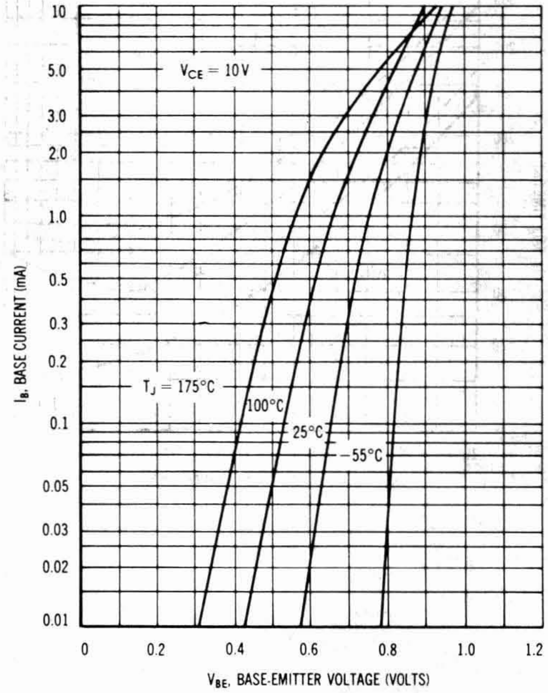
+2 V
0
−11.1 V
PW = 200 ns
RISE TIME ≤ 2 ns
DUTY CYCLE ≤ 2%
−30 V
30 Ω
SCOPE
100 Ω
+8.9 V
0
−11.1 V
t1
t2
t3
10 < t1 < 500 μs
t2 < 10 ns
t3 > 1 μs
DUTY CYCLE ≤ 2%
−30 V
30 Ω
SCOPE
100 Ω
1N916
+4 V

LARGE SIGNAL CHARACTERISTICS

TRANSCONDUCTANCE

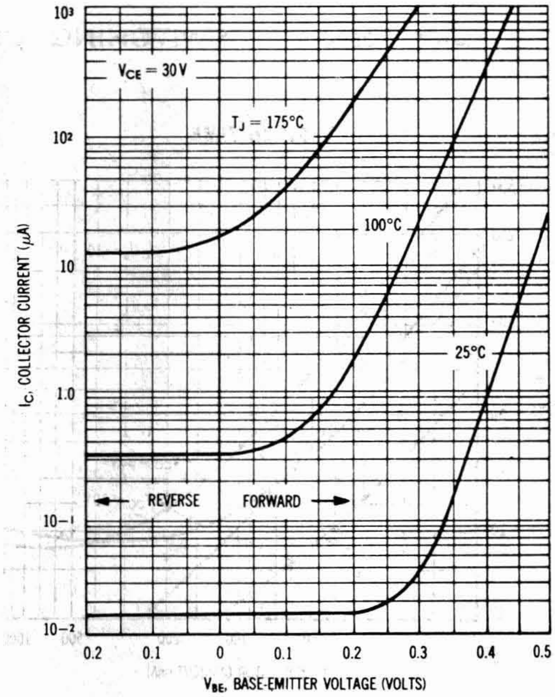


INPUT ADMITTANCE

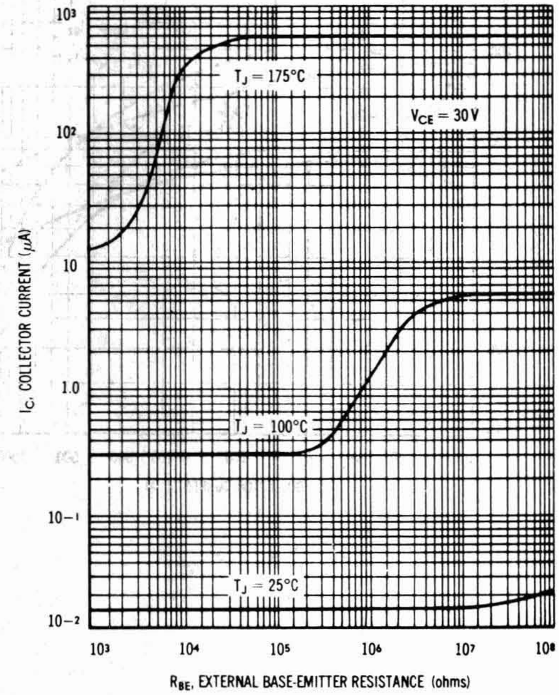


"OFF" CONDITION CHARACTERISTICS

TRANSCONDUCTANCE



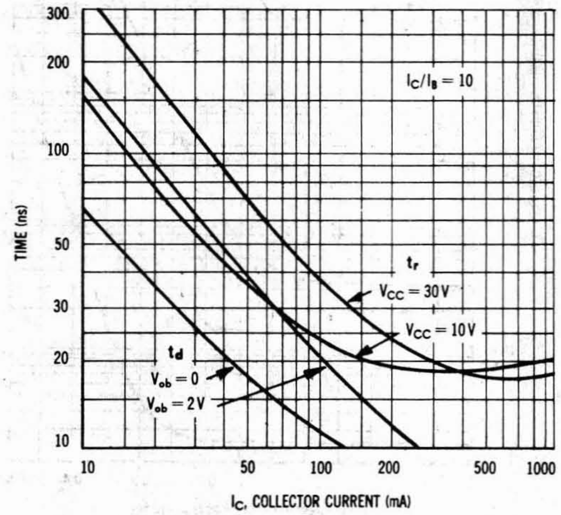
EFFECT OF BASE-EMITTER RESISTANCE



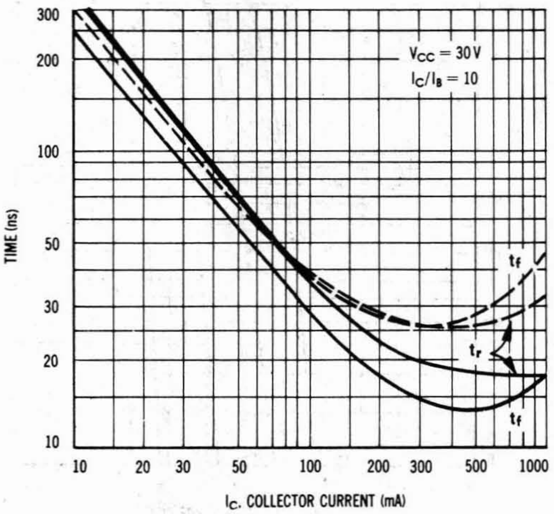
SWITCHING CHARACTERISTICS

— $T_J = 25°C$ -- $T_J = 150°C$

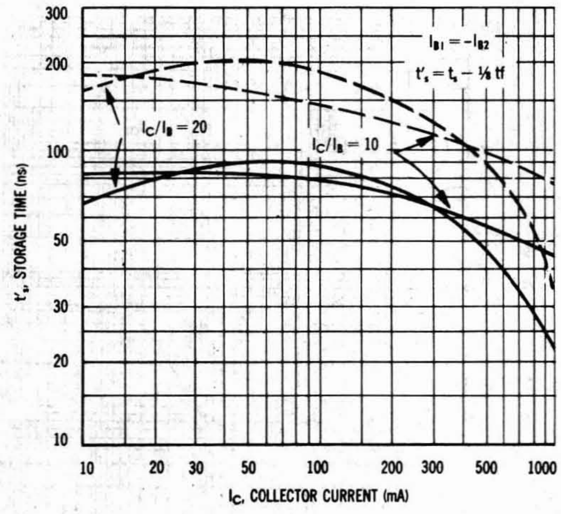
TURN-ON TIME



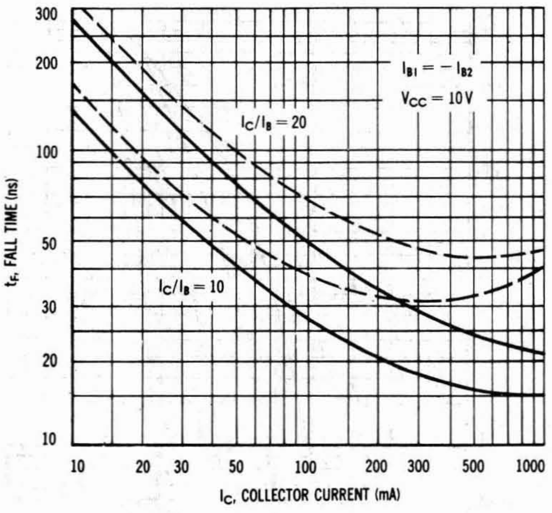
RISE AND FALL TIME



STORAGE TIME

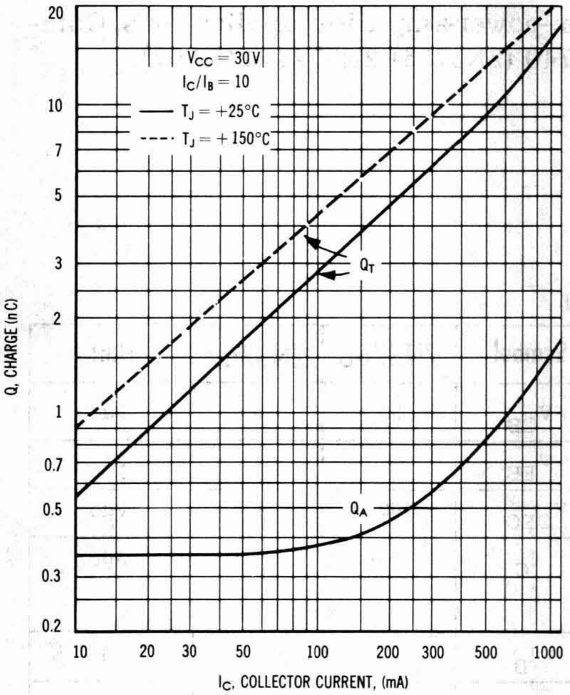


FALL TIME

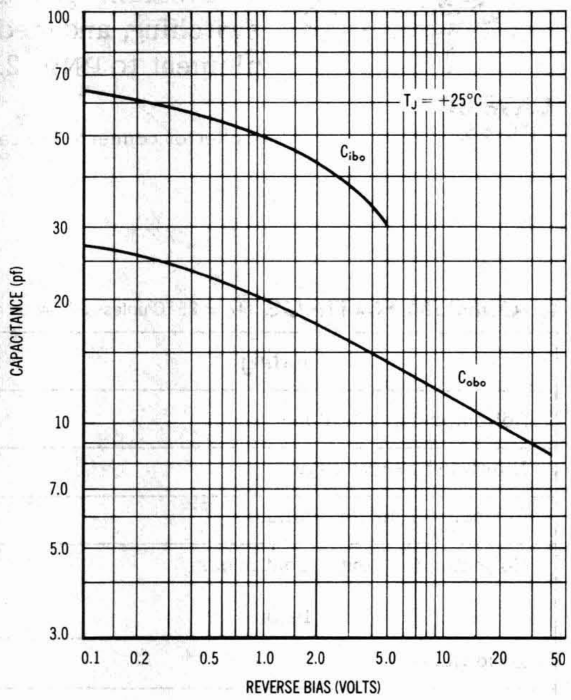


2N3762, 2N3763, 2N3764, 2N3765 (continued)

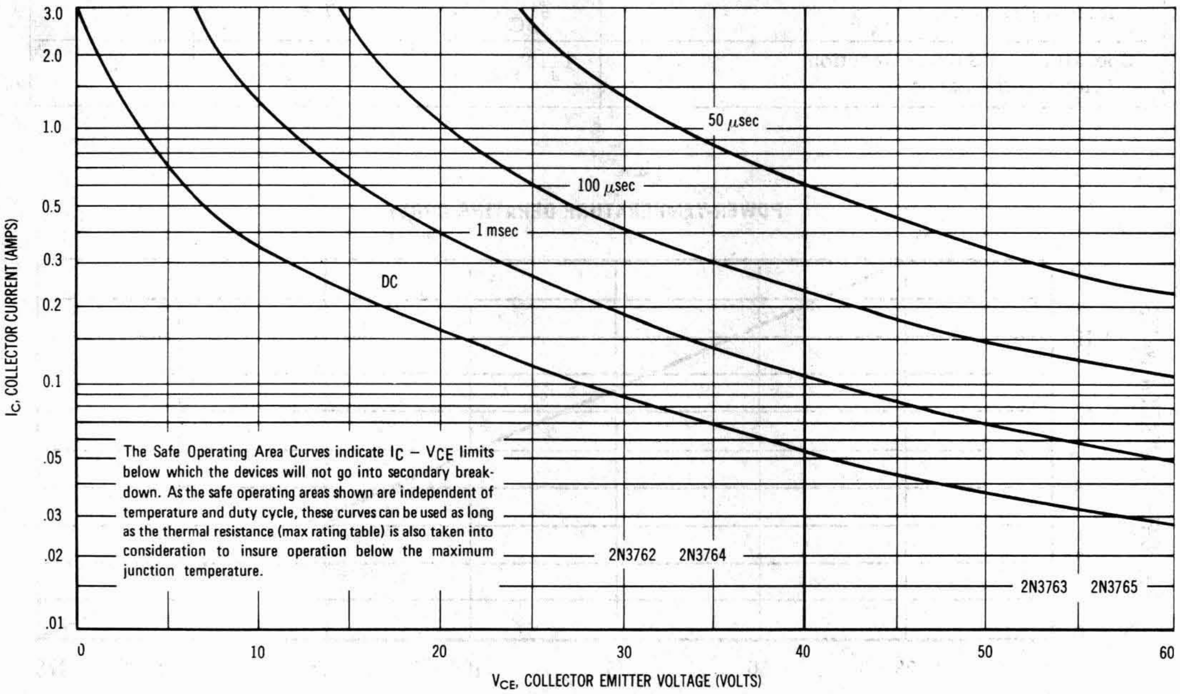
CHARGE DATA



CAPACITANCE

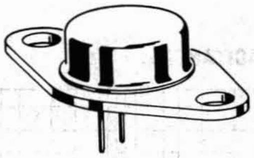


ACTIVE REGION SAFE OPERATING AREAS



The Safe Operating Area Curves indicate $I_C - V_{CE}$ limits below which the devices will not go into secondary breakdown. As the safe operating areas shown are independent of temperature and duty cycle, these curves can be used as long as the thermal resistance (max rating table) is also taken into consideration to insure operation below the maximum junction temperature.

2N3766 (SILICON)
2N3767



CASE 80
(TO-66)

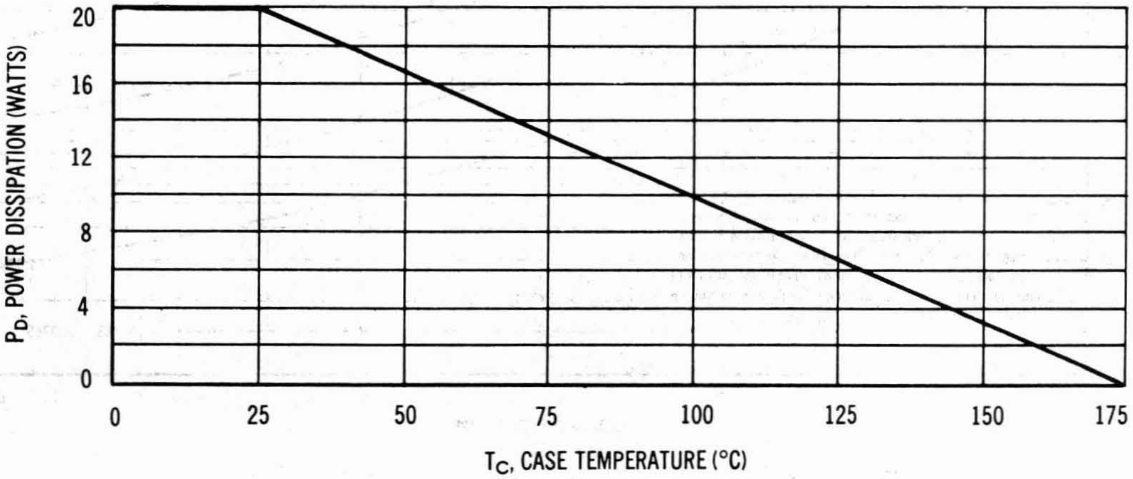
Medium-power NPN silicon transistors, for use in switching, and medium-power-amplifier applications. Complement to PNP 2N3740 (2N3766) 2N3741 (2N3767).

Collector connected to case

MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Rating	Symbol	2N3766	2N3767	Unit
Collector-Base Voltage	V_{CB}	80	100	Vdc
Emitter-Base Voltage	V_{EB}	6	6	Vdc
Collector-Emitter Voltage	V_{CEO}	60	80	Vdc
Collector Current - Continuous	I_C	4.0		Adc
Peak		4.0		
Base Current	I_B	2.0		Adc
Total Device Dissipation @ T_C = 25° C	P_D	20		Watts
Derate above 25° C		0.133		W/°C
Thermal Resistance	θ_{JC}	7.5		°C/W
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to °175		°C

POWER-TEMPERATURE DERATING CURVE

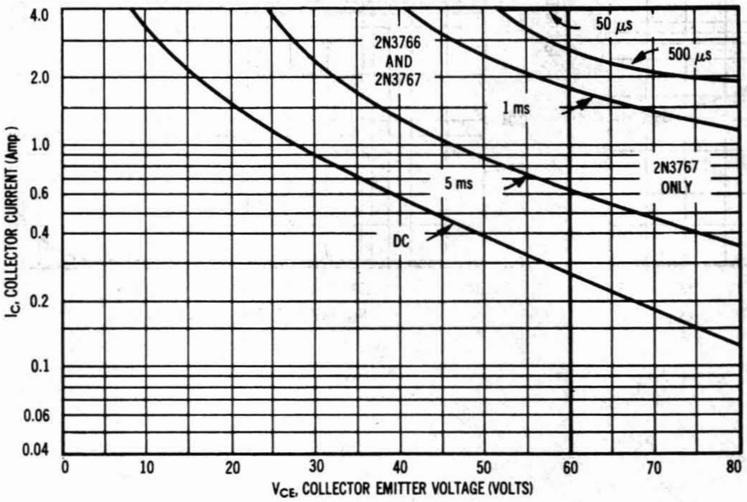


Safe area curves are indicated. Both limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS ($T_c = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Voltage*	BV_{CEO}*			Vdc
(I_C = 100 mAdc, I_B = 0) 2N3766		60	—	
2N3767		80	—	
Emitter-Base Cutoff Current (V_{EB} = 6 Vdc)	I_{EBO}	—	0.75	mAdc
Collector Cutoff Current	I_{CEX}			mAdc
(V_{CE} = 80 Vdc, V_{BE} = 1.5 Vdc) 2N3766		—	0.1	
(V_{CE} = 100 Vdc, V_{BE} = 1.5 Vdc) 2N3767		—	0.1	
(V_{CE} = 50 Vdc, V_{BE} = 1.5 Vdc, T_C = 150°C) 2N3766		—	1.0	
(V_{CE} = 70 Vdc, V_{BE} = 1.5 Vdc, T_C = 150°C) 2N3767		—	1.0	
Collector-Emitter Cutoff Current	I_{CEO}			mAdc
(V_{CE} = 60 Vdc, I_B = 0) 2N3766		—	0.7	
(V_{CE} = 80 Vdc, I_B = 0) 2N3767		—	0.7	
Collector-Base Cutoff Current	I_{CBO}			mAdc
(V_{CB} = 80 Vdc, I_E = 0) 2N3766		—	0.1	
(V_{CB} = 100 Vdc, I_E = 0) 2N3767		—	0.1	
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			—
(I_C = 50 mAdc, V_{CE} = 5 Vdc)		30	—	
(I_C = 500 mAdc, V_{CE} = 5 Vdc)		40	160	
(I_C = 1.0 Adc, V_{CE} = 10 Vdc)		20	—	
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$			Vdc
(I_C = 1 Adc, I_B = 0.1 Adc)		—	2.5	
(I_C = 500 mAdc, I_B = 50 mAdc)		—	1.0	
Base-Emitter Voltage (I_C = 1.0 Adc, V_{CE} = 10 Vdc)	V_{BE}	—	1.5	Vdc
TRANSIENT CHARACTERISTICS				
Current-Gain - Bandwidth Product (I_C = 500 mAdc, V_{CE} = 10 Vdc, f = 10 MHz)	f_T	10	—	MHz
Common-Base Output Capacitance (V_{CB} = 10 Vdc, I_C = 0 Adc, f = 100 kHz)	C_{ob}	—	50	pF
Small-Signal Current Gain (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{fe}	40	—	—

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%

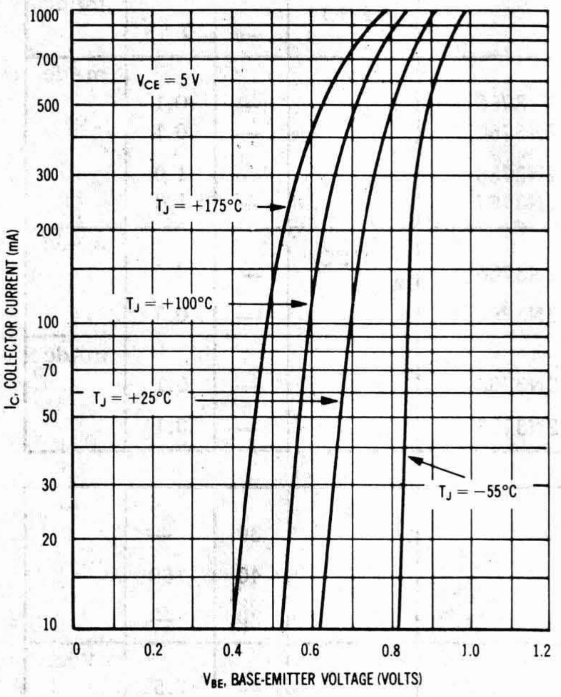


ACTIVE REGION SAFE AREAS

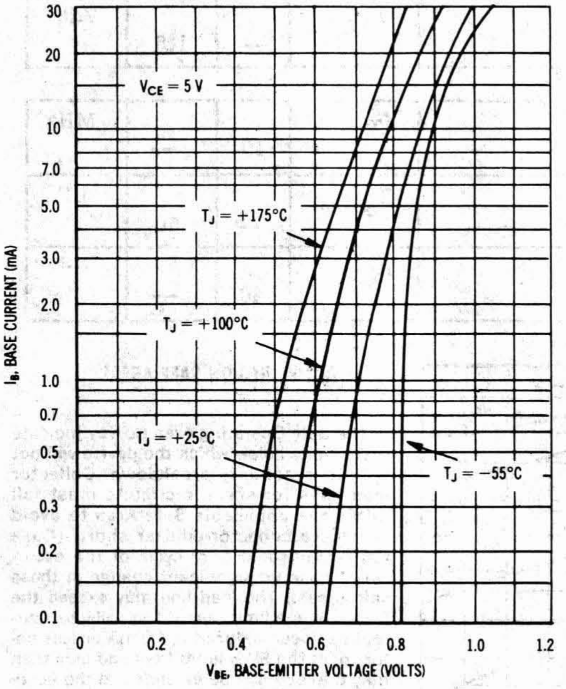
The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) The load line may exceed the BV_{CEO} voltage limit only if the collector current has been reduced to 20 mA or less before or at the BV_{CES} limit; then and only then may the load line be extended to the absolute maximum voltage rating of BV_{CBO}. To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

LARGE SIGNAL CHARACTERISTICS

TRANSCONDUCTANCE

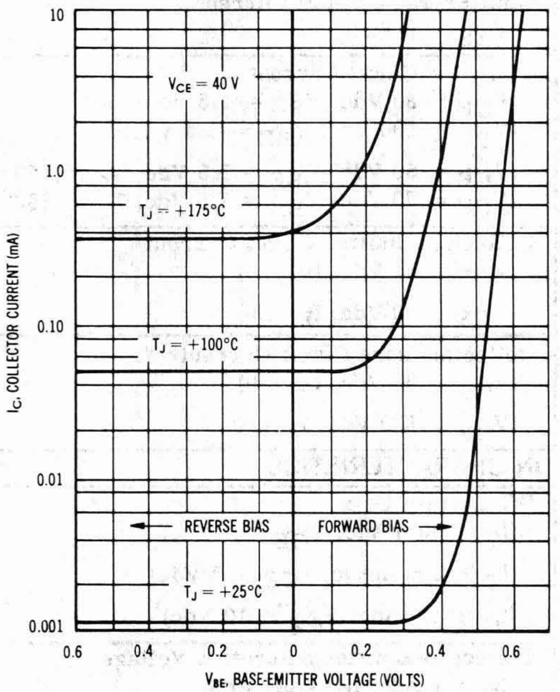


INPUT ADMITTANCE

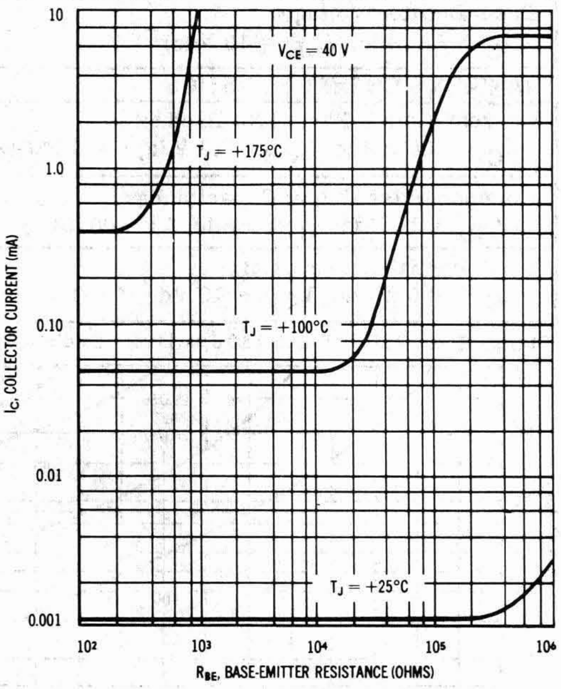


CUT-OFF CHARACTERISTICS

TRANSCONDUCTANCE

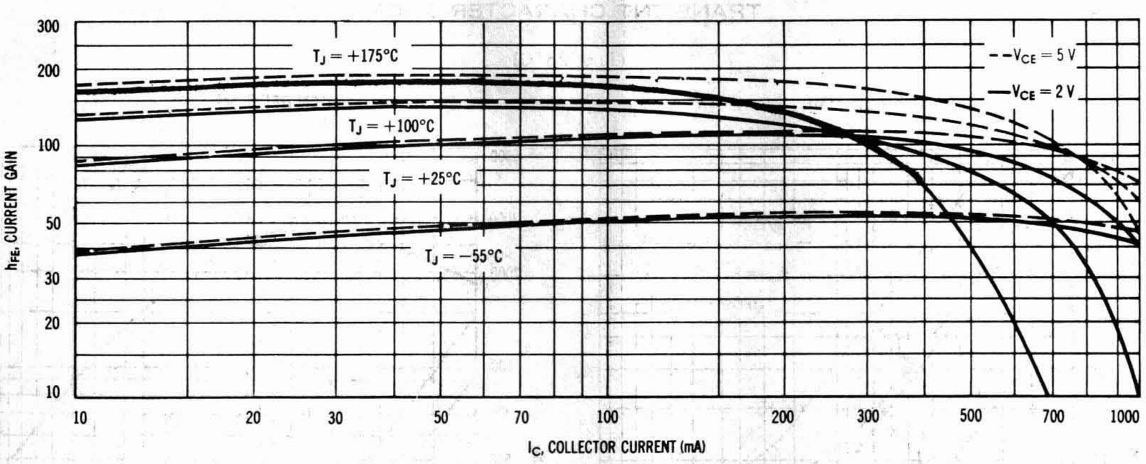


EFFECT OF BASE-EMITTER RESISTANCE

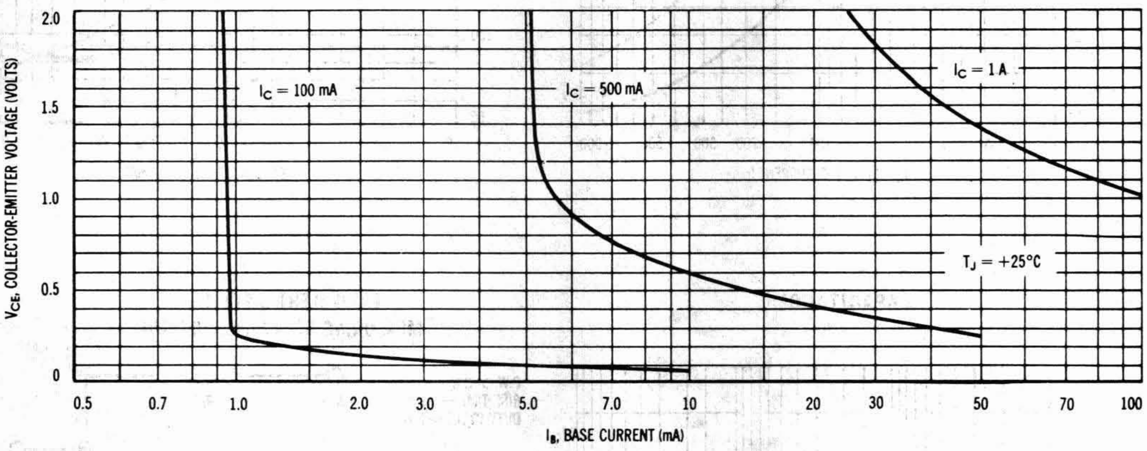


2N3766, 2N3767 (continued)

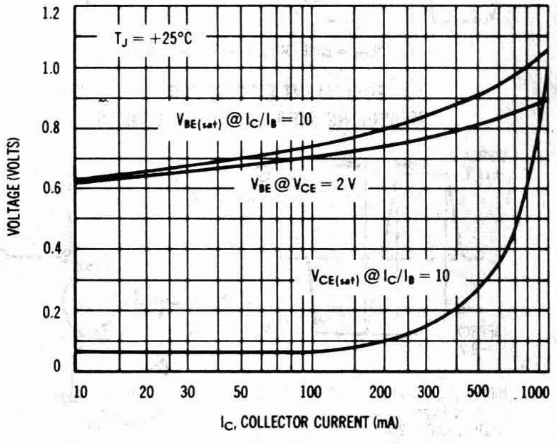
CURRENT GAIN



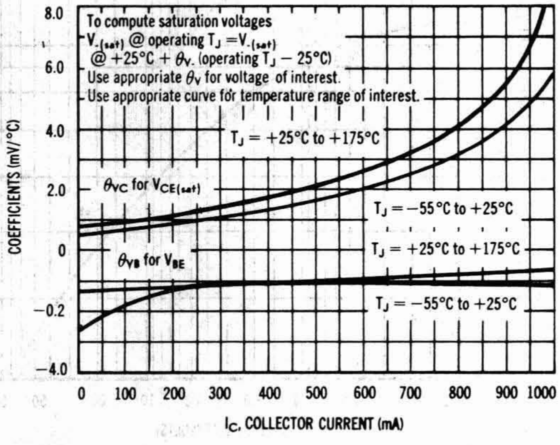
COLLECTOR SATURATION REGION



"ON" VOLTAGES



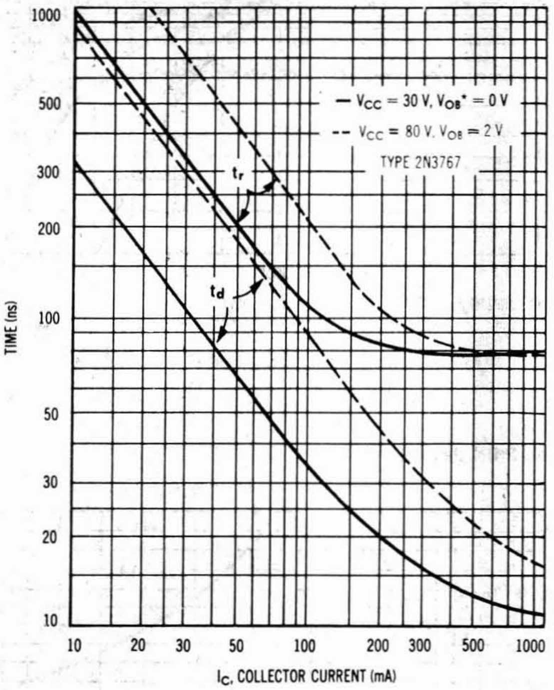
TEMPERATURE CO-EFFICIENTS



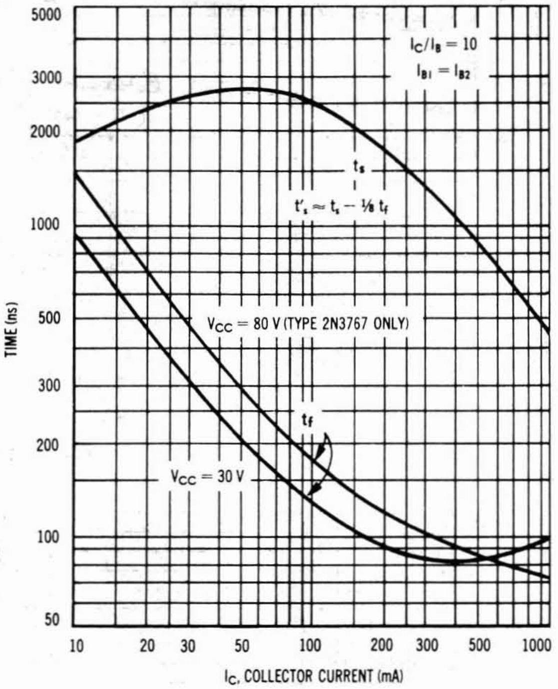
TRANSIENT CHARACTERISTICS

($T_J = 25\,°C$)

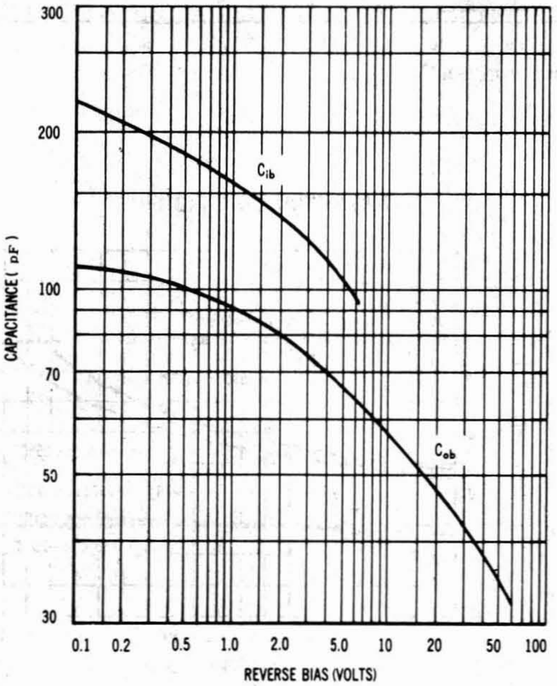
TURN-ON TIME



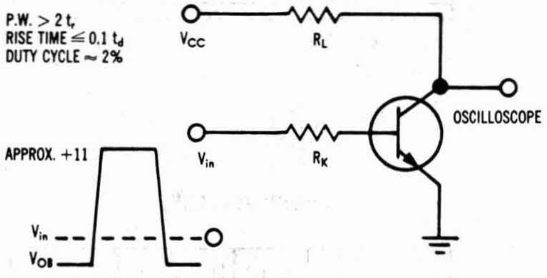
TURN-OFF TIME



CAPACITANCE

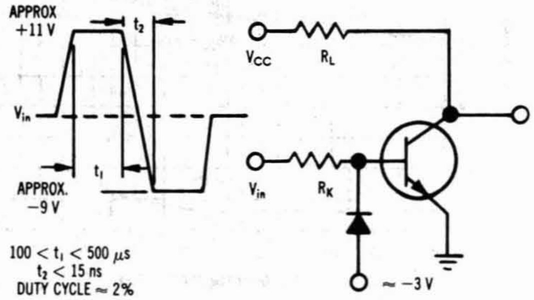


EQUIVALENT CIRCUIT FOR MEASURING DELAY AND RISE TIME

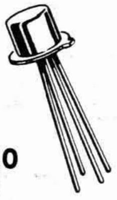

P.W. > 2 tr
RISE TIME ≤ 0.1 td
DUTY CYCLE ≈ 2%
VCC
RL
OSCILLOSCOPE
APPROX. +11
Vin
RK
Vin
VOB

*V_{OB} = BASE-EMITTER "OFF" BIAS VOLTAGE

EQUIVALENT CIRCUIT FOR MEASURING STORAGE AND FALL TIMES


APPROX +11 V
t2
VCC
RL
Vin
t1
APPROX. –9 V
Vin
RK
100 < t1 < 500 μs
t2 < 15 ns
DUTY CYCLE ≈ 2%
≈ –3 V

2N3783 thru 2N3785
(GERMANIUM)



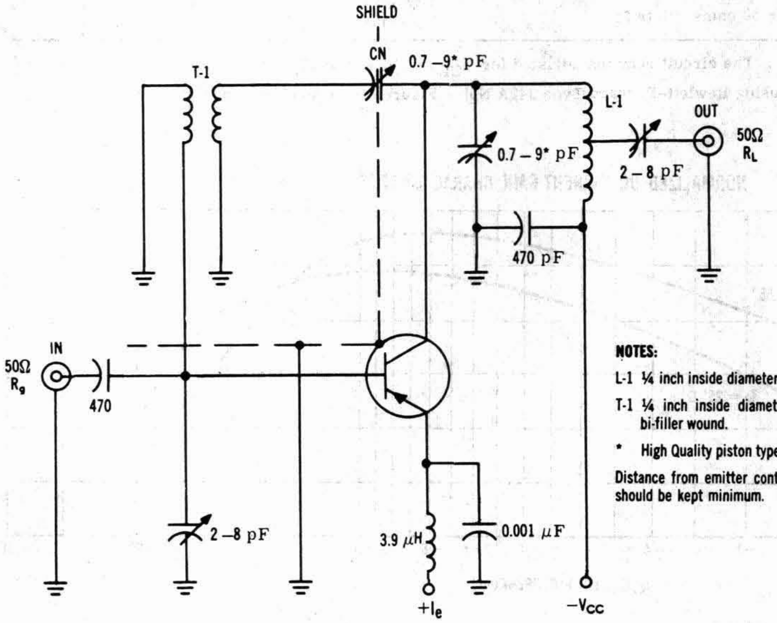
CASE 20
(TO-72)

PNP germanium epitaxial mesa transistors for high-gain, low-noise amplifier, oscillator and frequency multiplier applications.

MAXIMUM RATINGS

Rating	Symbol	2N3783 2N3784	2N3785	Unit
Collector-Base Voltage	V_{CB}	30	15	Vdc
Collector-Emitter Voltage	V_{CES}	30	15	Vdc
Collector-Emitter Voltage	V_{CEO}	20	12	Vdc
Emitter-Base Voltage	V_{EB}	0.5		Vdc
Collector Current	I_C	20		mAdc
Total Device Dissipation @ T_A = 25°C **Derate above 25°C**	P_D	150 2		mW mW/°C
Junction Operating & Storage Temperature Range	T_J, T_{stg}	-65 to +100		°C

FIGURE 1 — 200 MHz TEST CIRCUIT: POWER GAIN & NOISE FIGURE



NOTES:

L-1 ¼ inch inside diameter, ½ inch length, 4 turns #20 solid copper wire, center tapped.

T-1 ¼ inch inside diameter, close wound, 3 turns #26 solid copper wire. 1:1 ratio bi-filler wound.

* High Quality piston type capacitor.

Distance from emitter contact of transistor to ground side of bypass capacitor should be kept minimum.

2N3783 thru 2N3785 (continued)

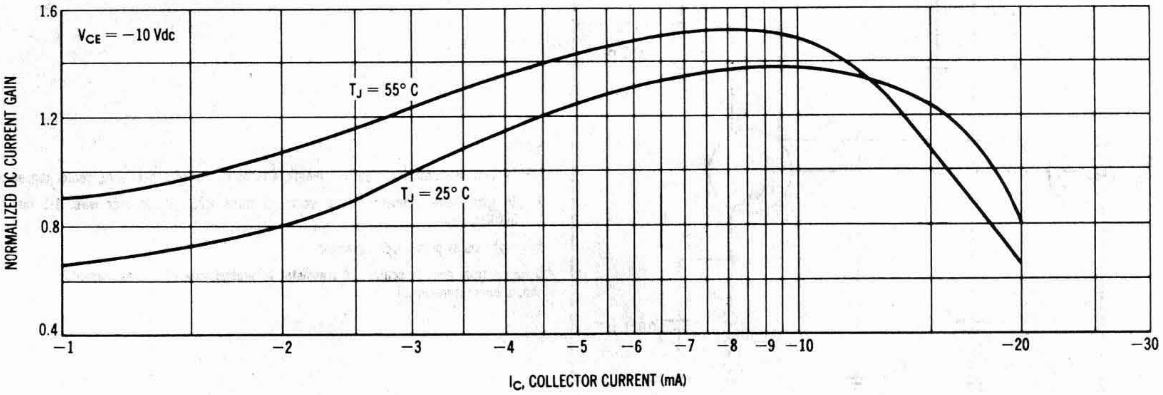
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Test Conditions		Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	BV_{CBO}	I_C = 100 μAdc, I_E = 0	2N3783, 2N3784 2N3785	30 15	— —	— —	Vdc
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 100 μAdc, V_{EB} = 0	2N3783, 2N3784 2N3785	30 15	— —	— —	Vdc
Collector-Emitter Breakdown Voltage	BV_{CEO}	I_C = 2 mAdc, I_B = 0	2N3783, 2N3784 2N3785	20 12	— —	— —	Vdc
Emitter-Base Breakdown Voltage	BV_{EBO}	I_E = 100 μAdc. I_C = 0	All Types	0.5	—	—	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 10 Vdc, I_E = 0 V_{CB} = 10 Vdc, I_E = 0, T_A = +55°C	All Types 2N3783, 2N3784	— —	— —	5 50	μAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 0.5 Vdc, I_C = 0	All Types	—	—	100	μAdc
DC Forward Current Transfer Ratio	h_{FE}	V_{CE} = 10 Vdc, I_C = 3 mAdc	2N3783, 2N3784 2N3785	20 15	— —	200 200	—
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 5.0 mAdc, I_B = 1.0 mAdc	2N3783, 2N3784 2N3785	— —	— —	0.25 0.35	Vdc
Base-Emitter Saturation Voltage	$V_{BE(sat)}$	I_C = 5.0 mAdc, I_B = 1.0 mAdc	2N3783, 2N3784 2N3785	— —	— —	0.55 0.65	Vdc
Small-Signal Forward Current Transfer Ratio	h_{fe}	I_C = 3 mAdc, V_{CE} = 10 Vdc, f = 1 kHz	2N3783, 2N3784 2N3785	20 15	— —	200 200	—
Current Gain - Bandwidth Product	f_τ	I_C = 3 mAdc, V_{CE} = 10 Vdc, f = 200 MHz	2N3783 2N3784, 2N3785	800 700	— —	1600 1600	MHz
Collector-Base Time Constant	$r'_b C_c$	V_{CB} = 10 Vdc, I_E = 3 mAdc, f = 31.8 MHz	2N3783, 2N3784 2N3785	1 1	— —	6 10	ps
Collector-Base Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz	2N3783, 2N3784 2N3785	— —	— —	1.0 1.2	pF
Power Gain	G_e	V_{CE} = 10 Vdc, I_C = 3 mAdc, f = 200 MHz	2N3783, 2N3784 2N3785	20 18	— —	33 33	dB
Noise Figure	NF	V_{CE} = 10 Vdc, I_C = 3 mAdc, f = 200 MHz R_G = 50 ohms	2N3783 2N3784 2N3785	— — —	— — —	2.2 2.5 2.9	dB
Power Gain (AGC) Note 1	G_e(AGC)	V_{CE} = 10 Vdc, I_C = 15 mAdc, f = 200 MHz	2N3783 2N3784, 2N3785	— —	— 0	0 —	dB
Noise Figure	NF	V_{CE} = 10 Vdc, I_C = 3 mAdc, f = 1000 MHz R_G = 50 ohms (Note 2)	2N3783 2N3784 2N3785	— — —	— 7.0 7.5	6.5 — —	dB

NOTE 1: AGC is obtained by increasing I_C. The circuit remains adjusted for V_{CE} = 10 Vdc and I_C = 3 mAdc.

NOTE 2: This Noise Figure was obtained using Hewlett-Packard Type 342A Noise Figure Meter and Type 349A Noise Source.

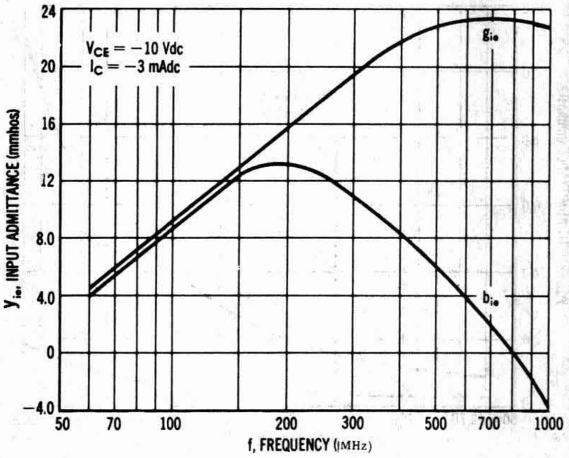
NORMALIZED DC CURRENT GAIN CHARACTERISTICS



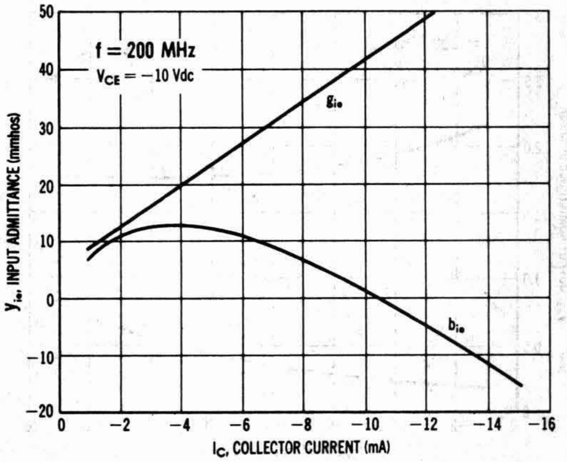
y_{ie}, INPUT ADMITTANCE CHARACTERISTICS

(T_A = 25° C unless otherwise noted)

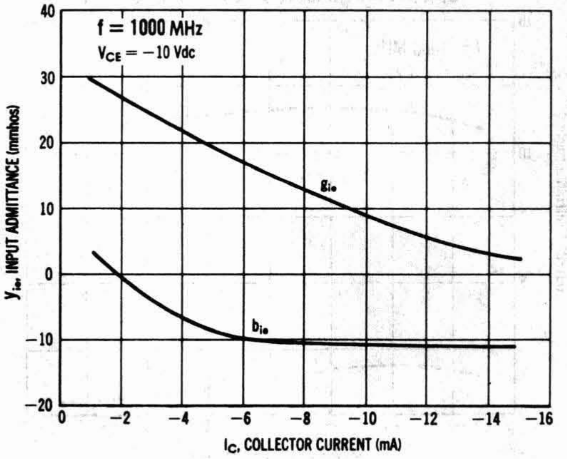
INPUT ADMITTANCE versus FREQUENCY



INPUT ADMITTANCE versus COLLECTOR CURRENT



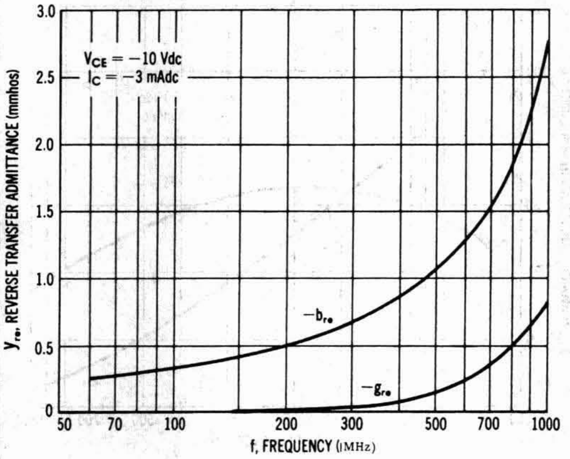
INPUT ADMITTANCE versus COLLECTOR CURRENT



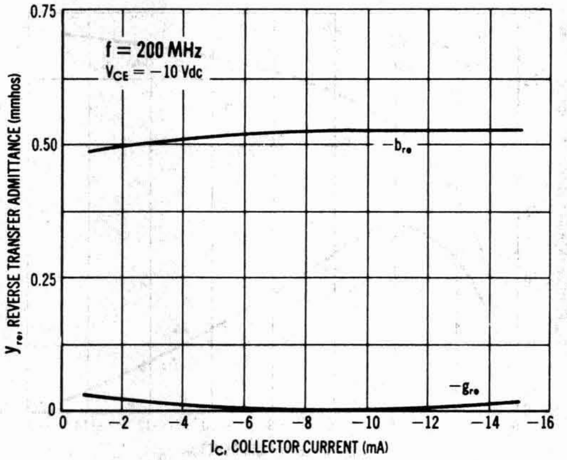
y_{re}, REVERSE TRANSFER ADMITTANCE CHARACTERISTICS

(T_A = 25° C unless otherwise noted)

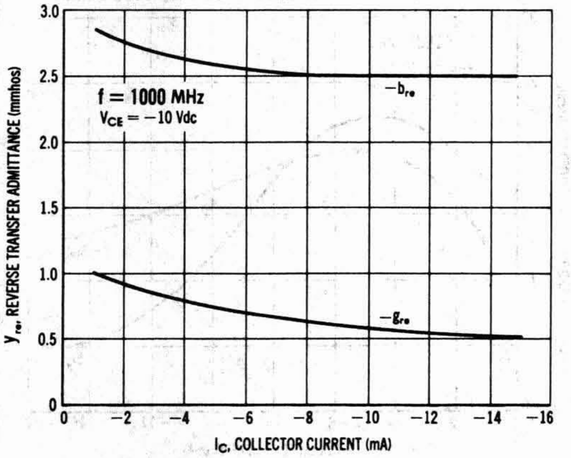
REVERSE TRANSFER ADMITTANCE versus FREQUENCY



REVERSE TRANSFER ADMITTANCE versus COLLECTOR CURRENT



REVERSE TRANSFER ADMITTANCE versus COLLECTOR CURRENT

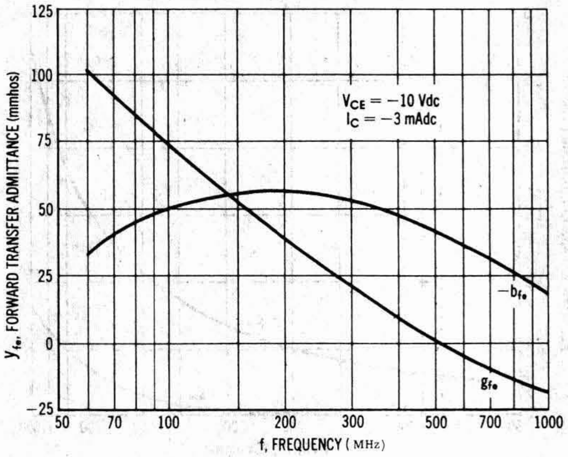


2N3783 thru 2N3785 (continued)

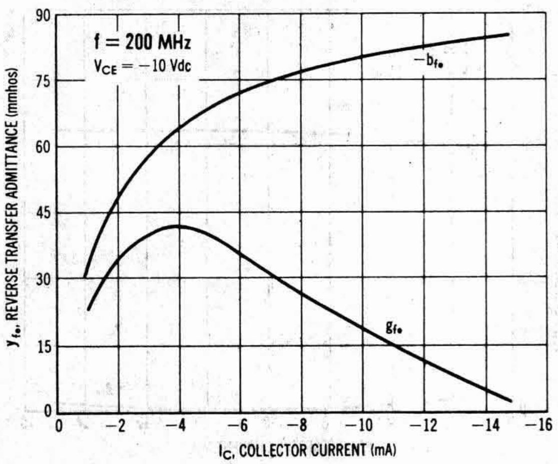
y_{fe}, FORWARD TRANSFER ADMITTANCE CHARACTERISTICS

($T_A = 25°$ C unless otherwise noted)

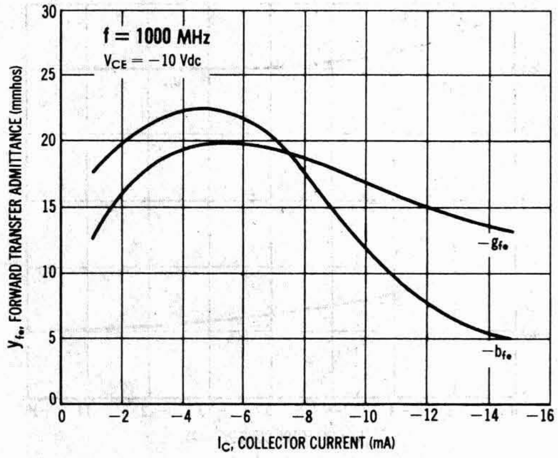
FORWARD TRANSFER ADMITTANCE versus FREQUENCY



FORWARD TRANSFER ADMITTANCE versus COLLECTOR CURRENT



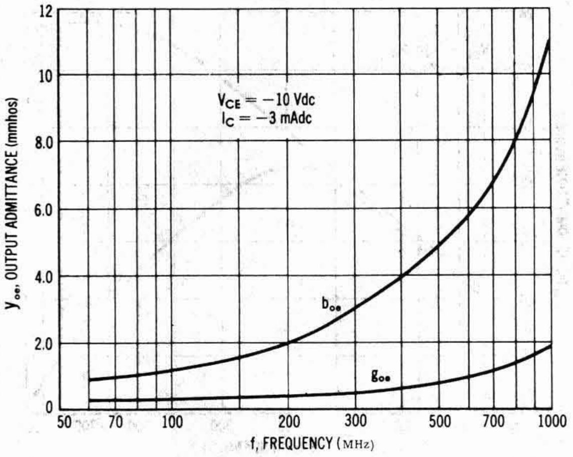
FORWARD TRANSFER ADMITTANCE versus COLLECTOR CURRENT



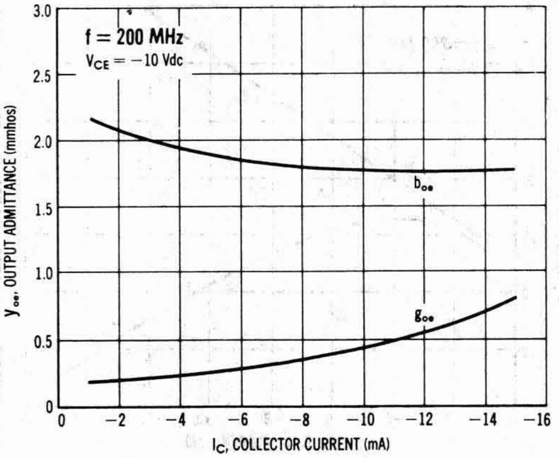
y_{oe}, OUTPUT ADMITTANCE CHARACTERISTICS

($T_A = 25°$ C unless otherwise noted)

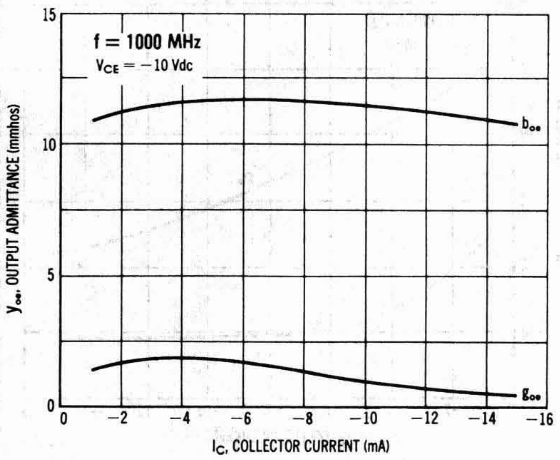
OUTPUT ADMITTANCE versus FREQUENCY



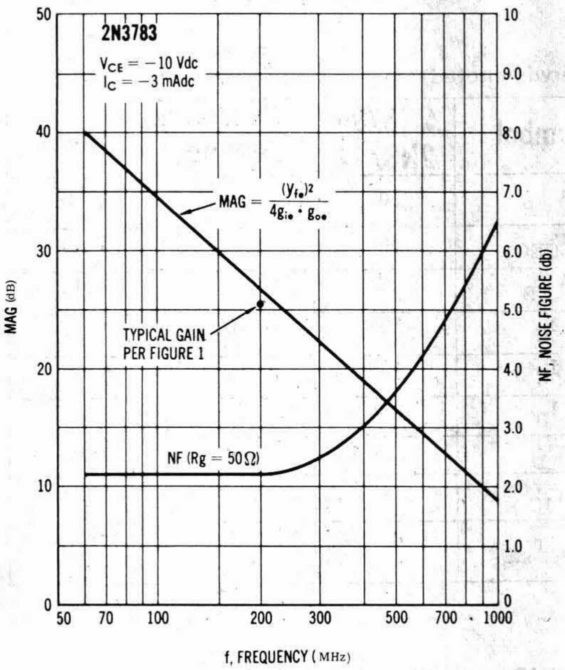
OUTPUT ADMITTANCE versus COLLECTOR CURRENT



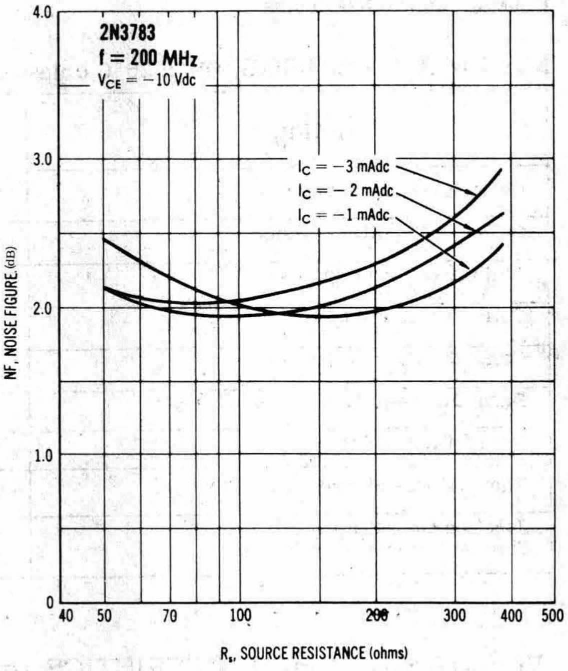
OUTPUT ADMITTANCE versus COLLECTOR CURRENT



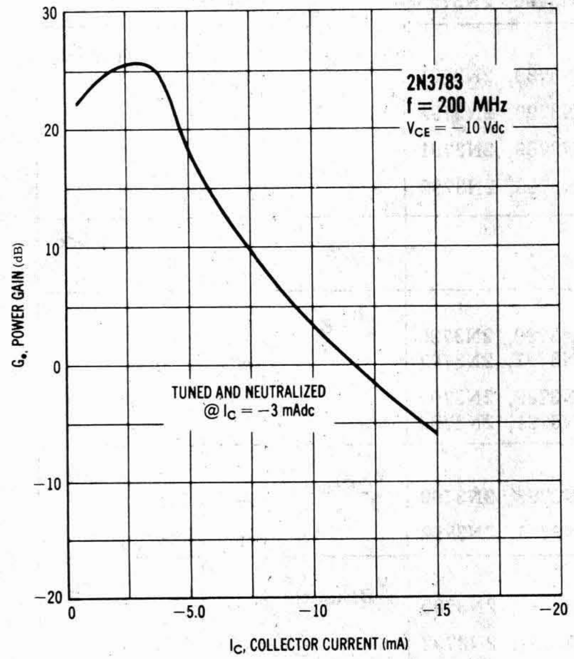
MAG & MAXIMUM NF versus FREQUENCY



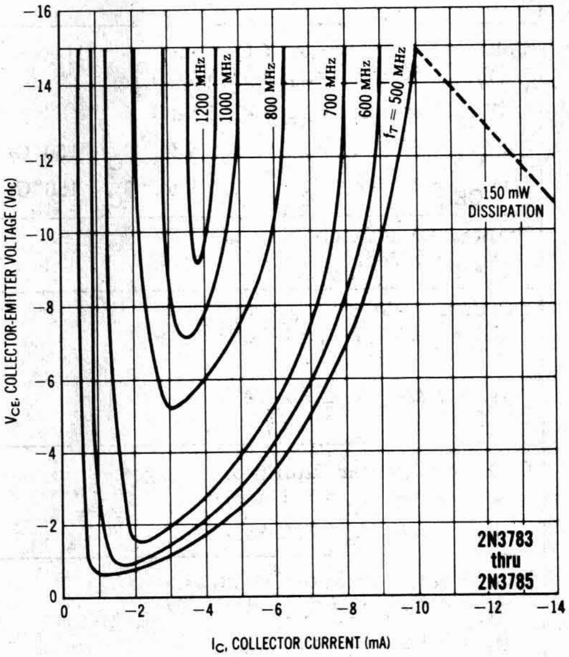
NOISE FIGURE versus SOURCE RESISTANCE



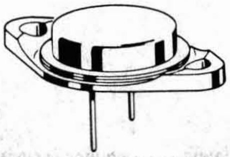
GAIN versus COLLECTOR CURRENT



CONTOURS OF CURRENT-GAIN — BANDWIDTH PRODUCT — f_T



2N3789 thru 2N3792 (SILICON)



CASE 11
(TO-3)
Collector connected to case

PNP silicon power transistors for medium-speed switching and amplifier applications. Complement to NPN type 2N3713 thru 2N3716.

MAXIMUM RATINGS (Tc = 25°C unless otherwise noted)

Rating	Symbol	2N3789 2N3791	2N3790 2N3792	Unit
Collector-Base Voltage	V_{CB}	60	80	Volts
Collector-Emitter Voltage	V_{CEO}	60	80	Volts
Emitter-Base Voltage	V_{EB}	7	7	Volts
Collector Current	I_C	10	10	Amp
Collector Current (Peak)	I_C	10	10	Amp
Base Current (Continuous)	I_B	4.0	4.0	Amp
Power Dissipation	P_D	150	150	Watts
Thermal Resistance	θ_{JC}	1.17	1.17	°C/W
Junction Operating and Storage Temperature Range	T_J, T_{stg}	-65 to +200		°C

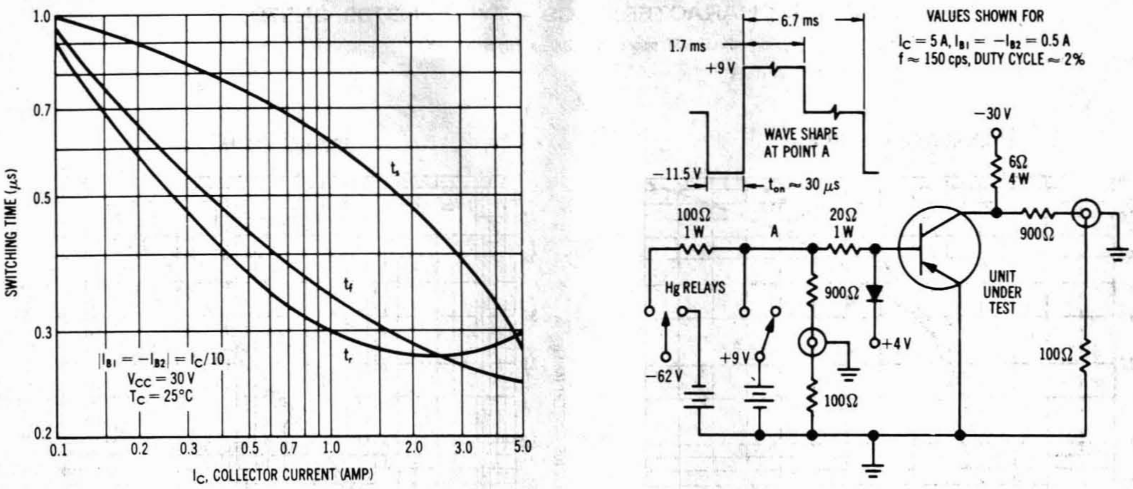
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Sustaining Voltage*		$V_{CEO(sus)}$*			Vdc
(I_C = 200 mAdc, I_B = 0)	2N3789, 2N3791		60	—	
	2N3790, 2N3792		80	—	
Collector-Emitter Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 60 Vdc, V_{BE} = -1.5 Vdc)	2N3789, 2N3791		—	1	
(V_{CE} = 80 Vdc, V_{BE} = -1.5 Vdc)	2N3790, 2N3792		—	1	
(V_{CE} = 60 Vdc, V_{BE} = -1.5 Vdc, T_C = 150°C)	2N3789, 2N3791		—	5	
(V_{CE} = 80 Vdc, V_{BE} = -1.5 Vdc, T_C = 150°C)	2N3790, 2N3792		—	5	
Emitter-Base Cutoff Current		I_{EBO}			mAdc
(V_{EB} = 7 Vdc)			—	5	
DC Current Gain*		h_{FE}*			—
(I_C = 1 Adc, V_{CE} = 2 Vdc)	2N3789, 2N3790		25	90	
	2N3791, 2N3792		50	150	
(I_C = 3 Adc, V_{CE} = 2 Vdc)	2N3789, 2N3790		15	—	
	2N3791, 2N3792		30	—	
Collector-Emitter Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 4 Adc, I_B = 0.4 Adc)	2N3789, 2N3790		—	1.0	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N3791, 2N3792		—	1.0	
Base-Emitter Saturation Voltage*		$V_{BE(sat)}$*			Vdc
(I_C = 4 Adc, I_B = 0.4 Adc)	2N3789, 2N3790		—	2.0	
(I_C = 5 Adc, I_B = 0.5 Adc)	2N3791, 2N3792		—	1.5	
Current Gain — Bandwidth Product		f_T			MHz
(V_{CE} = 10 Vdc, I_C = 0.5 Adc f = 1.0 MHz)			4	—	

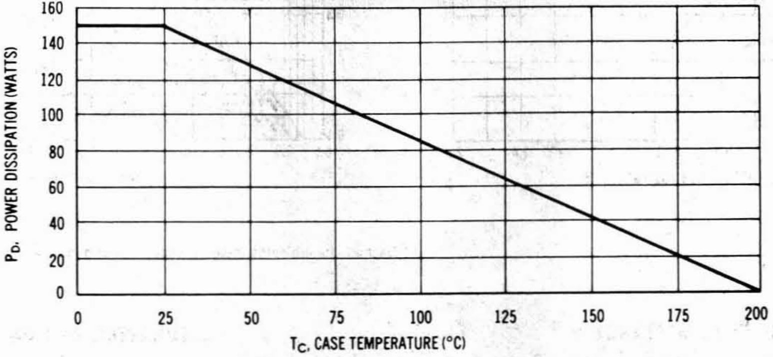
*Sweep Test: 1/2 sine wave cycle @ 60 Hz .

2N3789 thru 2N3792 (continued)

TYPICAL SWITCHING TIMES AND TEST CIRCUIT

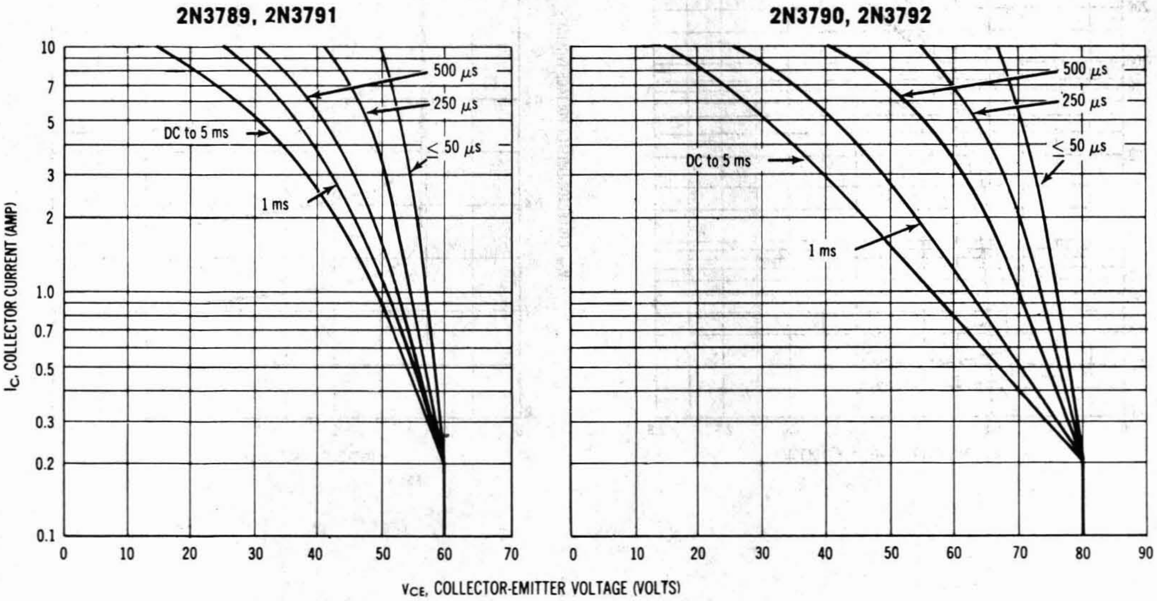


POWER-TEMPERATURE DERATING CURVE



Safe area curves are indicated. Both limits are applicable and must be observed.

ACTIVE-REGION SAFE OPERATING AREAS

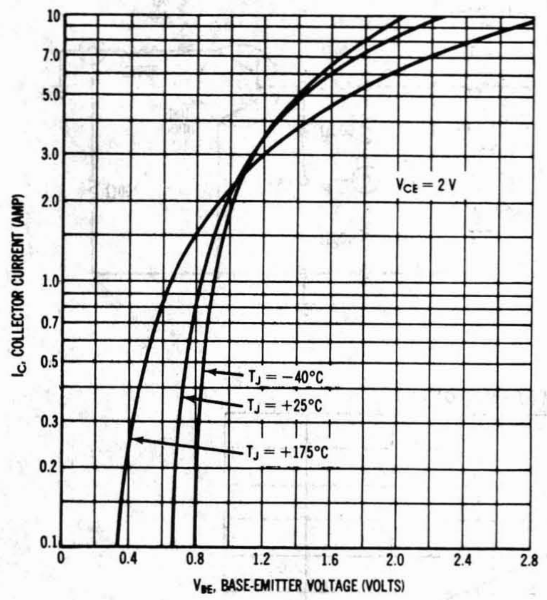

2N3789, 2N3791

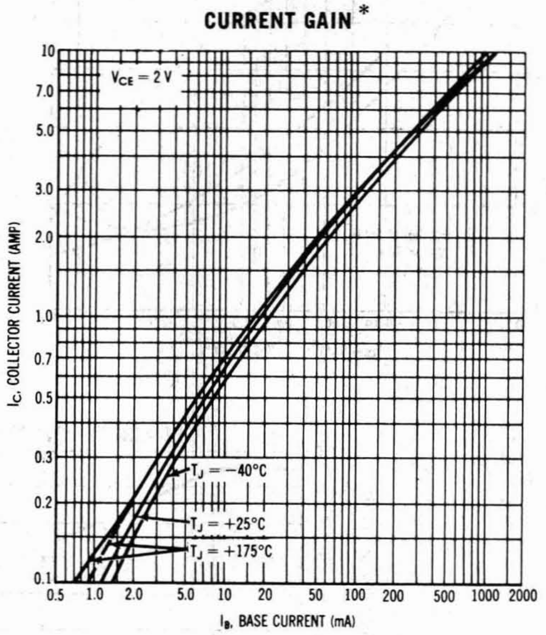
2N3790, 2N3792

The Safe Operating Area Curves indicate I_C - V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursion make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

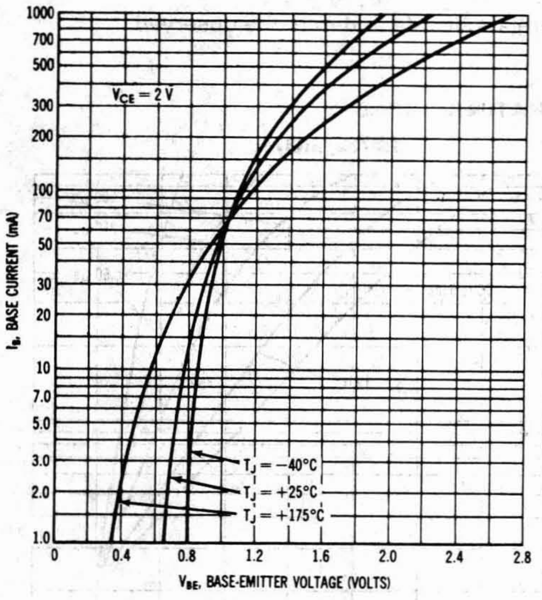
LARGE SIGNAL CHARACTERISTICS – TYPE 2N3789, 2N3790

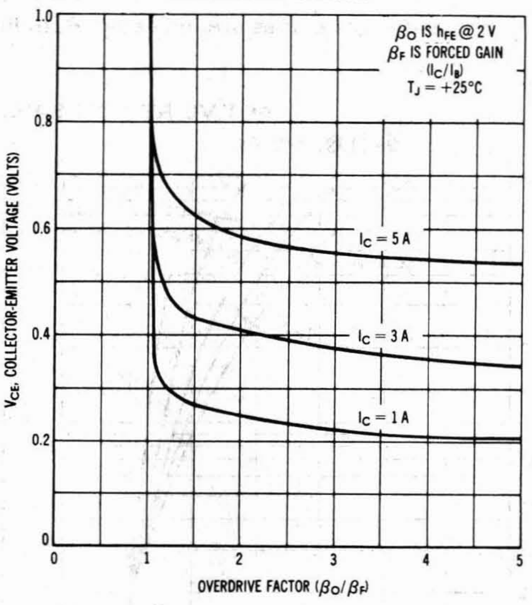
(PULSE TEST: pulse width ≈ 200 μs, duty cycle ≈ 1%)


TRANSCONDUCTANCE


CURRENT GAIN *

* Dashed line indicates metered base current minus I_{CBO} of the transistor at 175°C.

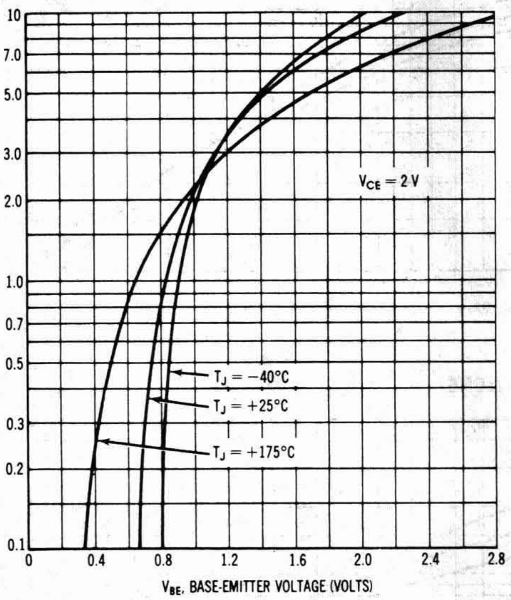

INPUT ADMITTANCE


SATURATION REGION

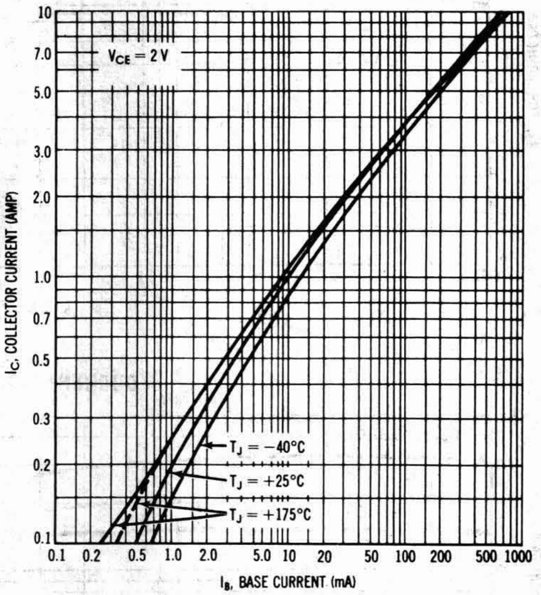
LARGE SIGNAL CHARACTERISTICS – TYPE 2N3791, 2N3792

(PULSE TEST: pulse width ≈ 200 μsec, duty cycle ≈ 1%)

TRANSCONDUCTANCE

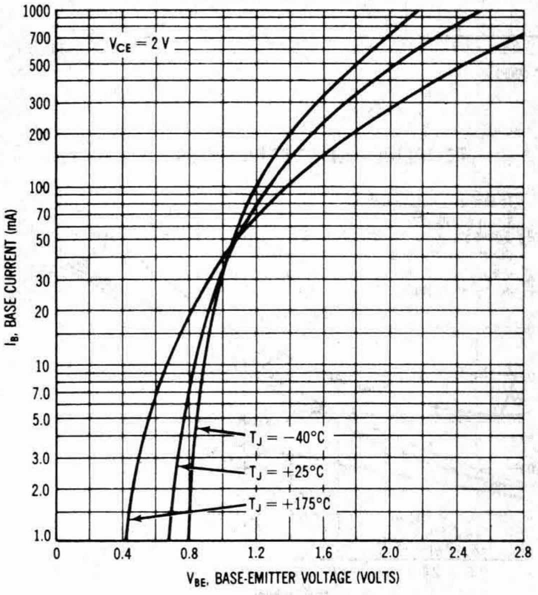


CURRENT GAIN

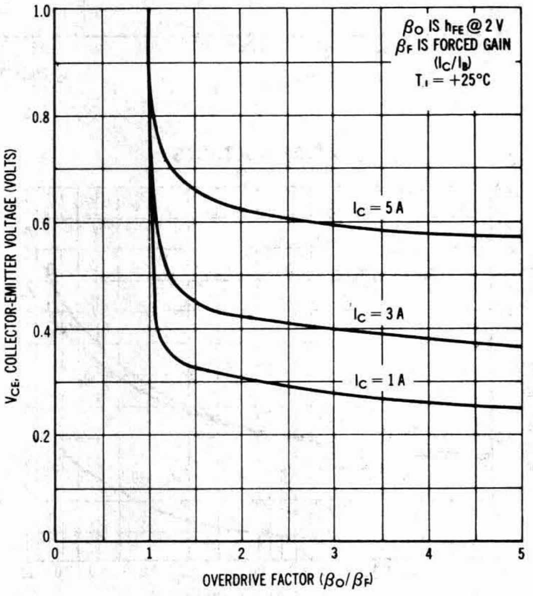


Dashed line indicates metered base current minus I_{CBO} of the transistor at 175°C.

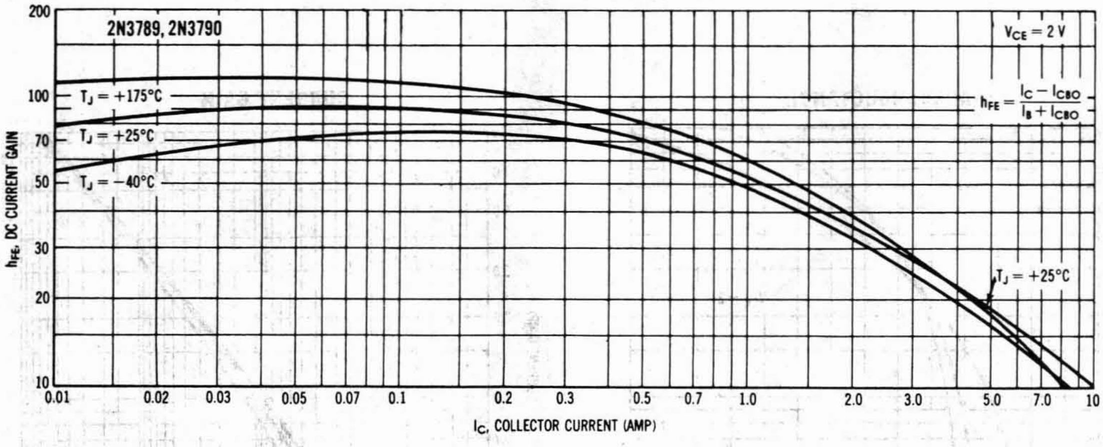
INPUT ADMITTANCE



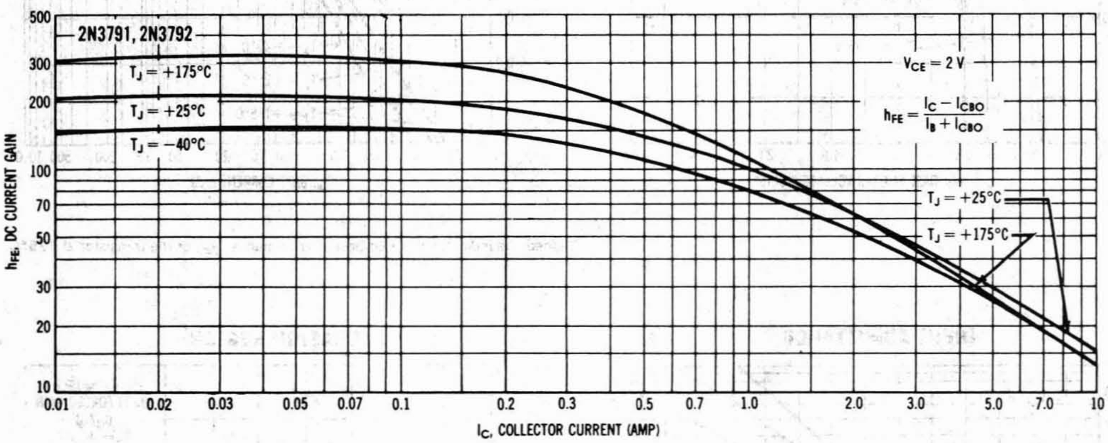
SATURATION REGION



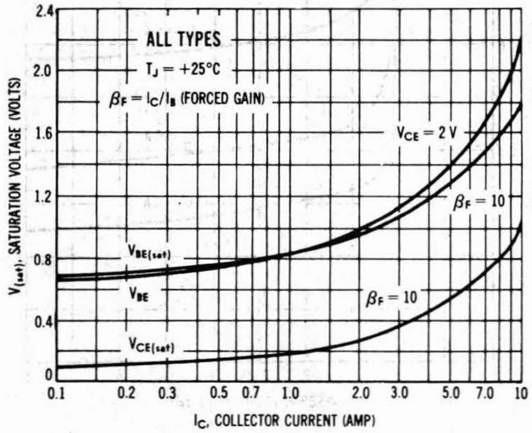
CURRENT GAIN VARIATIONS



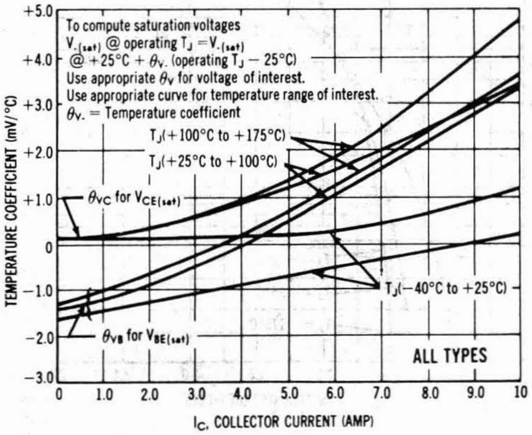
CURRENT GAIN VARIATIONS



SATURATION VOLTAGES



TEMPERATURE COEFFICIENTS


To compute saturation voltages

$V_{\cdot(sat)}$ @ operating $T_J = V_{\cdot(sat)}$ @ $+25°C + \theta_{V\cdot}$ (operating $T_J - 25°C$)

Use appropriate θ_V for voltage of interest.

Use appropriate curve for temperature range of interest.

$\theta_{V\cdot}$ = Temperature coefficient

2N3796 (SILICON)
2N3797

CASE 22 (2)
(TO-18)

Silicon N-channel MOS field-effect transistor designed for low-power applications in the audio frequency range.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}		Vdc
2N3796		25	
2N3797		20	
Gate-Source Voltage	V_{GS}	±30	Vdc
Drain Current	I_D	20	mAdc
Power Dissipation at $T_A = 25^oC$ Derate above 25^oC	P_D	300 1.7	mW mW/^oC
Operating Junction Temperature	T_J	+200	^oC
Storage Temperature Range	T_{stg}	-65 to +200	^oC

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

2N3796, 2N3797 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Drain-Source Breakdown Voltage	BV_{DSX}				Vdc
(V_{GS} = -4.0 V, I_D = 5.0 μA) 2N3796		25	30	—	
(V_{GS} = -7.0 V, I_D = 5.0 μA) 2N3797		20	25	—	
Zero-Gate-Voltage Drain Current	I_{DSS}				mAdc
(V_{DS} = 10 V, V_{GS} = 0) 2N3796		0.5	1.5	3.0	
2N3797		2.0	2.9	6.0	
Gate-Source Voltage Cutoff	$V_{GS(off)}$				Vdc
(I_D = 0.5 μA, V_{DS} = 10 V) 2N3796		—	3.0	4.0	
(I_D = 2.0 μA, V_{DS} = 10 V) 2N3797		—	5.0	7.0	
"On" Drain Current	$I_{D(on)}$				mAdc
(V_{DS} = 10 V, V_{GS} = +3.5 V) 2N3796		7.0	8.3	14	
2N3797		9.0	14	18	
Drain-Gate Reverse Current *	I_{DGO} *				pAdc
(V_{DG} = 10 V, I_S = 0)		—	—	1.0	
Gate-Reverse Current *	I_{GSS} *				pAdc
(V_{GS} = -10 V, V_{DS} = 0)		—	—	1.0	
(V_{GS} = -10 V, V_{DS} = 0, T_A = 150°C)		—	—	200	
Small-Signal, Common-Source Forward Transfer Admittance	$\|y_{fs}\|$				μmhos
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 kHz) 2N3796		900	1200	1800	
2N3797		1500	2300	3000	
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 MHz) 2N3796		900	—	—	
2N3797		1500	—	—	
Small-Signal, Common-Source, Output Admittance	$\|y_{os}\|$				μmhos
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 kHz) 2N3796		—	12	25	
2N3797		—	27	60	
Small-Signal, Common-Source, Input Capacitance	C_{iss}				pF
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 MHz) 2N3796		—	5.0	7.0	
2N3797		—	6.0	8.0	
Small-Signal, Common-Source, Reverse Transfer Capacitance	C_{rss}				pF
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 MHz)		—	0.5	0.8	
Noise Figure	NF				dB
(V_{DS} = 10 V, V_{GS} = 0, f = 1.0 kHz, R_S = 3 megohms)		—	3.8	—	

* This value of current includes both the FET leakage current as well as the leakage current associated with the test socket and fixture when measured under best attainable conditions.

TYPICAL DRAIN CHARACTERISTICS

FIGURE 1 — 2N3796

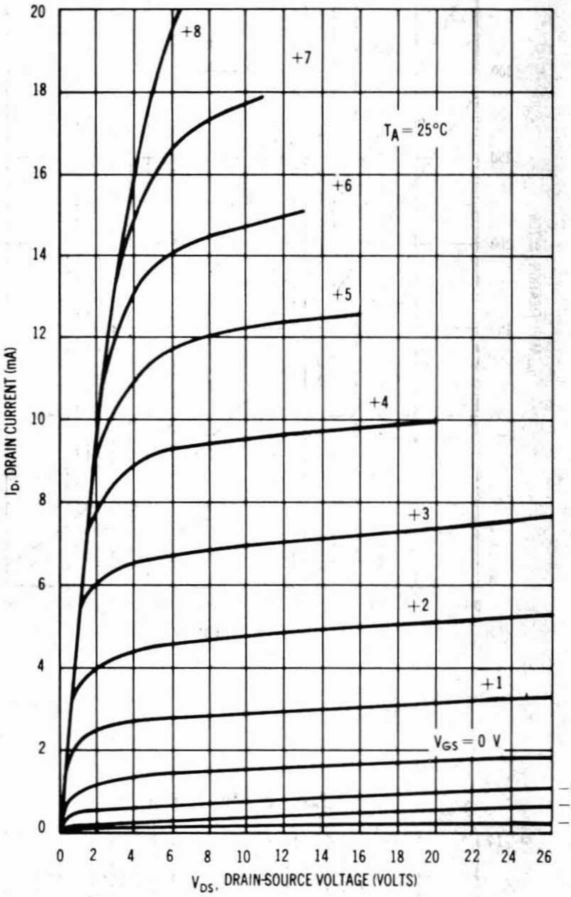
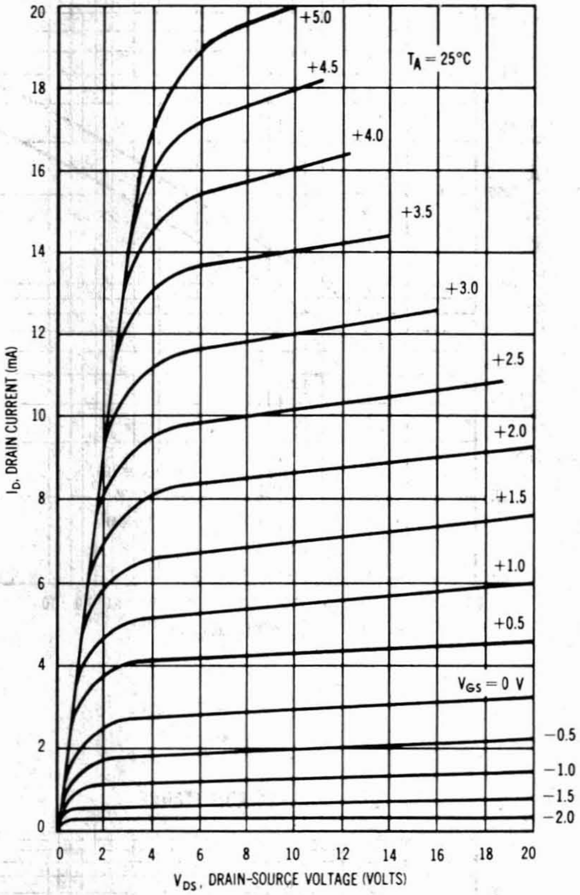


FIGURE 2 — 2N3797



COMMON SOURCE TRANSFER CHARACTERISTICS

FIGURE 3 — 2N3796

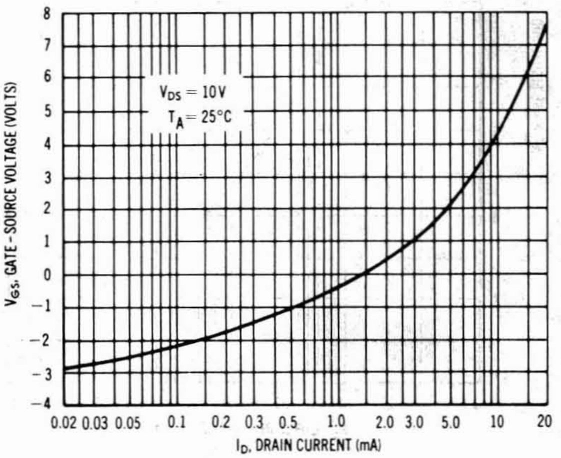


FIGURE 4 — 2N3797

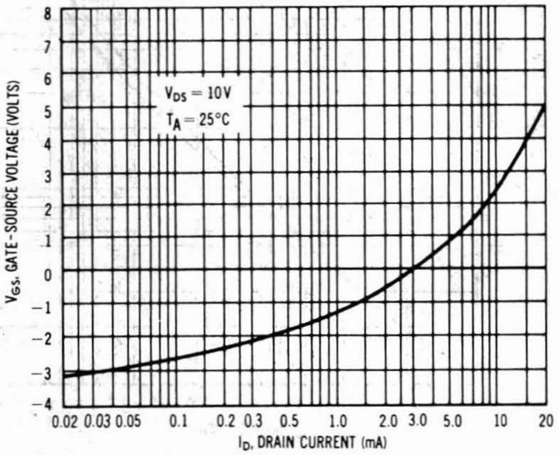


FIGURE 5 — FORWARD TRANSFER ADMITTANCE

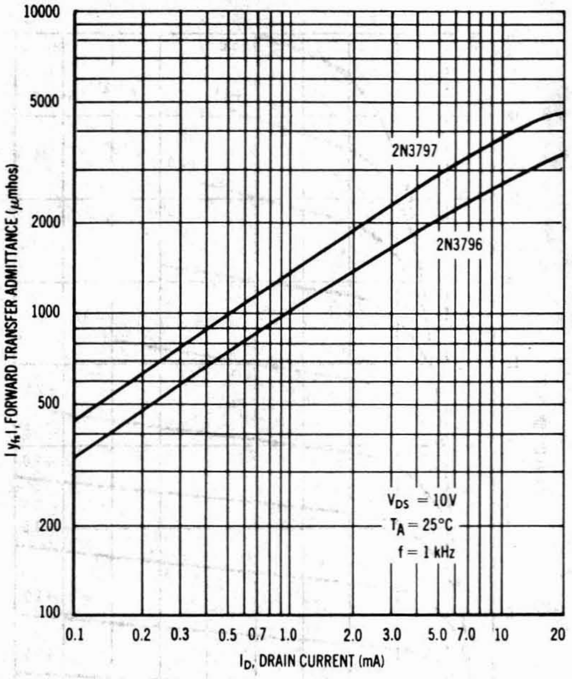


FIGURE 6 — AMPLIFICATION FACTOR

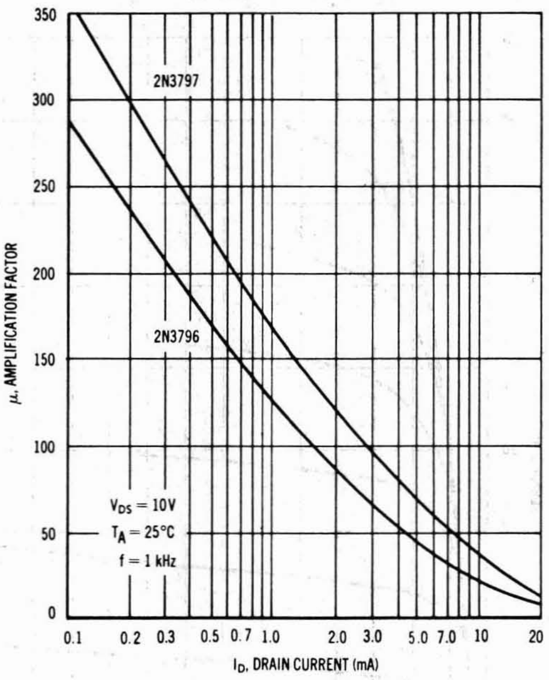


FIGURE 7 — OUTPUT ADMITTANCE

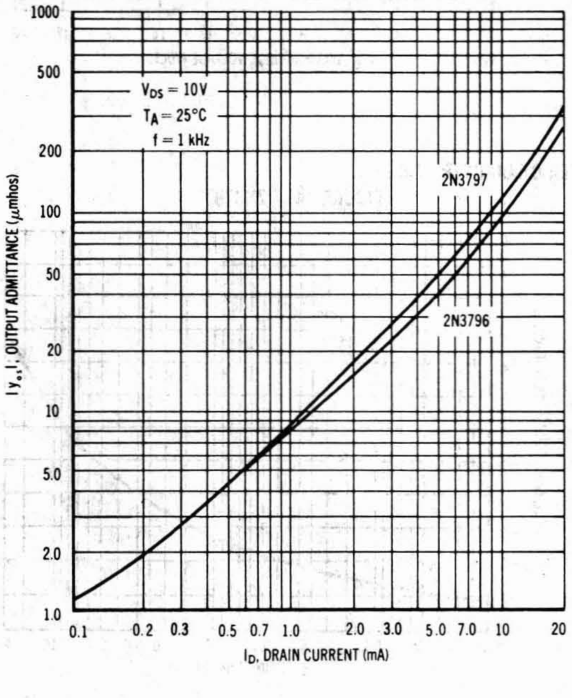
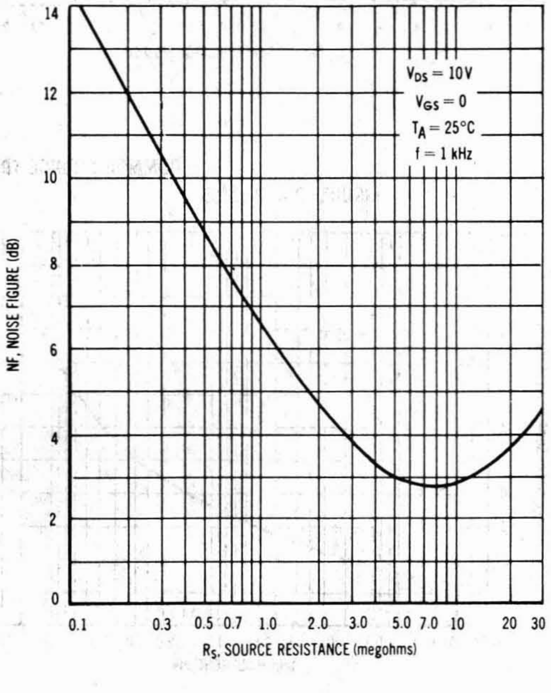


FIGURE 8 — NOISE FIGURE



2N3798 (SILICON)
2N3799

CASE 22
(TO-18)

PNP silicon annular transistors for low-level, low-noise amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ T_C = 25°C Derating Factor Above 25°C	P_D	1.2 6.9	Watts mW/°C
Total Device Dissipation @ T_A = 25°C Derating Factor Above 25°C	P_D	0.36 2.06	Watt mW/°C
Junction Operating Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

2N3798, 2N3799 (continued)

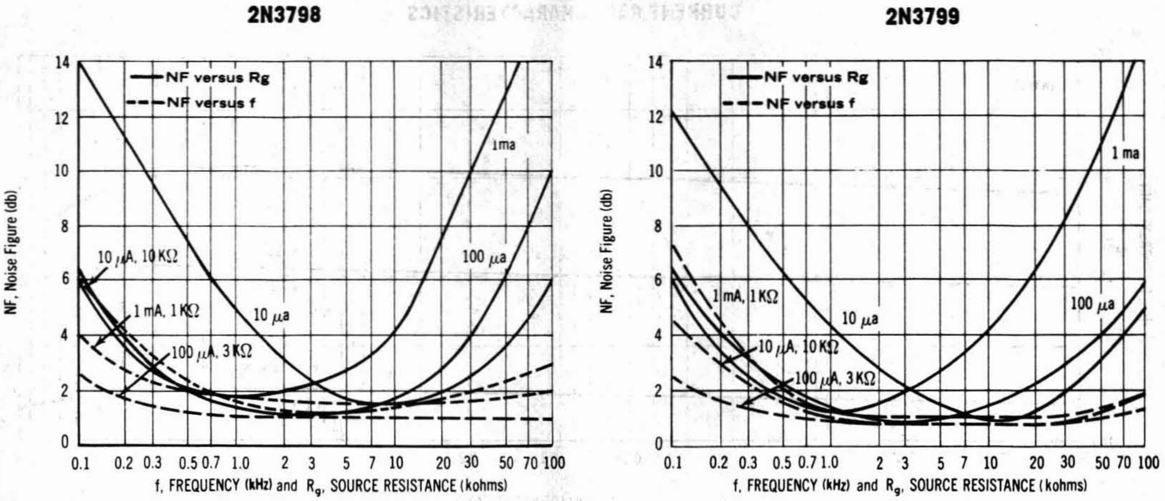
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	BV_{CBO}	60	—	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	60	90	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)	BV_{EBO}	5	—	—	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	—	—	.010 10	µAdc
Emitter Cutoff Current (V_{OB} = 4 Vdc, I_C = 0)	I_{EBO}	—	—	20	nAdc
Collector-Emitter Saturation Voltage* (I_C = 100 µAdc, I_B = 10 µAdc)	$V_{CE(sat)}$*	—	—	0.2	Vdc
(I_C = 1 mAdc, I_B = 100 µAdc)		—	—	0.25	
Base-Emitter Saturation Voltage* (I_C = 100 µAdc, I_B = 10 µAdc)	$V_{BE(sat)}$*	—	—	0.7	Vdc
(I_C = 1 mAdc, I_B = 100 µAdc)		—	—	0.8	
DC Forward Current Transfer Ratio* (I_C = 1 µAdc, V_{CE} = 5 Vdc) 2N3799	h_{FE}*	75	—	—	—
(I_C = 10 µAdc, V_{CE} = 5 Vdc) 2N3798		100	—	—	
2N3799		225	—	—	
(I_C = 100 µAdc, V_{CE} = 5 Vdc) 2N3798		150	—	450	
2N3799		300	—	900	
(I_C = 100 µAdc, V_{CE} = 5 Vdc, T_A = -55°C) 2N3798		75	—	—	
2N3799		150	—	—	
(I_C = 500 µAdc, V_{CE} = 5 Vdc) 2N3798		150	—	450	
2N3799		300	—	900	
(I_C = 1 mAdc, V_{CE} = 5 Vdc) 2N3798		150	—	450	
2N3799		300	—	900	
(I_C = 10 mAdc, V_{CE} = 5 Vdc) 2N3798		125	—	—	
2N3799		250	—	—	
Base Emitter "ON" Voltage (I_C = 100 µAdc, V_{CE} = 5 V)	$V_{BE(ON)}$	—	—	0.7	Vdc
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	—	4	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	—	8	pF
Small Signal Current Gain (I_C = 500 µA, V_{CE} = 5 V, f = 30 MHz)	h_{fe}	1.0	—	—	—
(I_C = 1 mA, V_{CE} = 5 V, f = 100 MHz)		1.0	—	5.0	
(I_C = 1 mA, V_{CE} = 10 V, f = 1 kHz) 2N3798		150	—	600	
2N3799		300	—	900	
Voltage Feedback Ratio (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	h_{re}	—	—	25	$X10^{-4}$
Input Impedance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz) 2N3798	h_{ie}	3	—	15	k ohms
2N3799		10	—	40	
Output Admittance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	h_{oe}	5	—	60	µmhos
Noise Figure (I_C = 100 µA, V_{CE} = 10 V, R_G = 3 k Ω) f = 100 Hz 2N3798	NF	—	4	7	dB
2N3799		—	2.5	4	
f = 1 kHz 2N3798		—	1.5	3	
2N3799		—	0.8	1.5	
f = 10 kHz 2N3798		—	1.0	2.5	
2N3799		—	0.8	1.5	
Noise Bandwidth 10 Hz to 15.7 kHz 2N3798		—	2.5	3.5	
2N3799		—	1.5	2.5	

* Pulse Test ≤ 300 µs, duty cycle ≤ 2% V_{OB} - Base-Emitter Reverse Bias

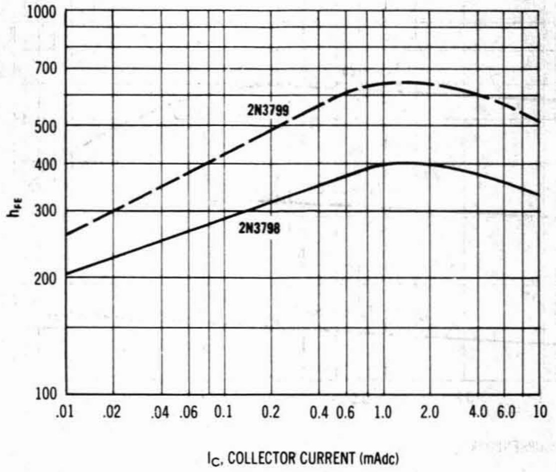
2N3798, 2N3799 (continued)

NOISE FIGURE versus FREQUENCY AND SOURCE RESISTANCE

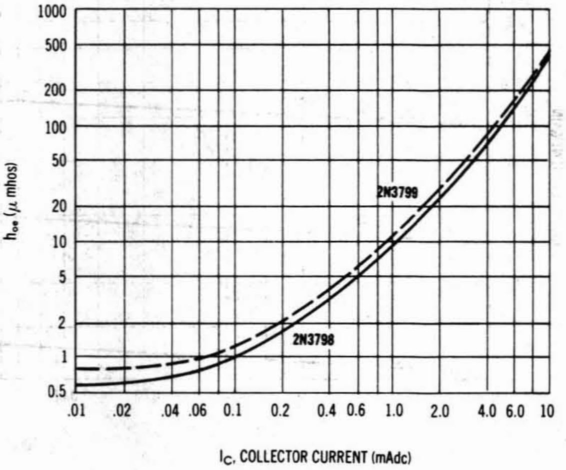

2N3798

2N3799

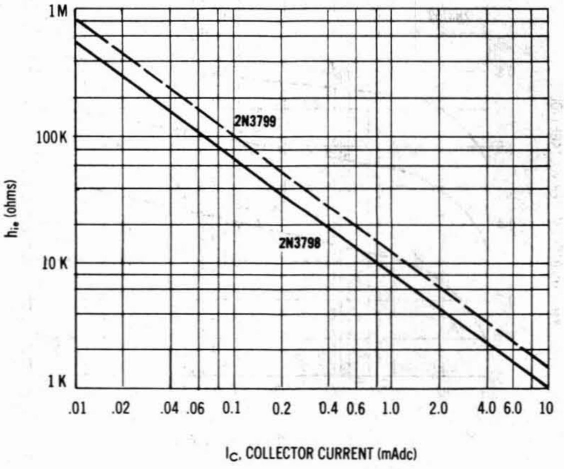
CURRENT GAIN



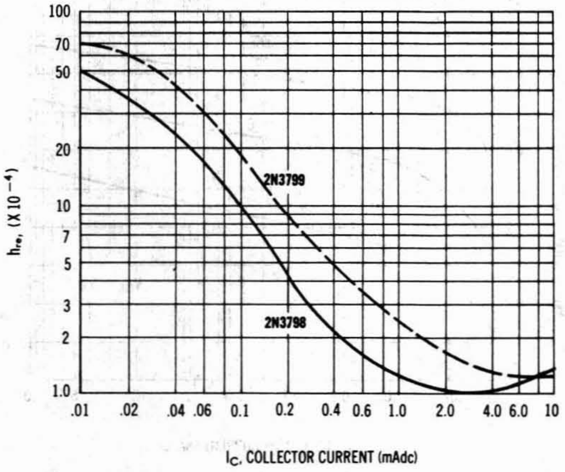
OUTPUT ADMITTANCE



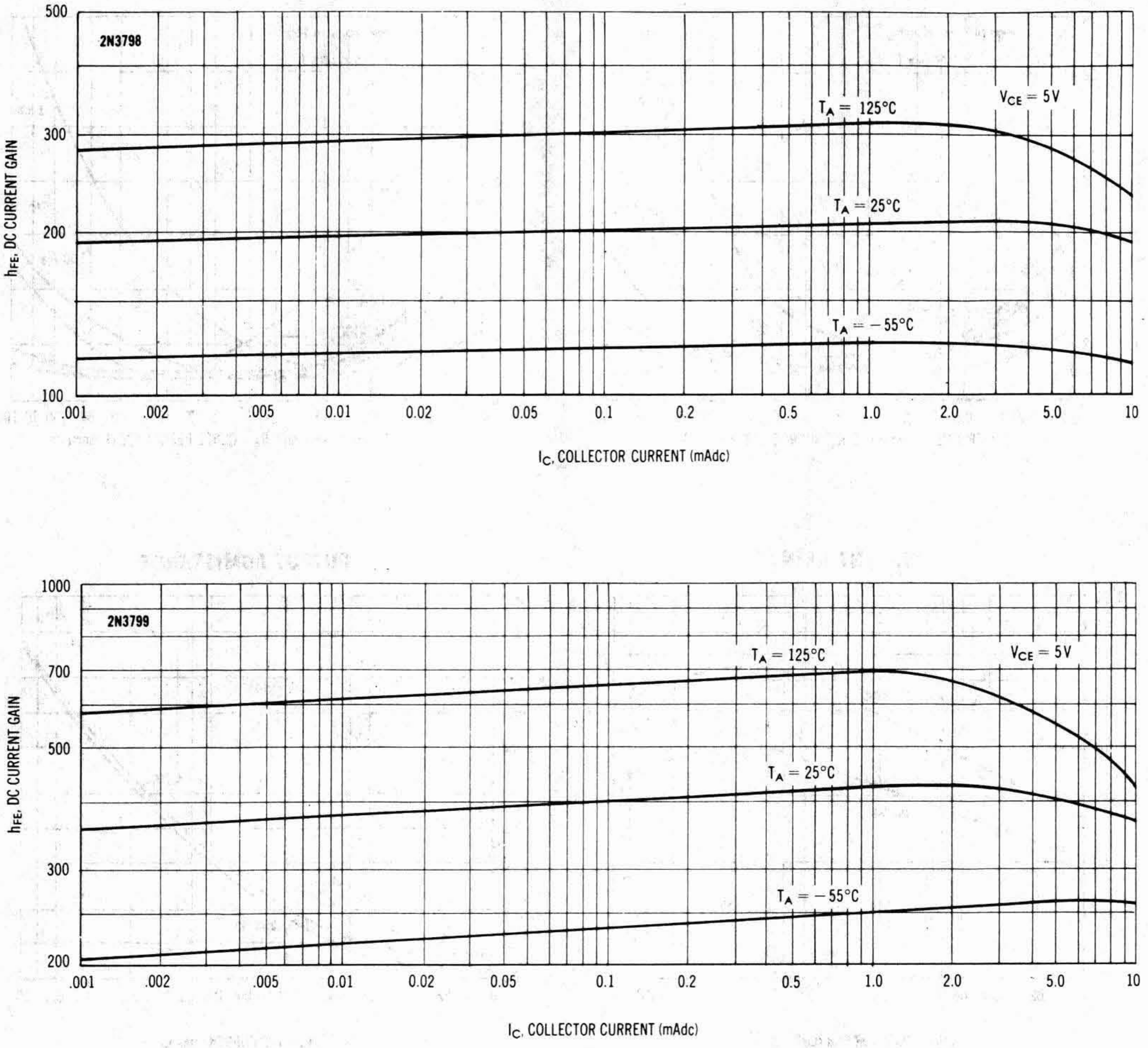
INPUT IMPEDANCE



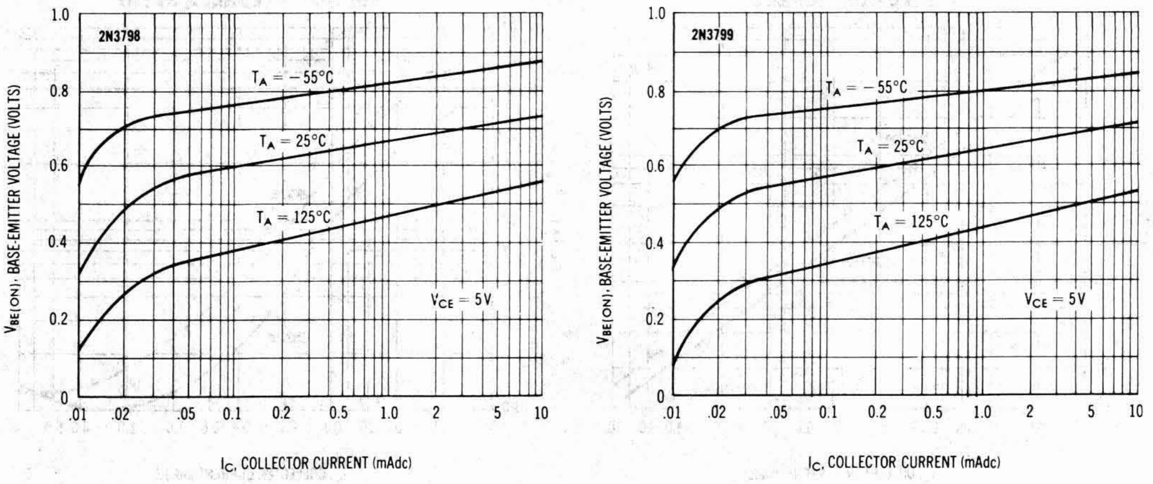
VOLTAGE FEEDBACK RATIO



CURRENT GAIN CHARACTERISTICS



BASE-EMITTER "ON" VOLTAGE versus TEMPERATURE

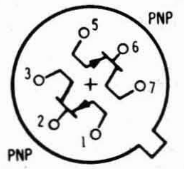


2N3800 thru 2N3817 (SILICON)

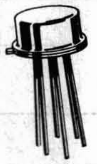
Dual PNP silicon annular transistors specifically designed for differential amplifier applications.

CASE 35
(TO-71)

2N3800
thru
2N3805

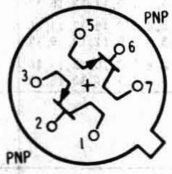


PINS 4 AND 8 OMITTED

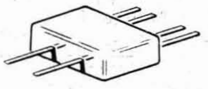


CASE 32 C

2N3806
thru
2N3811

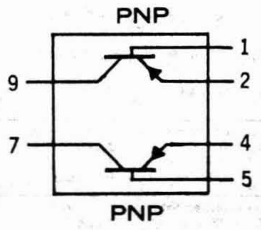


PINS 4 AND 8 OMITTED



CASE 33
(TO-89)

2N3812
thru
2N3817



Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	60		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	50		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ $T_A = 25°C$	P_D			
Metal Can (2N3800 thru 2N3811)		250	360	mW
Derate above 25°C		1.5	2.06	mW/°C
Flat Package (2N3812 thru 2N3817)		250	350	mW
Derate above 25°C		1.5	2.0	mW/°C

2N3800 thru 2N3817 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)
Characteristics apply also to corresponding flat package type numbers

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)		BV_{CEO}*	60		—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	60	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	—	—	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0)		I_{CBO}	—	—	0.01	μAdc
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)			—	—	10	
Emitter Cutoff Current ($V_{BE(off)}$ = 4.0 Vdc, I_C = 0)		I_{EBO}	—	—	20	nAdc
ON CHARACTERISTICS						
DC Current Gain* (I_C = 1.0 μAdc, V_{CE} = 5.0 Vdc)	2N3801, 3, 5, 7, 9, 11, 13, 15, 17	h_{FE}*	75	—	—	—
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16		100	—	—	
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		225	—	—	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16		150	—	450	
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		300	—	900	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16		75	—	—	
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		150	—	—	
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16		150	—	450	
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		300	—	900	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16		150	—	450	
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		300	—	900	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16		125	—	—	
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		250	—	—	
Collector-Emitter Saturation Voltage* (I_C = 100 μAdc, I_B = 10 μAdc)		$V_{CE(sat)}$*	—	—	0.2	Vdc
(I_C = 1.0 mAdc, I_B = 100 μAdc)			—	—	0.25	
Base-Emitter Saturation Voltage* (I_C = 100 μAdc, I_B = 10 μAdc)		$V_{BE(sat)}$*	—	—	0.7	Vdc
(I_C = 1.0 mAdc, I_B = 100 μAdc)			—	—	0.8	
Base-Emitter On Voltage (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)		$V_{BE(on)}$	—	—	0.7	Vdc
SMALL SIGNAL CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 30 MHz)		f_T	30	—	—	MHz
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 100 MHz)			100	—	500	
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	—	4.0	pF
Input Capacitance ($V_{BE(off)}$ = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	—	8.0	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16	h_{ie}	3.0	—	15	k ohms
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		10	—	40	
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{re}	—	—	25	X 10^{-4}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16	h_{fe}	150	—	600	—
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		300	—	900	
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{oe}	5.0	—	60	μmhos
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms,		NF				dB
f = 100 Hz)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16		—	4.0	7.0	
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		—	2.5	4.0	
f = 1.0 kHz)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16		—	1.5	3.0	
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		—	0.8	1.5	
f = 10 kHz)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16		—	1.0	2.5	
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		—	0.8	1.5	
Noise Bandwidth = 10 Hz to 15.7 kHz)	2N3800, 2, 4, 6, 8, 10, 12, 14, 16		—	2.5	3.5	
	2N3801, 3, 5, 7, 9, 11, 13, 15, 17		—	1.5	2.5	
MATCHING CHARACTERISTICS						
DC Current Gain Ratio** (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	2N3802, 3, 8, 9, 14, 15	h_{FE1}/h_{FE2}**	0.8	—	1.0	—
	2N3804, 5, 10, 11, 16, 17		0.9	—	1.0	
Base Voltage Differential (I_C = 10 μAdc, to 10 mAdc, V_{CE} = 5.0 Vdc)	2N3802, 3, 8, 9, 14, 15	$\vert V_{BE1}-V_{BE2}\vert$	—	—	8.0	mVdc
	2N3804, 5, 10, 11, 16, 17		—	—	5.0	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	2N3802, 3, 8, 9, 14, 15		—	—	5.0	
	2N3804, 5, 10, 11, 16, 17		—	—	3.0	
Base Voltage Differential Gradient (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55 to +25°C)		$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$				μV/°C
	2N3802, 3, 8, 9, 14, 15		—	—	20	
	2N3804, 5, 10, 11, 16, 17		—	—	10	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = +25 to +125°C)						
	2N3802, 3, 8, 9, 14, 15		—	—	20	
	2N3804, 5, 10, 11, 16, 17		—	—	10	

*Pulse Test: Pulse width $\leq$300 μs, duty cycle $\leq$2% **The lowest h_{FE} reading is taken as h_{FE1} for this ratio.

SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE

FIGURE 1 — FREQUENCY EFFECTS

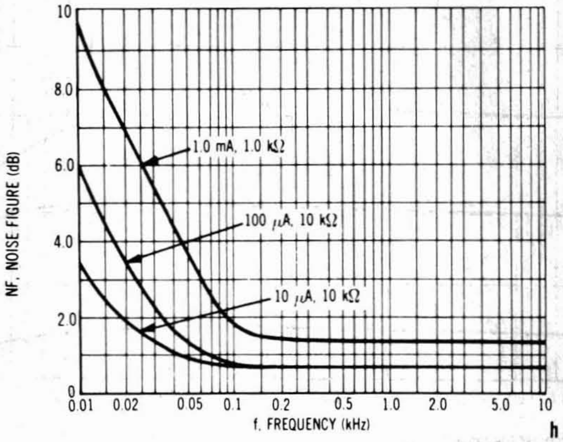
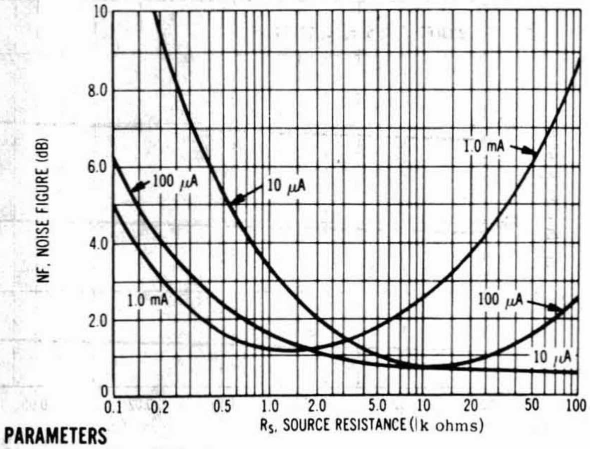


FIGURE 2 — SOURCE RESISTANCE EFFECTS



h PARAMETERS

V_{CE} = 10 Vdc, f = 1 kHz, T_A = 25°C

FIGURE 3 — INPUT IMPEDANCE

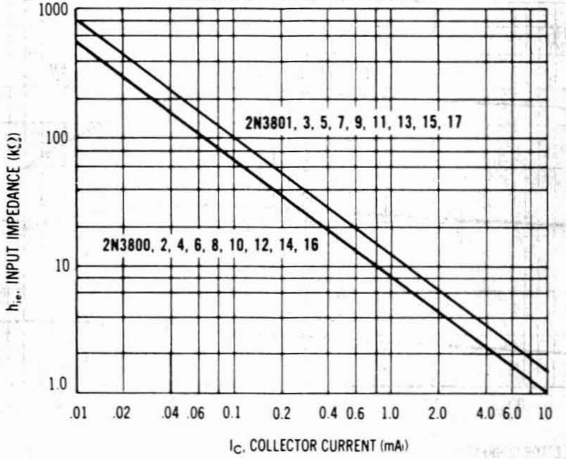


FIGURE 4 — VOLTAGE FEEDBACK RATIO

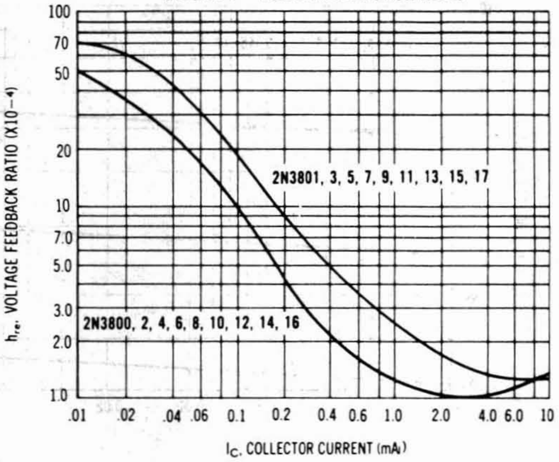


FIGURE 5 — CURRENT GAIN

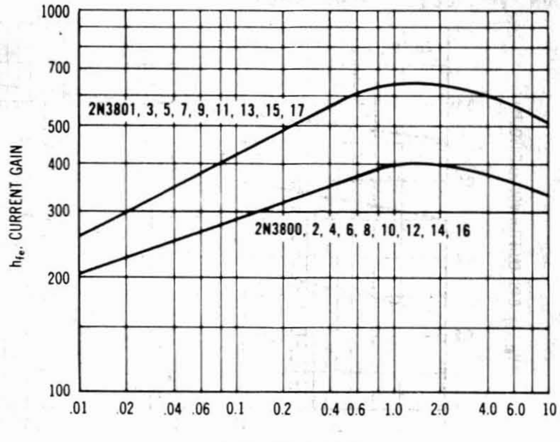


FIGURE 6 — OUTPUT ADMITTANCE

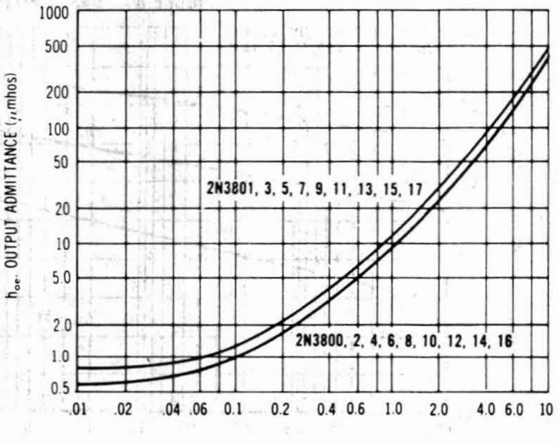


FIGURE 7 — TYPICAL CURRENT-GAIN CHARACTERISTICS

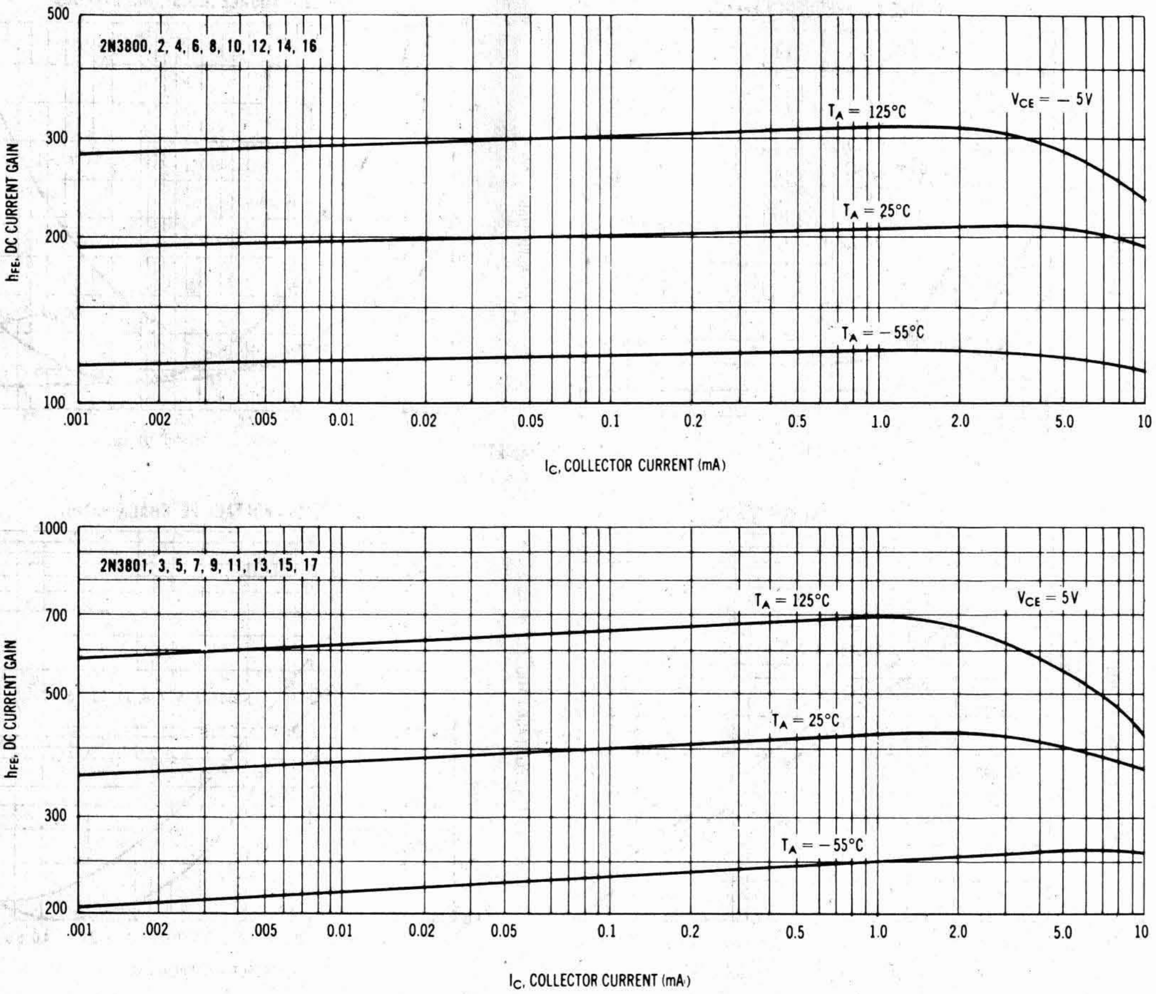
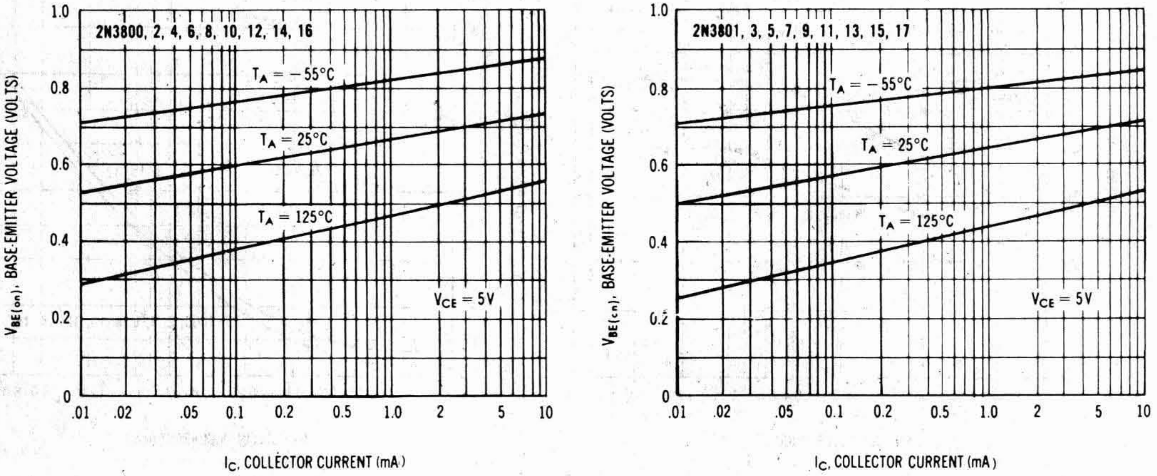


FIGURE 8 — BASE-EMITTER "ON" VOLTAGE versus TEMPERATURE

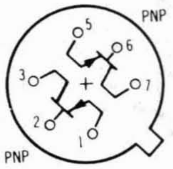


2N3804A, 2N3805A (SILICON)
2N3810A, 2N3811A
2N3816A, 2N3817A

Dual PNP silicon annular transistors specifically designed for differential amplifier applications.

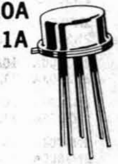
2N3804A
2N3805A

CASE 35
(TO-71)

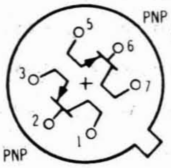


Pin Connections
Bottom View

2N3810A
2N3811A

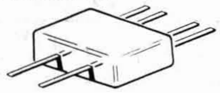


CASE 32C

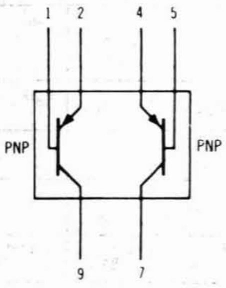


Pin Connections
Bottom View

2N3816A
and 2N3817A



CASE 33A
(TO-89)



Pin Connections
Bottom View

Lead 1 identified by square impression or dot on underside of case

All leads electrically isolated from case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	60		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	50		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ $T_A = 25°C$	P_D			
Metal Can (2N3804A and 2N3805A)		250	360	mW
Derate above 25°C		1.5	2.06	mW/°C
Metal Can (2N3810A and 2N3811A)		500	600	mW
Derate above 25°C		2.9	3.4	mW/°C
Flat Package (2N3816A and 2N3817A)		250	350	mW
Derate above 25°C		1.5	2.0	mW/°C

ELECTRICAL CHARACTERISTICS (each side) ($T_A = 25°C$ unless otherwise noted)

Characteristics apply also to corresponding flat package type numbers

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* ($I_C = 10$ mAdc, $I_B = 0$)	BV_{CEO}*	60		—	Vdc
Collector-Base Breakdown Voltage ($I_C = 10$ μAdc, $I_E = 0$)	BV_{CBO}	60	—	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10$ μAdc, $I_C = 0$)	BV_{EBO}	5.0	—	—	Vdc
Collector Cutoff Current ($V_{CB} = 50$ Vdc, $I_E = 0$) ($V_{CB} = 50$ Vdc, $I_E = 0$, $T_A = 150°C$)	I_{CBO}	— —	— —	0.01 10	μAdc
Emitter Cutoff Current ($V_{BE(off)} = 4.0$ Vdc, $I_C = 0$)	I_{EBO}	—	—	20	nAdc

2N3804A, 05A, 2N3810A, 11A, 2N3816A, 17A (continued)

(continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristics apply also to corresponding flat package type numbers

Characteristic	Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS					
DC Current Gain*	h_{FE}*				—
(I_C = 1.0 μAdc, V_{CE} = 5.0 Vdc) 2N3805A, 11A, 17A		75	—	—	
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc) 2N3804A, 10A, 16A		100	—	—	
2N3805A, 11A, 17A		225	—	—	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N3804A, 10A, 16A		150	—	450	
2N3805A, 11A, 17A		300	—	900	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C) 2N3804A, 10A, 16A		75	—	—	
2N3805A, 11A, 17A		150	—	—	
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc) 2N3804A, 10A, 16A		150	—	450	
2N3805A, 11A, 17A		300	—	900	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N3804A, 10A, 16A		150	—	450	
2N3805A, 11A, 17A		300	—	900	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc) 2N3804A, 10A, 16A		125	—	—	
2N3805A, 11A, 17A		250	—	—	
Collector-Emitter Saturation Voltage*	$V_{CE(sat)}$*				Vdc
(I_C = 100 μAdc, I_B = 10 μAdc)		—	—	0.2	
(I_C = 1.0 mAdc, I_B = 100 μAdc)		—	—	0.25	
Base-Emitter Saturation Voltage*	$V_{BE(sat)}$*				Vdc
(I_C = 100 μAdc, I_B = 10 μAdc)		—	—	0.7	
(I_C = 1.0 mAdc, I_B = 100 μAdc)		—	—	0.8	
Base-Emitter On Voltage (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	$V_{BE(on)}$	—	—	0.7	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product	f_T				MHz
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 30 MHz)		30	—	—	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 100 MHz)		100	—	500	
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	—	4.0	pF
Input Capacitance ($V_{BE(off)}$ = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	—	8.0	pF
Input Impedance	h_{ie}				kΩ
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3804A, 10A, 16A		3.0	—	15	
2N3805A, 11A, 17A		10	—	40	
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{re}	—	—	25	X 10^{-4}
Small-Signal Current Gain	h_{fe}				—
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) 2N3804A, 10A, 16A		150	—	600	
2N3805A, 11A, 17A		300	—	900	
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	5.0	—	60	μmhos
Noise Figure	NF				dB
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, f = 100 Hz) 2N2804A, 10A, 16A		—	4.0	7.0	
2N3805A, 11A, 17A		—	2.5	4.0	
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, f = 1.0 kHz) 2N3804A, 10A, 16A		—	1.5	3.0	
2N3805A, 11A, 17A		—	0.8	1.5	
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, f = 10 kHz) 2N3804A, 10A, 16A		—	1.0	2.5	
2N3805A, 11A, 17A		—	0.8	1.5	
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, Noise Bandwidth = 10 Hz to 15.7 kHz) 2N3804A, 10A, 16A		—	2.5	3.5	
2N3805A, 11A, 17A		—	1.5	2.5	
MATCHING CHARACTERISTICS					
DC Current Gain Ratio**	h_{FE1}/h_{FE2}**				—
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)		0.95	—	1.0	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C to +125°C)		0.85	—	1.0	
Base Voltage Differential	$\vert V_{BE1}-V_{BE2}\vert$				mVdc
(I_C = 10 μAdc to 10 mAdc, V_{CE} = 5.0 Vdc)		—	—	5.0	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)		—	—	1.5	
Base Voltage Differential Gradient	$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$				μV/°C
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C to +25°C)		—	—	5.0	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = +25°C to +125°C)		—	—	5.0	

*Pulse Test: Pulse width ≤300 μs, duty cycle ≤2% **The lowest h_{FE} reading is taken as h_{FE1} for this ratio.

SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE

FIGURE 1 — FREQUENCY EFFECTS

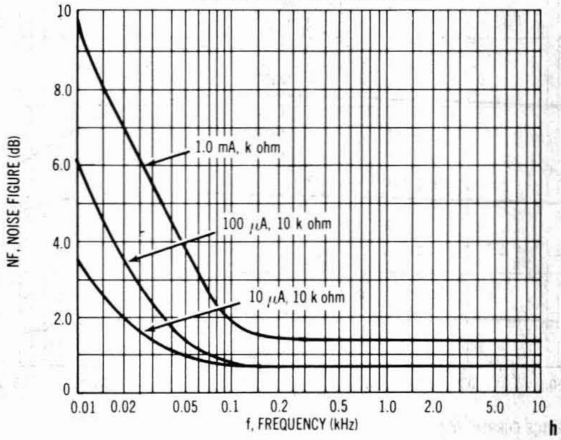
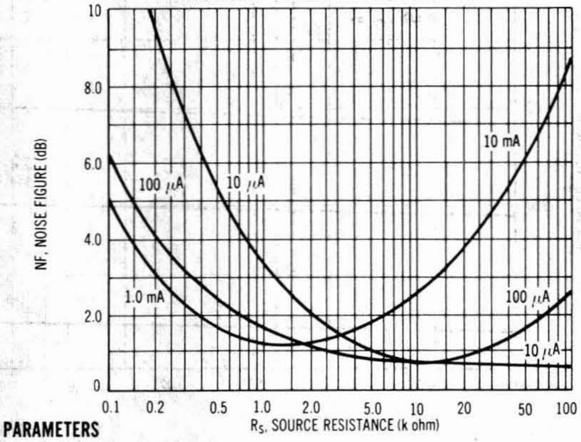


FIGURE 2 — SOURCE RESISTANCE EFFECTS



h PARAMETERS

$V_{CE} = 10$ Vdc, f = 1.0 kHz, $T_A = 25°C$

FIGURE 3 — INPUT IMPEDANCE

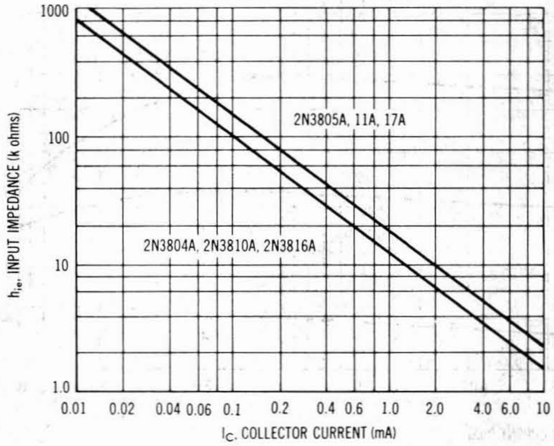


FIGURE 4 — VOLTAGE FEEDBACK RATIO

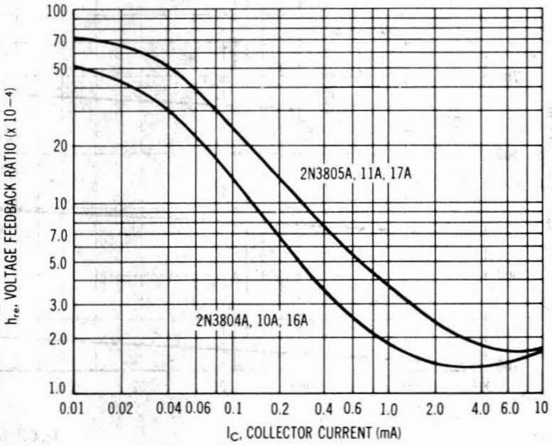


FIGURE 5 — CURRENT GAIN

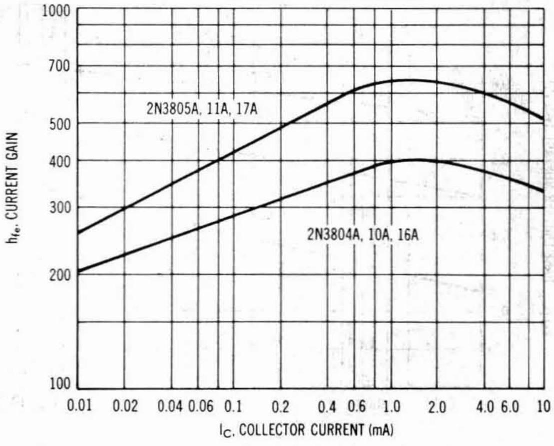


FIGURE 6 — OUTPUT ADMITTANCE

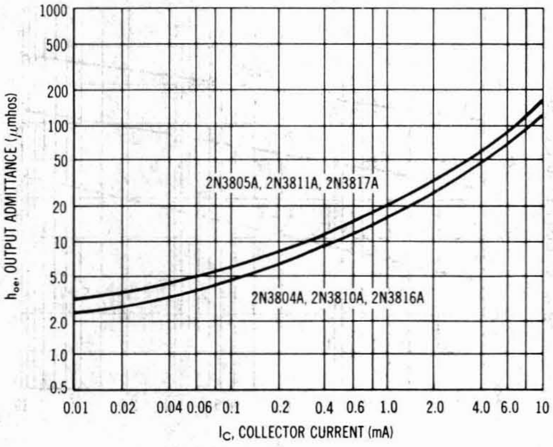


FIGURE 7 — TYPICAL CURRENT-GAIN CHARACTERISTICS

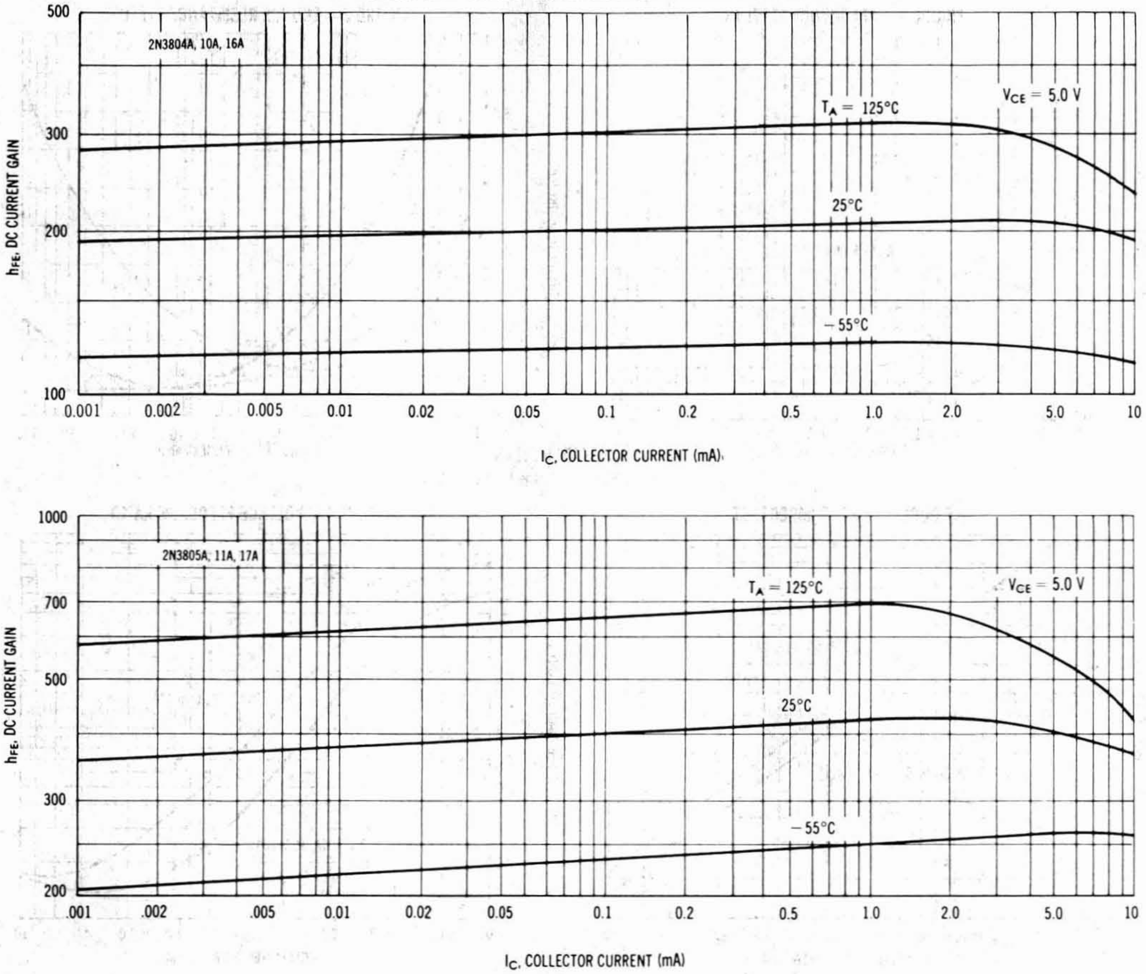
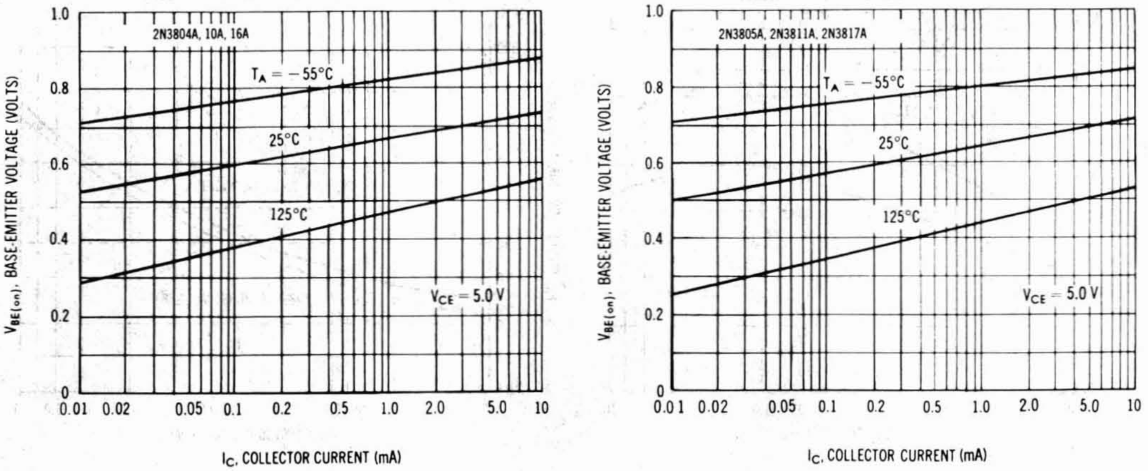


FIGURE 8 — BASE-EMITTER "ON" VOLTAGE versus TEMPERATURE



2N3818 (SILICON)

NPN silicon annular transistor for high-frequency power applications to 150 MHz.

All leads isolated from case

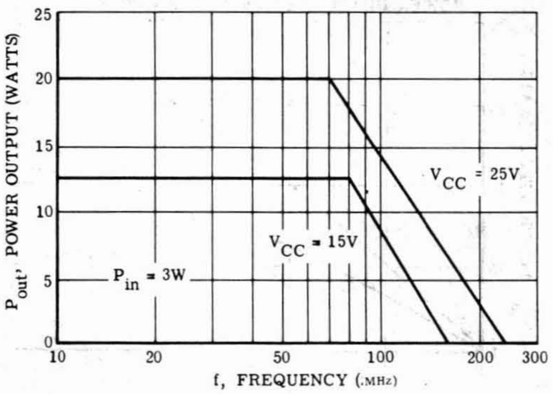
CASE 36
(TO-60)

MAXIMUM RATINGS *

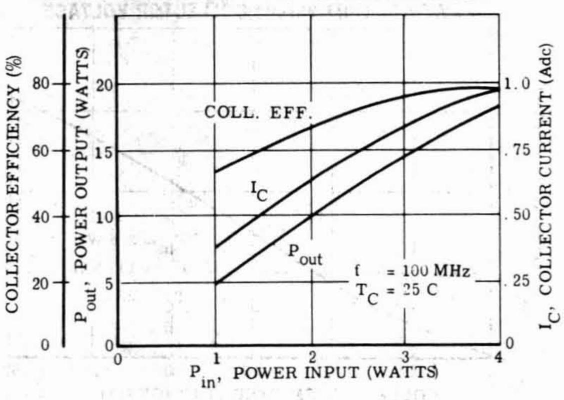
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CES}	60	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector-Current (continuous)	I_C	2.0	Adc
Base-Current (continuous)	I_B	1.0	mAdc
Power Input (Nominal)	P_{in}	5.0	Watts
Power Output (Nominal)	P_{out}	20.0	Watts
Total Device Dissipation @ 25°C Case Temperature	P_D	25.0	Watts
Derating Factor above 25°C		167	mW/°C
Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

* The maximum ratings as given for dc conditions can be exceeded on a pulse basis. See electrical characteristics.

POWER OUTPUT versus FREQUENCY



OUTPUT CHARACTERISTICS versus POWER OUT

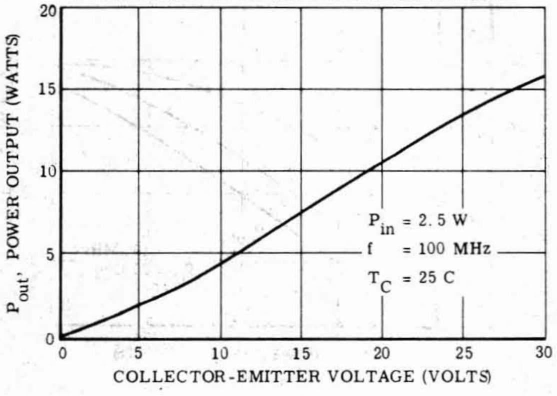


ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

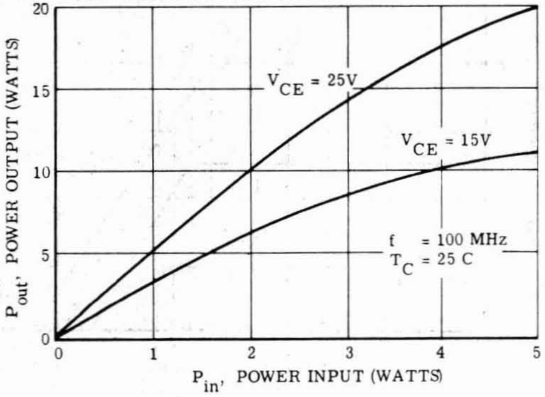
Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Emitter Sustain Voltage I_C = 0.25 Adc, R_{BE} = 0	$V_{CES(sus)}$*	80	100	--	Vdc
Collector-Emitter-Open Base Sustain Voltage I_C = 0.25 Adc, I_B = 0	$V_{CEO(sus)}$*	40	--	--	Vdc
Collector-Emitter Current V_{CE} = 60 Vdc, V_{BE} = 0 V_{CE} = 50 Vdc, V_{BE} = 0, T_C = 175°C	I_{CES}	-- --	-- --	0.5 1.0	mAdc
Collector Cutoff Current V_{CB} = 50 Vdc, I_E = 0	I_{CBO}	--	--	1	μAdc
Emitter Cutoff Current V_{EB} = 4 Vdc, I_C = 0	I_{EBO}	--	--	100	μAdc
DC Current Gain I_C = 400 mAdc, V_{CE} = 2 Vdc I_C = 1 Adc, V_{CE} = 2 Vdc	h_{FE}	5.0 5.0	-- --	50 --	
Collector-Emitter Saturation Voltage I_C = 1.0 Adc, I_B = 250 mAdc	$V_{CE(sat)}$	--	--	0.5	Vdc
Base-Emitter Saturation Voltage I_C = 1.0 Adc, I_B = 250 mAdc	$V_{BE(sat)}$	--	--	2.0	Vdc
AC Current Gain V_{CE} = 2.0 Vdc, I_C = 400 mAdc, f = 50 mc	$\|h_{fe}\|$	3	--	--	
Collector Output Capacitance V_{CB} = 25 Vdc, I_E = 0, f = 100 kHz	C_{ob}	--	--	40	pF
Power Input P_{out} = 15 W, f = 100 MHz, V_{CE} = 25 Vdc, $I_{C(max.)}$ = 1 Adc	P_{in}	--	3.0	3.75	Watts
Efficiency	η	60	70	--	%

*Pulse Measurement: Pulse Test: Pulse Width ≤ 100 μs, Duty Cycle ≤ 2.0%.

POWER OUTPUT versus COLLECTOR VOLTAGE

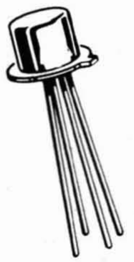


POWER OUTPUT versus POWER INPUT

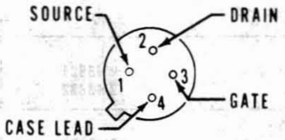


2N3821 (SILICON)
2N3822
2N3824

N-channel junction silicon field-effect transistors designed for audio amplifier, chopper and switching applications.



CASE 20(1)
(TO-72)



Drain and Source may be interchanged.

MAXIMUM RATINGS ($T_A = 25°C$)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	50	Vdc
Drain-Gate Voltage	V_{DG}	50	Vdc
Gate-Source Voltage	V_{GS}	50	Vdc
Drain Current	I_D	10	mAdc
Power Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 2	mW mW/°C
Operating Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to + 200	°C

2N3821, 2N3822, 2N3824 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = -1 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	50	-	Vdc
Gate Reverse Current (V_{GS} = -30 Vdc, V_{DS} = 0)		I_{GSS}	-	0.1	nAdc
(V_{GS} = -30 Vdc, V_{DS} = 0, T_A = 150°C)			-	100	
Gate-Source Cutoff Voltage (I_D = 0.5 nAdc, V_{DS} = 15 Vdc)	2N3821	$V_{GS(off)}$	-	4	Vdc
	2N3822		-	6	
Gate-Source Voltage (I_D = 50 μAdc, V_{DS} = 15 Vdc)	2N3821	V_{GS}	0.5	2.0	Vdc
(I_D = 200 μAdc, V_{DS} = 15 Vdc)	2N3822		1.0	4.0	
Drain Cutoff Current (V_{DS} = 15 Vdc, V_{GS} = -8 Vdc)	2N3824	$I_{D(off)}$	-	0.1	nAdc
(V_{DS} = 15 Vdc, V_{GS} = -8 Vdc, T_A = 150°C)	2N3824		-	100	
ON CHARACTERISTICS					
Zero-Gate-Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0)	2N3821	I_{DSS}*	0.5	2.5	mAdc
	2N3822		2.0	10	
DYNAMIC CHARACTERISTICS					
Forward Transfer Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 kHz)*	2N3821	$\lvert y_{fs} \rvert$	1500	4500	μmhos
	2N3822		3000	6500	
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)	2N3821		1500	-	
	2N3822		3000	-	
Output Admittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 kHz)	2N3821	$\lvert y_{os} \rvert$*	-	10	μmhos
	2N3822		-	20	
Drain-Source Resistance (V_{GS} = 0, I_D = 0, f = 1 kHz)	2N3824	$r_{ds(on)}$	-	250	Ohms
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)		C_{iss}	-	6	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)	2N3821	C_{rss}	-	3	pF
	2N3822		-	3	
(V_{GS} = -8 Vdc, V_{DS} = 0, f = 1 MHz)	2N3824		-	3	
Average Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_S = 1 megohm, f = 10 Hz, Noise Bandwidth = 5 Hz)	2N3821, 2N3822	NF	-	5	dB
Equivalent Input Noise Voltage (V_{DS} = 15 Vdc, V_{GS} = 0, f = 10 Hz, Noise Bandwidth = 5 Hz)	2N3821, 2N3822	e_n	-	200	nv/Hz$^{\frac{1}{2}}$

*Pulse Test: Pulse Width ≤ 100 ms, Duty Cycle ≤ 10%

2N3823 (SILICON)

CASE 20 (1)
(TO-72)

Silicon N-channel junction field-effect transistor designed for VHF amplifier and mixer applications. Drain and source may be interchanged.

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	30	Vdc
Gate Current	I_G	10	mAdc
Power Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 2	mW mW/°C
Operating Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

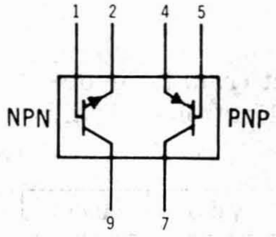
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage ($I_G = -1\ \mu$Adc, $V_{DS} = 0$)	$V_{(BR)GSS}$	30	-	Vdc
Gate Reverse Current ($V_{GS} = -20$ Vdc, $V_{DS} = 0$) ($V_{GS} = -20$ Vdc, $V_{DS} = 0$, $T_A = 150°C$)	I_{GSS}	- -	0.50 500	nAdc
Gate-Source Cutoff Voltage ($I_D = 0.50$ nAdc, $V_{DS} = 15$ Vdc)	$V_{GS(off)}$	-	8	Vdc
Gate-Source Voltage ($I_D = 0.4$ mAdc, $V_{DS} = 15$ Vdc)	V_{GS}	1.0	7.5	Vdc
ON CHARACTERISTICS				
Zero-Gate-Voltage Drain Current* ($V_{DS} = 15$ Vdc, $V_{GS} = 0$)	I_{DSS}*	4	20	mAdc
DYNAMIC CHARACTERISTICS				
Forward Transfer Admittance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1 kHz)* ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 200 MHz)	$\|y_{fs}\|$*	3500 3200	6500 -	μmhos
Input Conductance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 200 MHz)	$Re(y_{is})$	-	800	μmhos
Output Conductance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1 kHz)* ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 200 MHz)	$\|y_{os}\|$* $Re(y_{os})$	- -	35 200	μmhos
Input Capacitance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1 MHz)	C_{iss}	-	6	pF
Reverse Transfer Capacitance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1 MHz)	C_{rss}	-	2	pF
Common-Source Spot Noise Figure ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, $R_S = 1000$ ohms, f = 100 MHz)	NF	-	2.5	dB

*Pulse Test: Pulse Width = 100 ms, Duty Cycle ≤ 10%

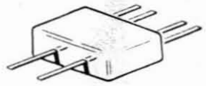
2N3824

For Specifications, See 2N3821 Data.

2N3838 (SILICON)


1
2
4
5
NPN
PNP
9
7

Pin Connections, Bottom View



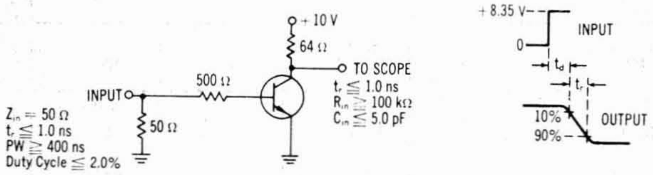
CASE 33
(TO-89)

NPN-PNP complementary pair silicon annular transistor designed for switching and general purpose amplifier applications.

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage (Applicable from 0 to 10 mAdc)	V_{CEO}	40		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current — Continuous	I_C	600		mAdc
Operating Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D	0.25	0.35	Watt
Derate above 25°C		1.67	2.34	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	0.7	1.4	Watt
Derate above 25°C		4.67	9.34	mW/°C

FIGURE 1 — TURN-ON TIME TEST CIRCUIT


+10 V
64 Ω
TO SCOPE
$t_r \leq 1.0$ ns
$R_{in} \geq 100$ kΩ
$C_{in} \leq 5.0$ pF
500 Ω
INPUT
$Z_{in} = 50$ Ω
$t_r \leq 1.0$ ns
PW ≧ 400 ns
Duty Cycle ≦ 2.0%
50 Ω
+8.35 V
0
INPUT
t_d
t_r
10%
90%
OUTPUT

(Reverse voltage polarities when testing the PNP unit.)

FIGURE 2 — TURN-OFF TIME TEST CIRCUIT

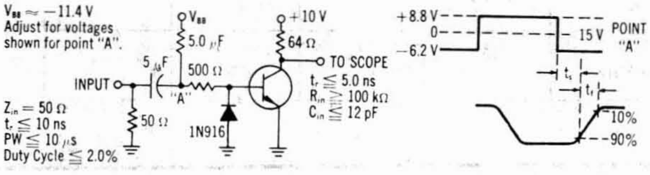
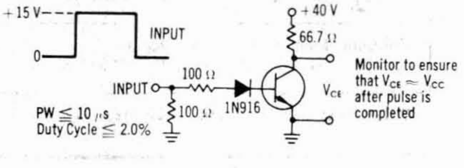

$V_{BB} \approx -11.4$ V
Adjust for voltages shown for point "A".
V_{BB}
5.0 μF
+10 V
64 Ω
TO SCOPE
$t_r \leq 5.0$ ns
$R_{in} \geq 100$ kΩ
$C_{in} \leq 12$ pF
5 μF
500 Ω
INPUT
"A"
$Z_{in} = 50$ Ω
$t_r \leq 10$ ns
PW ≦ 10 μs
Duty Cycle ≦ 2.0%
50 Ω
1N916
+8.8 V
0
−6.2 V
15 V
POINT "A"
t_s
t_f
10%
90%

FIGURE 3 — COLLECTOR-EMITTER NONLATCHING VOLTAGE TEST CIRCUIT


+15 V
0
INPUT
+40 V
66.7 Ω
100 Ω
INPUT
100 Ω
1N916
V_{CE}
PW ≦ 10 μs
Duty Cycle ≦ 2.0%
Monitor to ensure that $V_{CE} \approx V_{CC}$ after pulse is completed

2N3838 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	40	-	Vdc
Collector-Emitter Nonlatching Voltage (Figure 3)† ($I_{C(on)}$ = 600 mAdc, $I_{B(on)}$ = 120 mAdc, $I_{B(off)}$ = 0)	$V_{CEO(NL)}$†	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 50 Vdc, $V_{BE(off)}$ = 0.5 Vdc) (V_{CE} = 50 Vdc, $V_{BE(off)}$ = 0.5 Vdc, T_A = 150°C)	I_{CEV}	 - -	 0.01 10	μAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	10	nAdc
Base Cutoff Current (V_{CE} = 50 Vdc, $V_{BE(off)}$ = 0.5 Vdc)	I_{BEV}	-	10	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) (I_C = 1.0 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc)* (I_C = 150 mAdc, V_{CE} = 10 Vdc)* (I_C = 150 mAdc, V_{CE} = 1.0 Vdc)*	h_{FE}	 35 50 75 100 50	 - - - 300 -	-
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$*	-	0.4	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$*	0.85	1.3	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	200	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	8.0	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}	1.5	9.0	k ohm
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	60	300	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	-	50	μmho
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 1.0 k ohm, f = 1.0 kHz)	NF	-	8.0	dB
Delay Time (V_{CC} = 10 Vdc, $V_{BE(off)}$ = 0 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc, Figure 1)	t_d	-	10	ns
Rise Time	t_r	-	40	ns
Storage Time (V_{CC} = 10 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc, Figure 2)	t_s	-	250	ns
Fall Time	t_f	-	90	ns

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

† The highest value of collector supply voltage that may be safely used with a resistive load switching circuit in which the collector current is 600 mAdc.

2N3839

For Specifications, See 2N2857 Data.

2N3866 (SILICON)

CASE 79
(TO-39)

NPN silicon transistor, designed for amplifier, frequency-multiplier, or oscillator applications in military and industrial equipment. Suitable for uses as output, driver, or pre-driver stages in VHF and UHF equipment.

Collector connected to case

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	55	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector Current	I_C	0.4	Amp
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	5 28.6	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

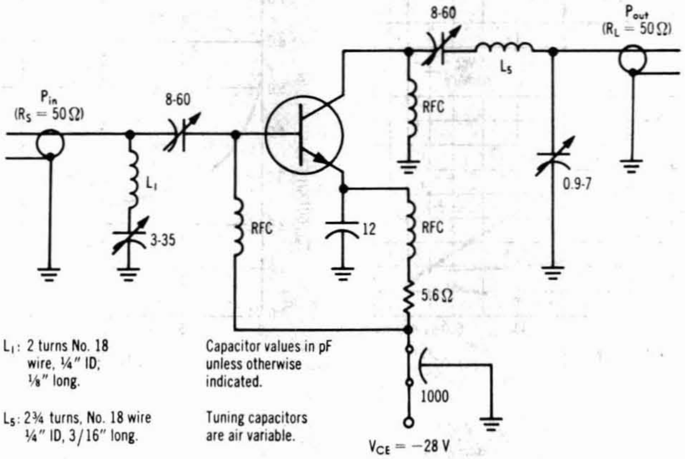
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage ($I_C = 5$ mAdc, $I_B = 0$)	$BV_{CEO(sus)}$	30	—	—	Vdc
Collector-Base Breakdown Voltage ($I_E = 0$, $I_C = 0.1$ mAdc)	BV_{CBO}	55	—	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 0.1$ mAdc, $I_C = 0$)	BV_{EBO}	3.5	—	—	Vdc
Collector Cutoff Current ($V_{CE} = 28$ Vdc, $I_B = 0$)	I_{CEO}	—	—	20	μA
ON CHARACTERISTICS					
DC Current Gain ($I_C = 0.36$ Adc, $V_{CE} = 5$ Vdc) ($I_C = 0.05$ Adc, $V_{CE} = 5$ Vdc)	h_{FE}	 5 10	 — —	 — 200	—
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product ($I_C = 50$ mAdc, $V_{CE} = 15$ Vdc, f = 200 MHz)	f_T	500	800	—	MHz
Output Capacitance ($V_{CB} = 30$ Vdc, $I_E = 0$, f = 1 MHz)	C_{ob}	—	2.0	3.0	pF

FUNCTIONAL TEST

Power Gain	Test Circuit-Figure 1 $P_{in} = 0.1$ W, $V_{CE} = 28$ Vdc f = 400 MHz, $T_C = 25°C$	G_{pe}	10	—	—	dB
Power Output		P_{out}	1.0	—	—	Watts
Collector Efficiency		η	45	—	—	%

FIGURE 1 — 400 MHz RF AMPLIFIER CIRCUIT FOR POWER-OUTPUT TEST


P_{in}
(R_S = 50 Ω)
8-60
L_1
3-35
RFC
12
RFC
5.6 Ω
1000
V_{CE} = −28 V
8-60
L_S
RFC
0.9-7
P_{out}
(R_L = 50 Ω)

L_1: 2 turns No. 18 wire, ¼″ ID; ⅛″ long.

L_S: 2¾ turns, No. 18 wire ¼″ ID, 3/16″ long.

Capacitor values in pF unless otherwise indicated.

Tuning capacitors are air variable.

FIGURE 2 — POWER OUTPUT versus FREQUENCY (Class C)

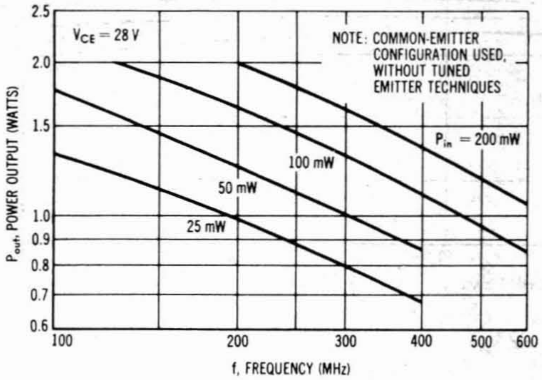


FIGURE 4 — PARALLEL INPUT RESISTANCE AND CAPACITANCE versus FREQUENCY (Class C)

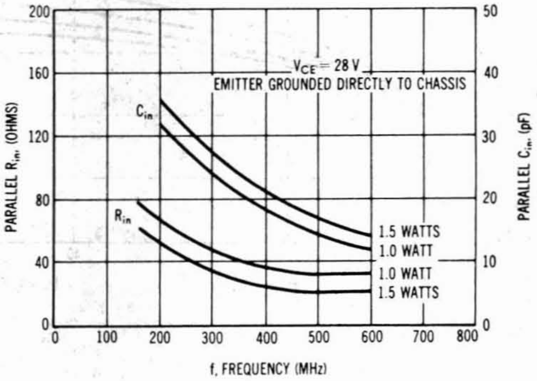


FIGURE 3 — POWER OUTPUT versus POWER INPUT (Class C)

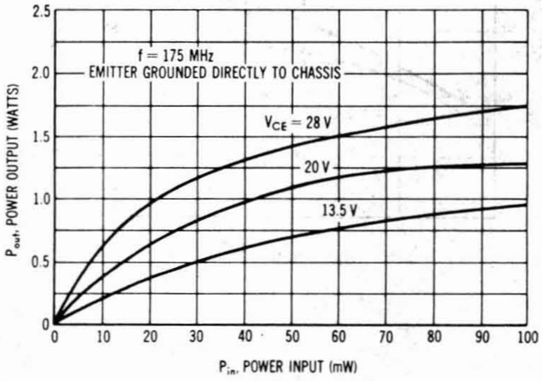


FIGURE 5 — PARALLEL OUTPUT CAPACITANCE versus FREQUENCY (Class C)

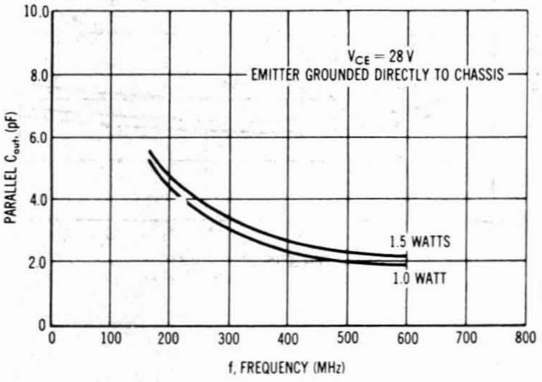


FIGURE 6 — SMALL-SIGNAL CURRENT GAIN versus FREQUENCY

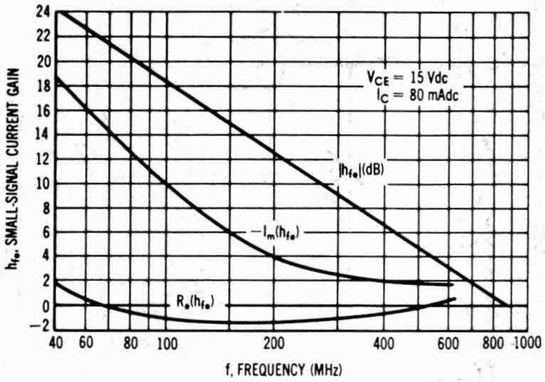


FIGURE 7 — OUTPUT CAPACITANCE versus COLLECTOR VOLTAGE

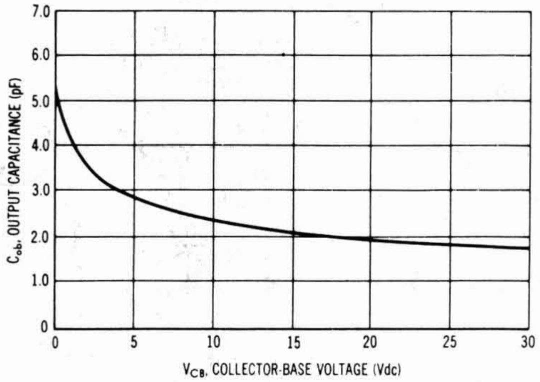


FIGURE 8 — f_T versus COLLECTOR CURRENT

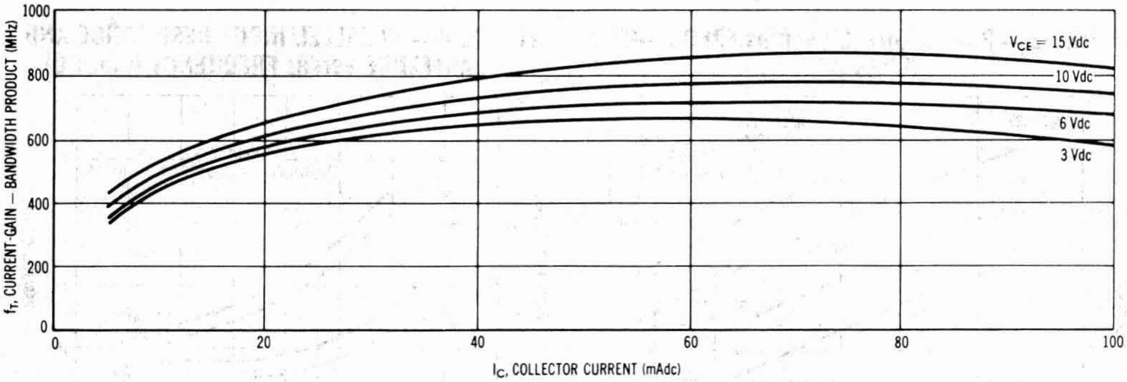


FIGURE 9 — $r_b'C_c$ versus COLLECTOR CURRENT

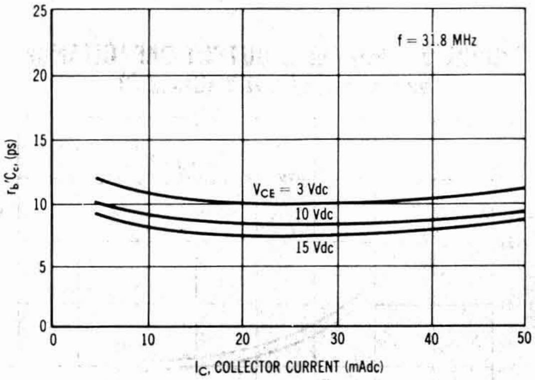
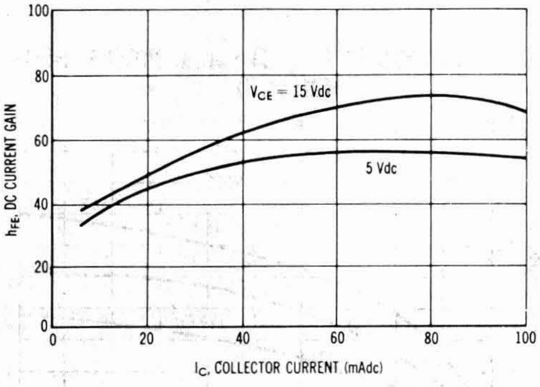


FIGURE 10 — DC CURRENT GAIN versus COLLECTOR CURRENT



y PARAMETER VARIATIONS

FIGURE 11 — SMALL-SIGNAL INPUT ADMITTANCE versus COLLECTOR CURRENT

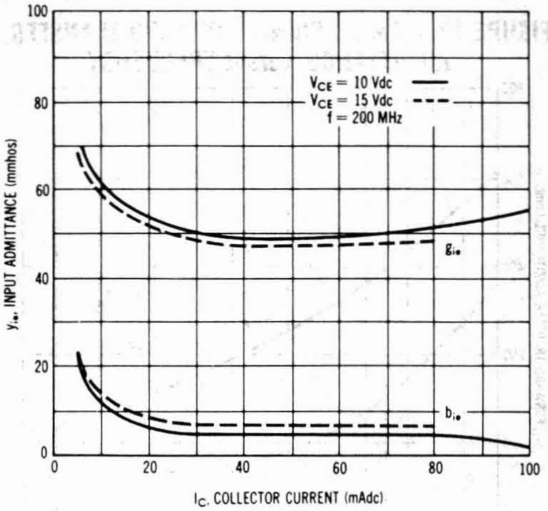


FIGURE 12 — SMALL-SIGNAL REVERSE TRANSFER ADMITTANCE versus COLLECTOR CURRENT

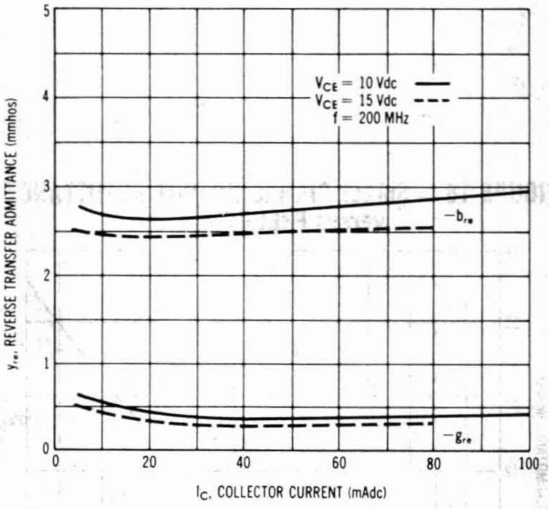


FIGURE 13 — SMALL-SIGNAL FORWARD TRANSFER ADMITTANCE versus COLLECTOR CURRENT

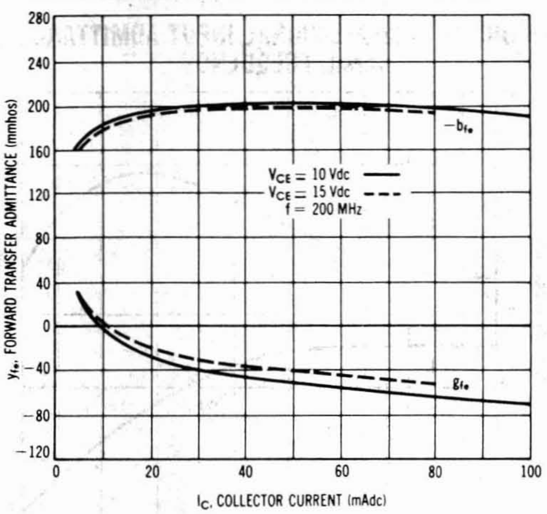
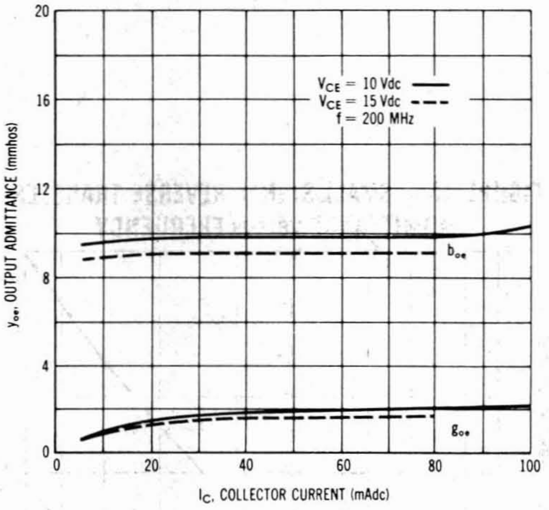


FIGURE 14 — SMALL-SIGNAL OUTPUT ADMITTANCE versus COLLECTOR CURRENT



DESIGN NOTE

Figures 11 through 18 show small-signal admittance-parameter data. This data can be used for Class A amplifier designs.

For Class C power-amplifier designs, the small-signal parameters are not applicable. Figures 4 and 5 give parallel output capacitance and the parallel input resistance and capacitance for Class C power-amplifier operation.

The parallel resistive portion of the collector load impedance for a power amplifier, R_L', may be computed by assuming a peak voltage swing equal to V_{CC}, and using the expression

$$R_L' = \frac{V_{CC}^2}{2\,P}$$

where P = RF power output. The computed R_L' may then be combined with the data in Figures 2 and 3 to comprise complete device impedance data for Class C power amplifier design.

y PARAMETER VARIATIONS

($V_{CE} = 15$ Vdc, $I_C = 80$ mAdc, $T_A = 25°C$)

FIGURE 15 — SMALL-SIGNAL INPUT ADMITTANCE versus FREQUENCY

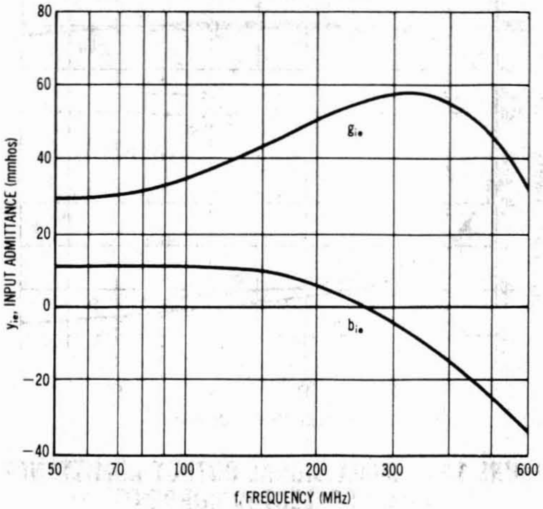


FIGURE 17 — SMALL-SIGNAL FORWARD TRANSFER ADMITTANCE versus FREQUENCY

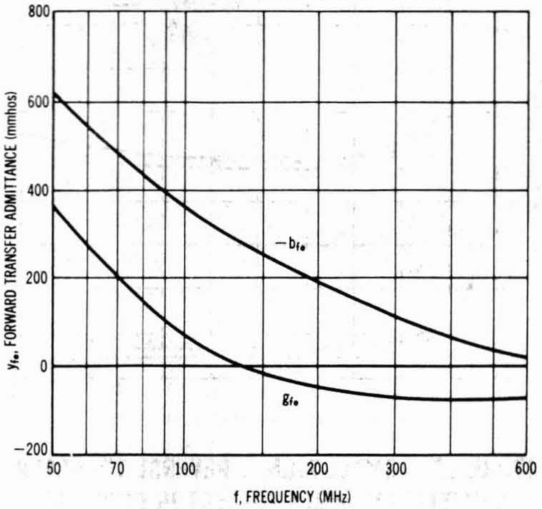


FIGURE 16 — SMALL-SIGNAL REVERSE TRANSFER ADMITTANCE versus FREQUENCY

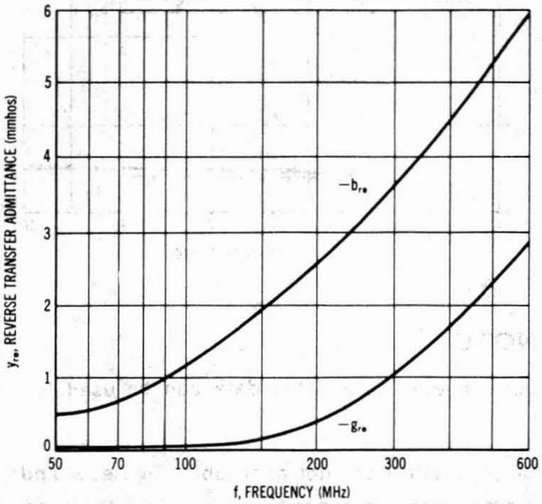
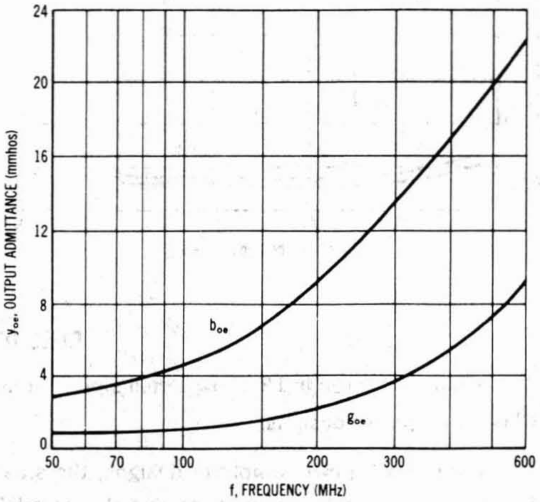


FIGURE 18 — SMALL-SIGNAL OUTPUT ADMITTANCE versus FREQUENCY



2N3883 (GERMANIUM)

CASE 31
(TO-5)

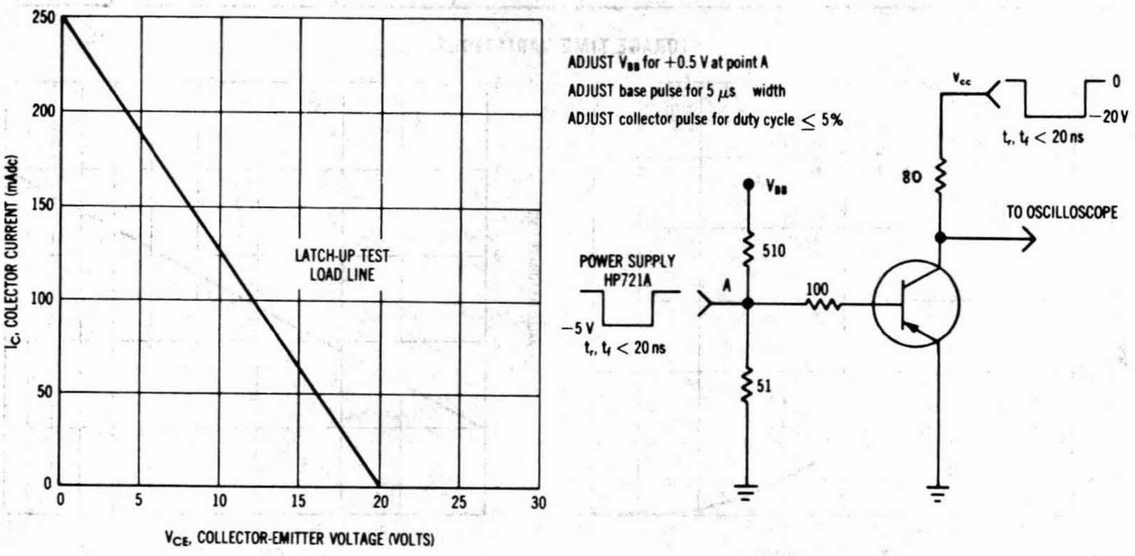
Collector connected to case

Medium-current, germanium PNP high-speed switching transistor.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Units
Collector-Base Voltage	V_{CB}	25	Vdc
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Emitter-Base Voltage	V_{EB}	3	Vdc
Collector Current (Continuous)	I_C	300	mAdc
Junction Temperature	T_J	100	°C
Storage Temperature	T_{stg}	-65 to +100	°C
Device Dissipation @ 25°C Case Temperature (Derate 10 mW/°C above 25°C)	P_D	750	mW
Device Dissipation @ 25°C Ambient (Derate 4 mW/°C)	P_D	300	mW

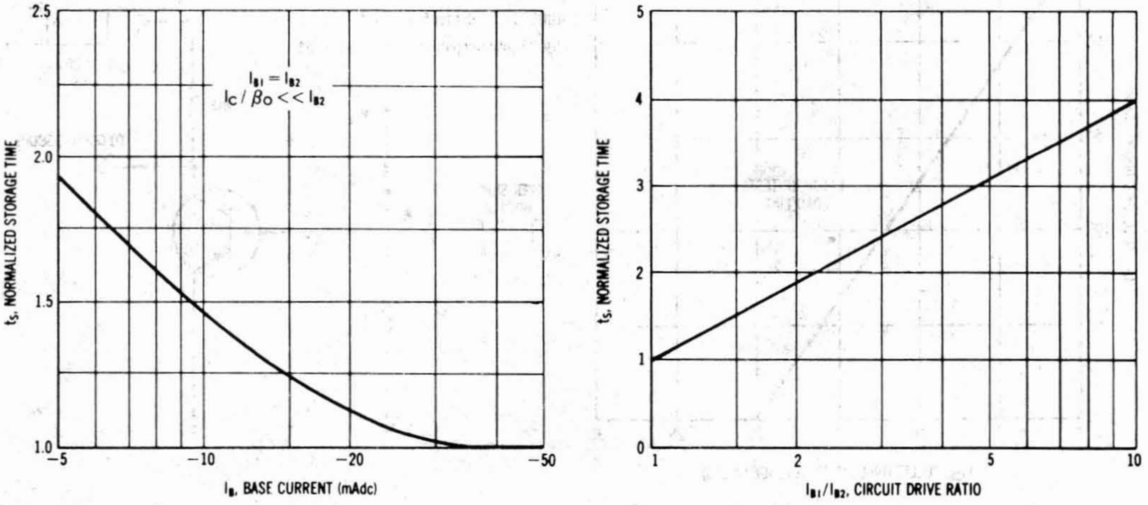
COLLECTOR LATCH-UP VOLTAGE AND TEST CIRCUIT



ELECTRICAL CHARACTERISTICS (At 25°C Ambient unless otherwise noted)

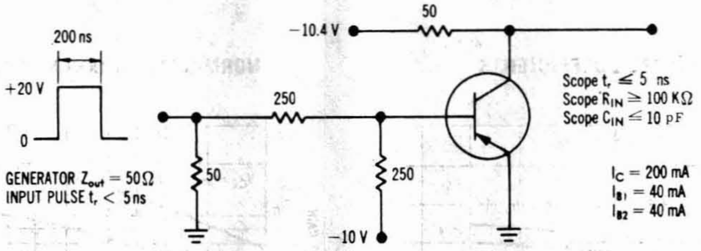
Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100μAdc, I_E = 0)	BV_{CBO}	25	—	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10mAdc, I_B = 0)	BV_{CEO}	15	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3	—	—	Vdc
Latch-Up Voltage	LV_{CEX}	20	—	—	Vdc
Collector-Emitter Leakage Current (V_{CE} = 15 Vdc, V_{EB} = 0)	I_{CES}	—	—	100	μAdc
Base Cutoff Current (V_{CE} = 15 Vdc, V_{EB} = 0)	I_B	—	—	100	μAdc
DC Current Gain (I_C = 200 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	30	—	—	—
Collector-Emitter Saturation Voltage (I_C = 200 mAdc, I_B = 40 mAdc	$V_{CE(sat)}$	—	0.35	0.5	Vdc
Base-Emitter Voltage (I_C = 200 mAdc, I_B = 40 mAdc)	V_{BE}	0.4	0.65	0.9	Vdc
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	4.5	8	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	10	25	pF
Current-Gain — Bandwidth Product (V_{CE} = 10 Vdc, I_C = 40 mAdc, f = 100 MHz)	f_T	100	300	—	MHz
Delay Time	t_d	—	8	15	ns
Rise Time	t_r	—	28	40	ns
Storage Time	t_s	—	40	70	ns
Fall Time	t_f	—	28	40	ns

STORAGE TIME VARIATIONS

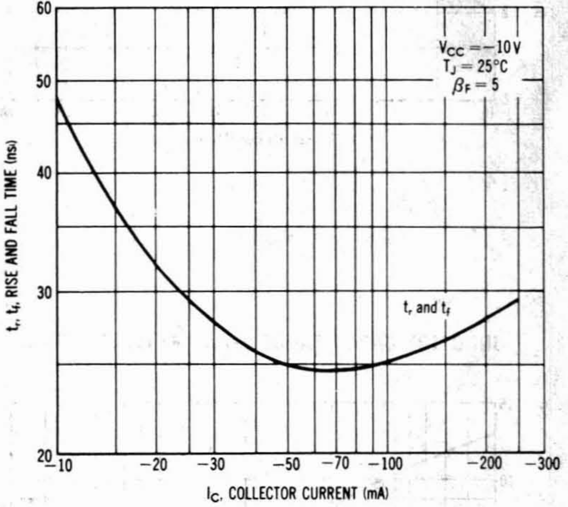


2N3883 (continued)

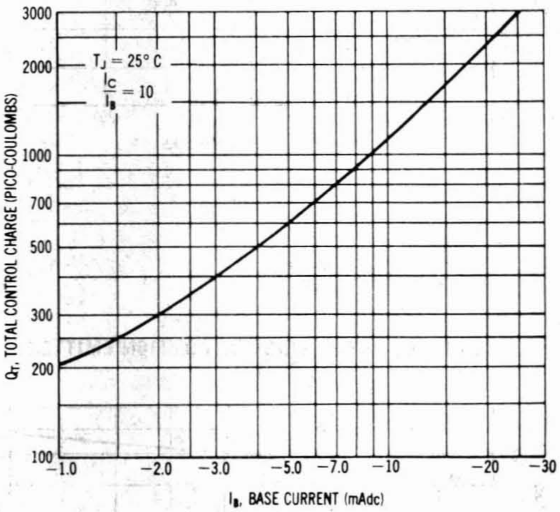
SWITCHING TIME TEST CIRCUIT


200 ns
+20 V
0
GENERATOR $Z_{out} = 50\Omega$
INPUT PULSE $t_r < 5$ ns
50
250
250
−10 V
−10.4 V
50
Scope $t_r \leq 5$ ns
Scope $R_{IN} \geq 100$ KΩ
Scope $C_{IN} \leq 10$ pF
$I_C = 200$ mA
$I_{B1} = 40$ mA
$I_{B2} = 40$ mA

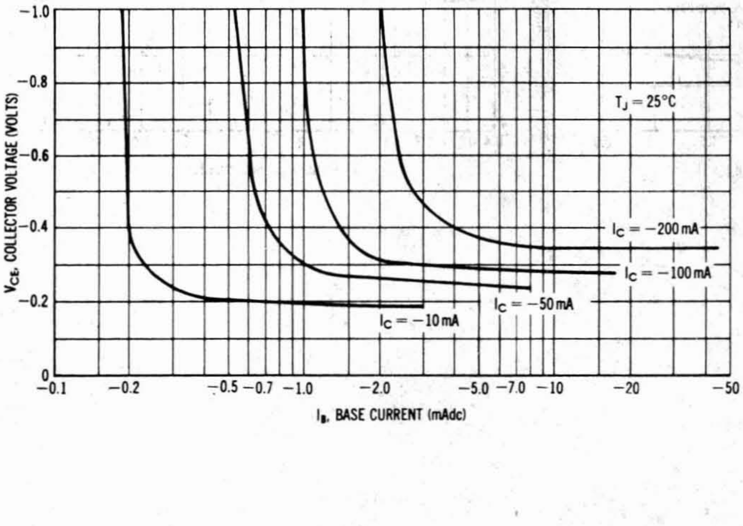
TYPICAL RISE AND FALL TIME BEHAVIOR



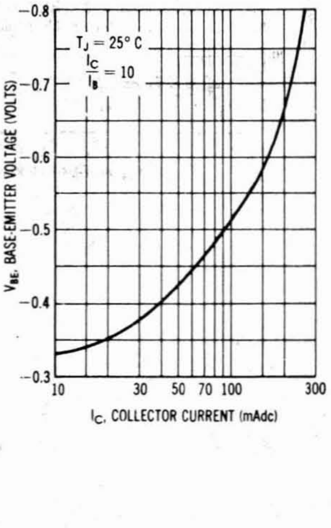
TOTAL CONTROL CHARGE



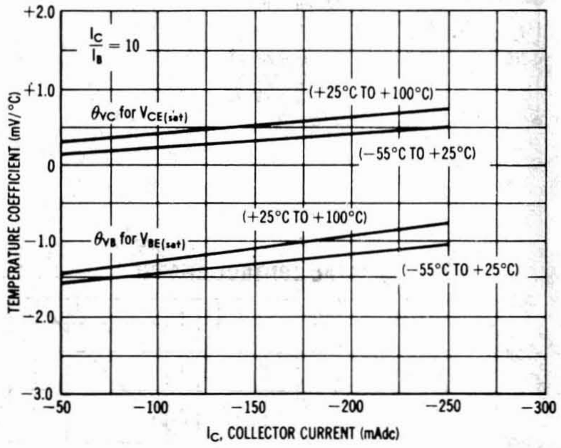
COLLECTOR-EMITTER SATURATION VOLTAGES versus BASE CURRENT



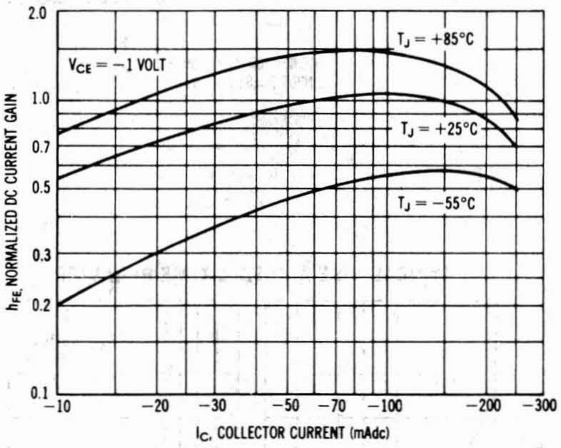
BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT



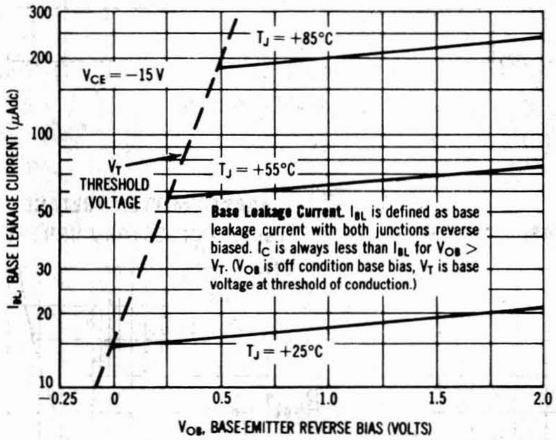
TEMPERATURE COEFFICIENTS



NORMALIZED CURRENT GAIN CHARACTERISTICS

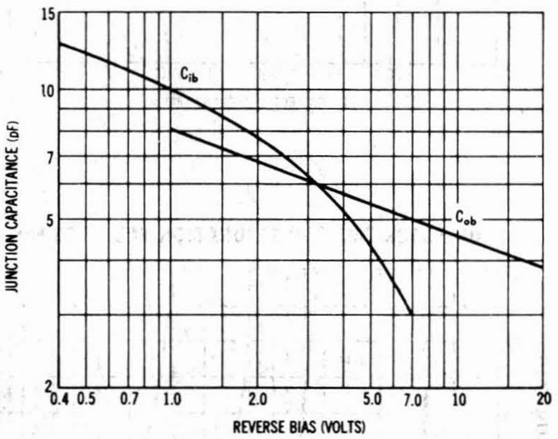


LEAKAGE CHARACTERISTICS COMMON EMITTER

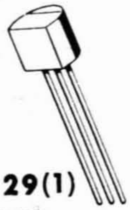


Base Leakage Current. I_{BL} is defined as base leakage current with both junctions reverse biased. I_C is always less than I_{BL} for $V_{OB} > V_T$. (V_{OB} is off condition base bias, V_T is base voltage at threshold of conduction.)

JUNCTION CAPACITANCE versus REVERSE VOLTAGE



2N3903 (SILICON)
2N3904



CASE 29(1)
(TO-92)

NPN silicon annular transistors, designed for general-purpose switching and amplifier applications, features one-piece, injection-molded plastic package for high reliability. The 2N3903 and 2N3904 are complementary with PNP types 2N3905 and 2N3906, respectively.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ $T_A = 60°C$ Derate above 25°C	P_D	310 210 2.81	mW mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)			BV_{CBO}	60	-	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 1.0 mAdc, I_B = 0)			BV_{CEO}*	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)			BV_{EBO}	6.0	-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, $V_{EB(off)}$ = 3.0 Vdc)			I_{CEX}	-	50	nAdc
Base Cutoff Current (V_{CE} = 30 Vdc, $V_{EB(off)}$ = 3.0 Vdc)			I_{BL}	-	50	nAdc
ON CHARACTERISTICS						
DC Current Gain* (I_C = 0.1 mAdc, V_{CE} = 1.0 Vdc)	2N3903 2N3904	15	h_{FE}*	20 40	- -	-
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc)	2N3903 2N3904			35 70	- -	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N3903 2N3904			50 100	150 300	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)	2N3903 2N3904			30 60	- -	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	2N3903 2N3904			15 30	- -	
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)		16, 17	$V_{CE(sat)}$*	- -	0.2 0.3	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)		17	$V_{BE(sat)}$*	0.65 -	0.85 0.95	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N3903 2N3904		f_T	250 300	- -	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)		3	C_{ob}	-	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		3	C_{ib}	-	8.0	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3903 2N3904	13	h_{ie}	0.5 1.0	8.0 10	k ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3903 2N3904	14	h_{re}	0.1 0.5	5.0 8.0	X 10-4
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	2N3903 2N3904	11	h_{fe}	50 100	200 400	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		12	h_{oe}	1.0	40	μmhos
Noise Figure (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, R_S = 1.0 k ohms, f = 10 Hz to 15.7 kHz)	2N3903 2N3904	9, 10	NF	- -	6.0 5.0	dB
SWITCHING CHARACTERISTICS						
Delay Time	(V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_C = 10 mAdc, I_{B1} = 1.0 mAdc)	1, 5	t_d	-	35	ns
Rise Time		1, 5, 6	t_r	-	35	ns
Storage Time	(V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 1.0 mAdc) 2N3903 2N3904	2, 7	t_s	- -	175 200	ns
Fall Time		2, 8	t_f	-	50	ns

* Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2.0%.

FIGURE 1 — DELAY AND RISE TIME EQUIVALENT TEST CIRCUIT

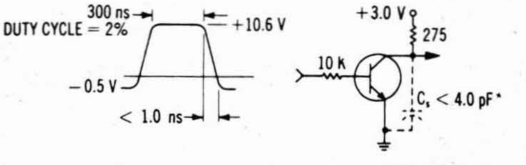
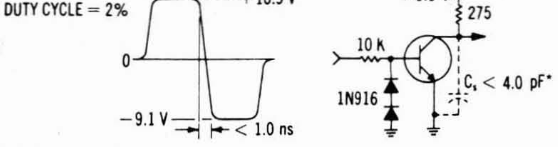


FIGURE 2 — STORAGE AND FALL TIME EQUIVALENT TEST CIRCUIT



*Total shunt capacitance of test jig and connectors

TRANSIENT CHARACTERISTICS

— $T_J = 25°C$ - - - $T_J = 125°C$

FIGURE 3 — CAPACITANCE

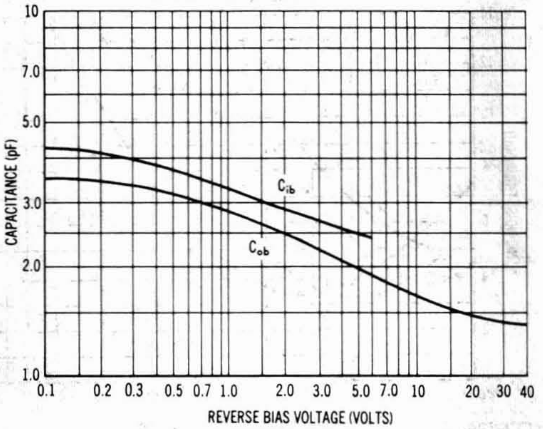


FIGURE 4 — CHARGE DATA

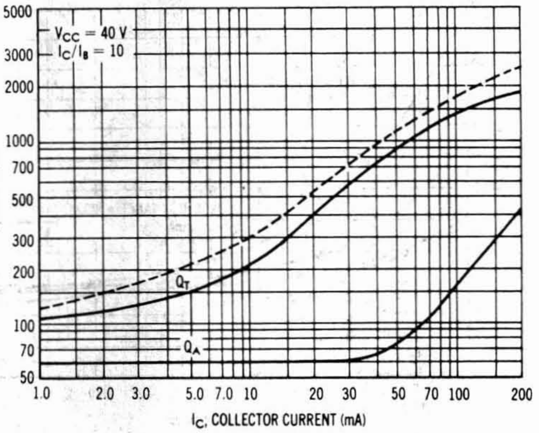


FIGURE 5 — TURN-ON TIME

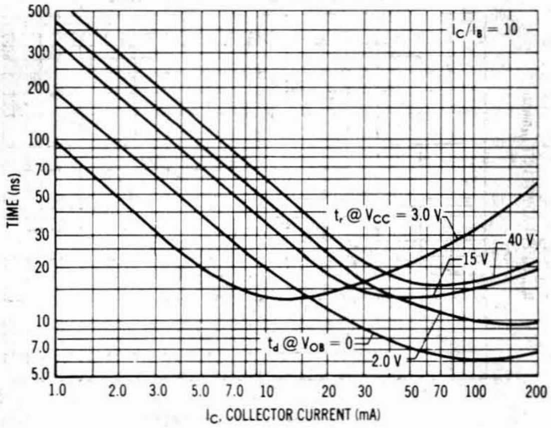


FIGURE 6 — RISE TIME

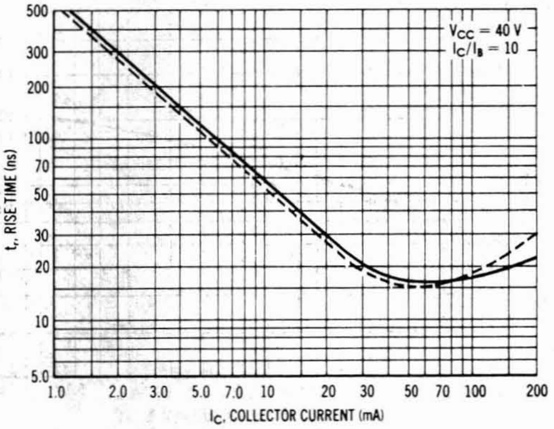


FIGURE 7 — STORAGE TIME

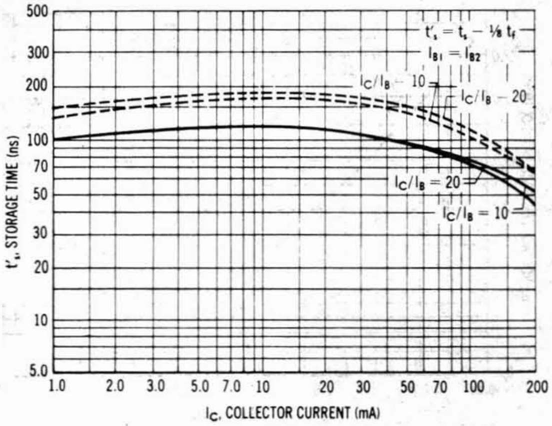
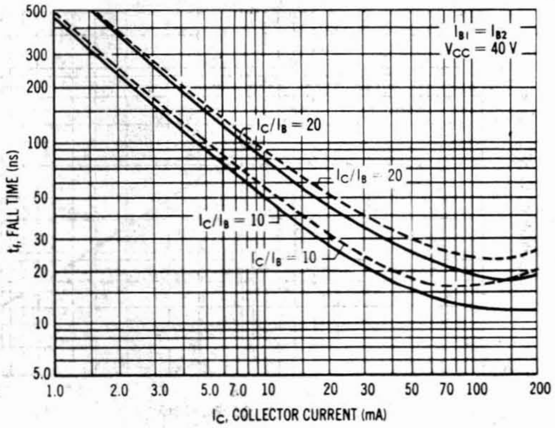


FIGURE 8 — FALL TIME



AUDIO SMALL SIGNAL CHARACTERISTICS

NOISE FIGURE VARIATIONS

$V_{CE} = 5.0$ Vdc, $T_A = 25°C$

FIGURE 9

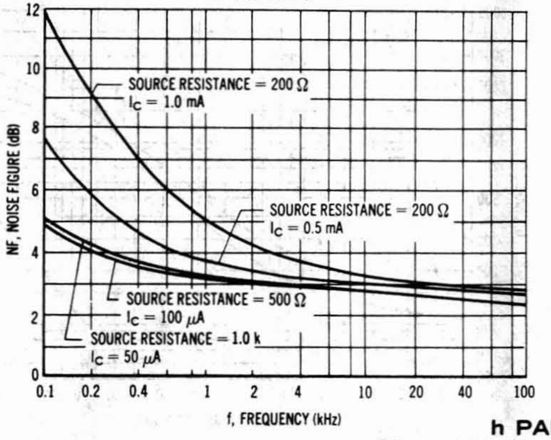
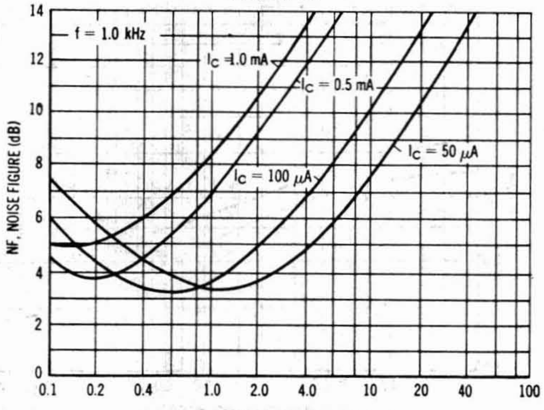


FIGURE 10



h PARAMETERS

($V_{CE} = 10$ Vdc, f = 1.0 kHz, $T_A = 25°C$)

FIGURE 11 – CURRENT GAIN

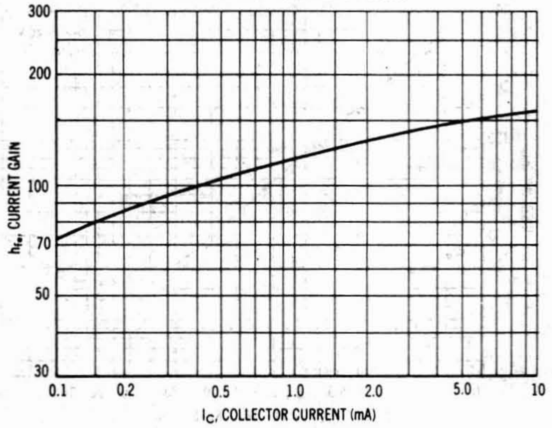


FIGURE 12 – OUTPUT ADMITTANCE

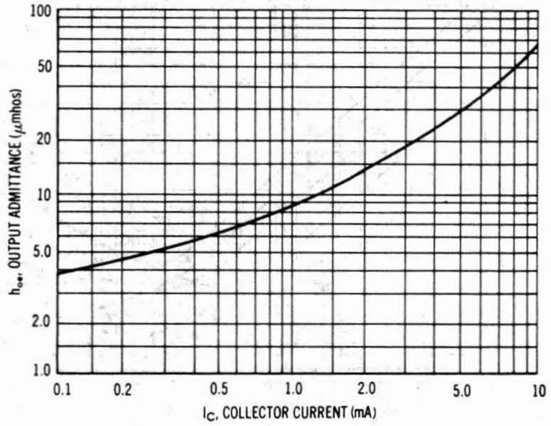


FIGURE 13 – INPUT IMPEDANCE

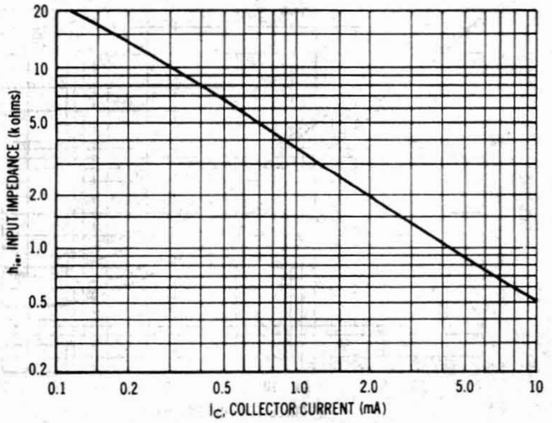
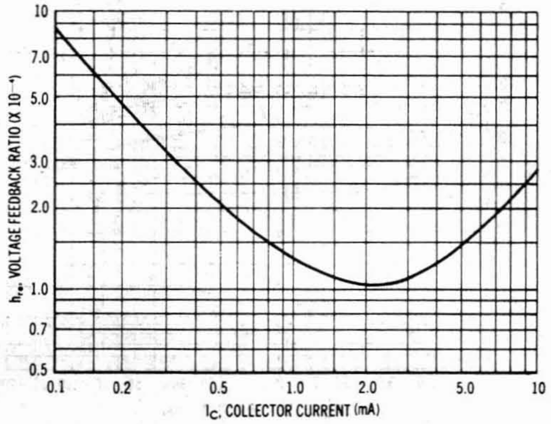


FIGURE 14 – VOLTAGE FEEDBACK RATIO



STATIC CHARACTERISTICS

FIGURE 15 — NORMALIZED CURRENT GAIN

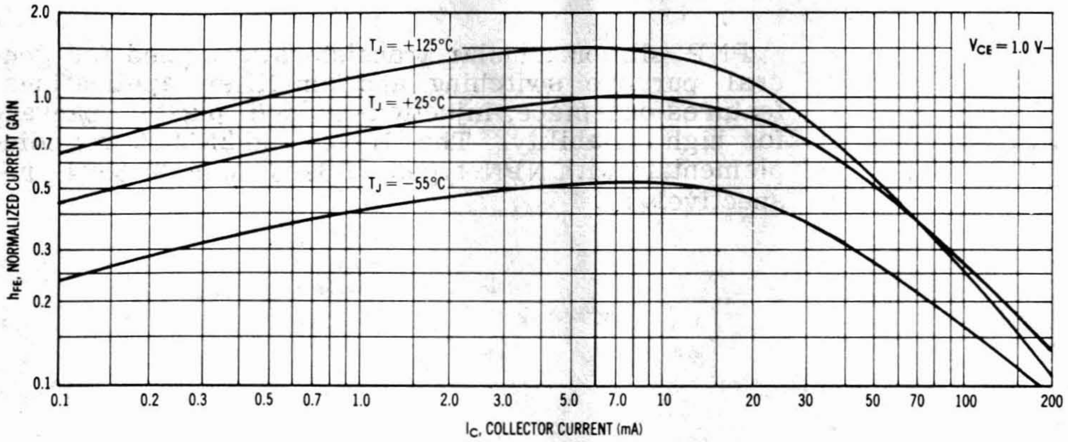


FIGURE 16 — COLLECTOR SATURATION REGION

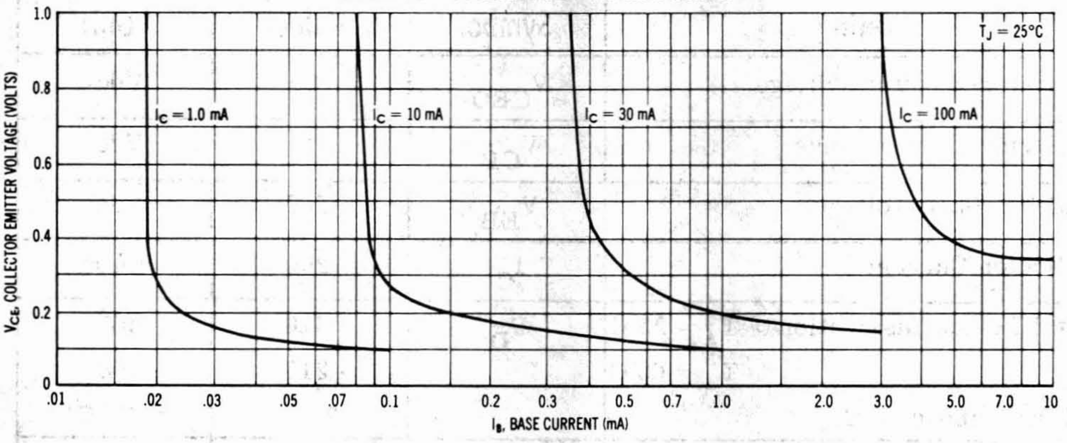


FIGURE 17 — "ON" VOLTAGES

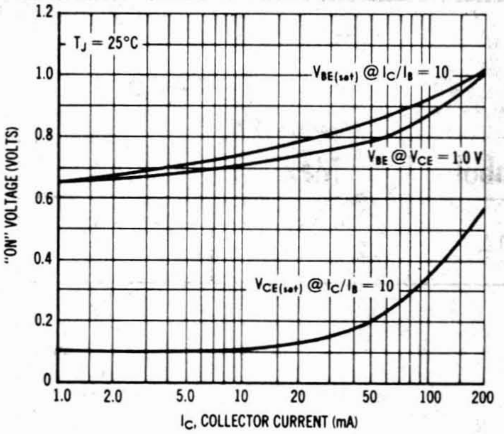
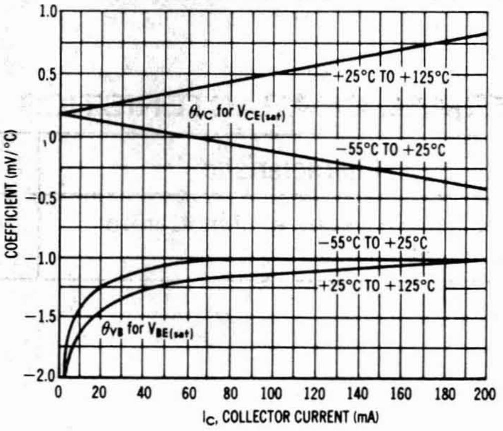
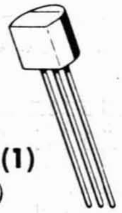


FIGURE 18 — TEMPERATURE COEFFICIENTS



2N3905 (SILICON)
2N3906



CASE 29(1)
(TO-92)

PNP silicon annular **transistors,** designed for general purpose switching and amplifier applications, features one-piece, injection-molded plastic package for high reliability. The 2N3905 and 2N3906 are complementary with NPN types 2N3903 and 2N3904, respectively.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ $T_A = 60°C$ Derate above 25°C	P_D	310 210 2.81	mW mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

2N3905, 2N3906 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Base Breakdown Voltage ($I_C = 10\ \mu Adc$, $I_E = 0$)			BV_{CBO}	40	-	Vdc
Collector-Emitter Breakdown Voltage* ($I_C = 1.0\ mAdc$, $I_B = 0$)			BV_{CEO}*	40	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10\ \mu Adc$, $I_C = 0$)			BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current ($V_{CE} = 30\ Vdc$, $V_{BE(off)} = 3.0\ Vdc$)			I_{CEX}	-	50	nAdc
Base Cutoff Current ($V_{CE} = 30\ Vdc$, $V_{BE(off)} = 3.0\ Vdc$)			I_{BL}	-	50	nAdc
ON CHARACTERISTICS						
DC Current Gain* ($I_C = 0.1\ mAdc$, $V_{CE} = 1.0\ Vdc$)	2N3905	15	h_{FE}*	30	-	-
	2N3906			60	-	
($I_C = 1.0\ mAdc$, $V_{CE} = 1.0\ Vdc$)	2N3905			40	-	
	2N3906			80	-	
($I_C = 10\ mAdc$, $V_{CE} = 1.0\ Vdc$)	2N3905			50	150	
	2N3906			100	300	
($I_C = 50\ mAdc$, $V_{CE} = 1.0\ Vdc$)	2N3905			30	-	
	2N3906			60	-	
($I_C = 100\ mAdc$, $V_{CE} = 1.0\ Vdc$)	2N3905			15	-	
	2N3906			30	-	
Collector-Emitter Saturation Voltage* ($I_C = 10\ mAdc$, $I_B = 1.0\ mAdc$)		16, 17	$V_{CE(sat)}$*	-	0.25	Vdc
($I_C = 50\ mAdc$, $I_B = 5.0\ mAdc$)				-	0.4	
Base-Emitter Saturation Voltage* ($I_C = 10\ mAdc$, $I_B = 1.0\ mAdc$)		17	$V_{BE(sat)}$*	0.65	0.85	Vdc
($I_C = 50\ mAdc$, $I_B = 5.0\ mAdc$)				-	0.95	
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product ($I_C = 10\ mAdc$, $V_{CE} = 20\ Vdc$, $f = 100\ MHz$)	2N3905		f_T	200	-	MHz
	2N3906			250	-	
Output Capacitance ($V_{CB} = 5.0\ Vdc$, $I_E = 0$, $f = 100\ kHz$)		3	C_{ob}	-	4.5	pF
Input Capacitance ($V_{BE} = 0.5\ Vdc$, $I_C = 0$, $f = 100\ kHz$)		3	C_{ib}	-	10	pF
Input Impedance ($I_C = 1.0\ mAdc$, $V_{CE} = 10\ Vdc$, $f = 1.0\ kHz$)	2N3905	13	h_{ie}	0.5	8.0	k ohms
	2N3906			2.0	12	
Voltage Feedback Ratio ($I_C = 1.0\ mAdc$, $V_{CE} = 10\ Vdc$, $f = 1.0\ kHz$)	2N3905	14	h_{re}	0.1	5.0	X 10^{-4}
	2N3906			1.0	10	
Small-Signal Current Gain ($I_C = 1.0\ mAdc$, $V_{CE} = 10\ Vdc$, $f = 1.0\ kHz$)	2N3905	11	h_{fe}	50	200	-
	2N3906			100	400	
Output Admittance ($I_C = 1.0\ mAdc$, $V_{CE} = 10\ Vdc$, $f = 1.0\ kHz$)	2N3905	12	h_{oe}	1.0	40	μmhos
	2N3906			3.0	60	
Noise Figure ($I_C = 100\ \mu Adc$, $V_{CE} = 5.0\ Vdc$, $R_S = 1.0\ k\ ohm$, $f = 10\ Hz$ to $15.7\ kHz$)	2N3905	9, 10	NF	-	5.0	dB
	2N3906			-	4.0	

SWITCHING CHARACTERISTICS

			Fig. No.	Symbol	Min	Max	Unit
Delay Time	($V_{CC} = 3.0\ Vdc$, $V_{BE(off)} = 0.5\ Vdc$, $I_C = 10\ mAdc$, $I_{B1} = 1.0\ mAdc$)		1, 5	t_d	-	35	ns
Rise Time			1, 5, 6	t_r	-	35	ns
Storage Time	($V_{CC} = 3.0\ Vdc$, $I_C = 10\ mAdc$, $I_{B1} = I_{B2} = 1.0\ mAdc$)	2N3905	2, 7	t_s	-	200	ns
		2N3906			-	225	
Fall Time		2N3905	2, 8	t_f	-	60	ns
		2N3906			-	75	

* Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2.0%.

FIGURE 1 — DELAY AND RISE TIME EQUIVALENT TEST CIRCUIT

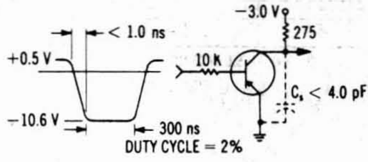
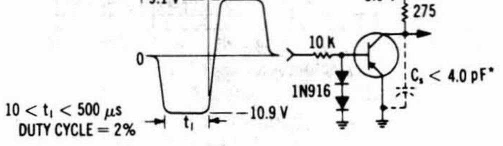


FIGURE 2 — STORAGE AND FALL TIME EQUIVALENT TEST CIRCUIT



*Total shunt capacitance of test jig and connectors

TRANSIENT CHARACTERISTICS

—— $T_J = 25°C$ - - - $T_J = 125°C$

FIGURE 3 — CAPACITANCE

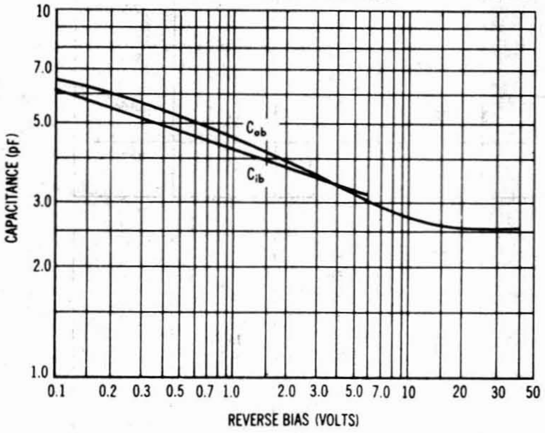


FIGURE 4 — CHARGE DATA

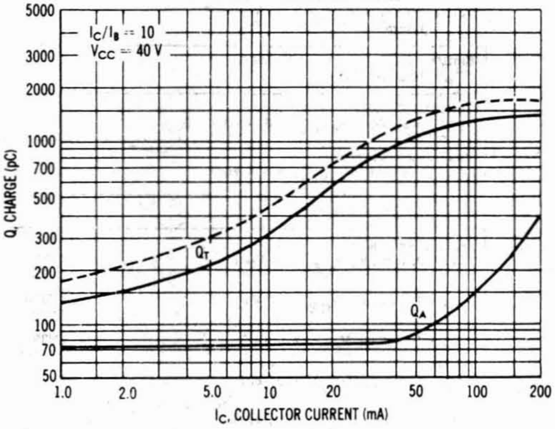


FIGURE 5 — TURN-ON TIME

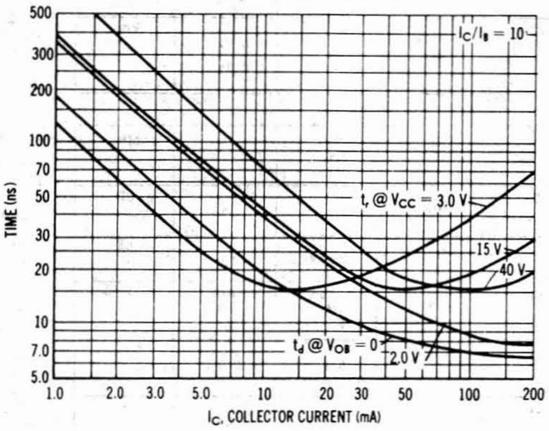


FIGURE 6 — RISE TIME

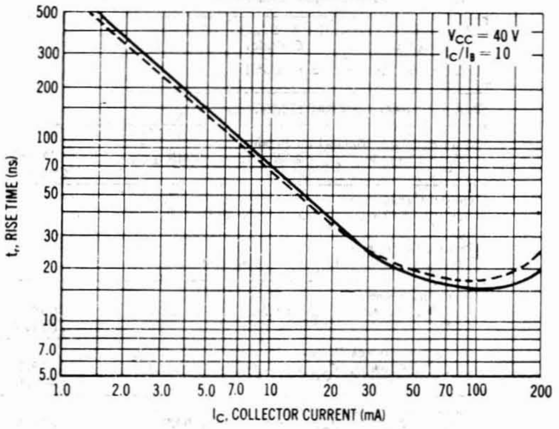


FIGURE 7 — STORAGE TIME

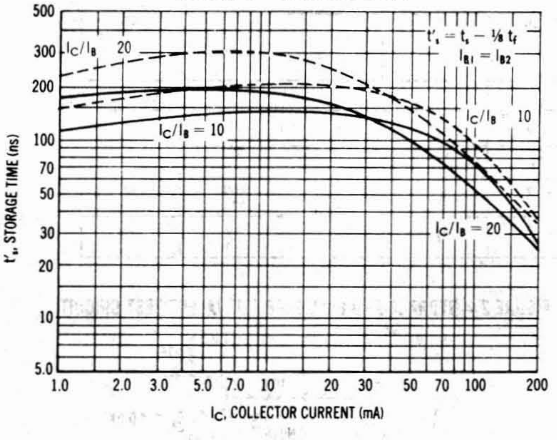
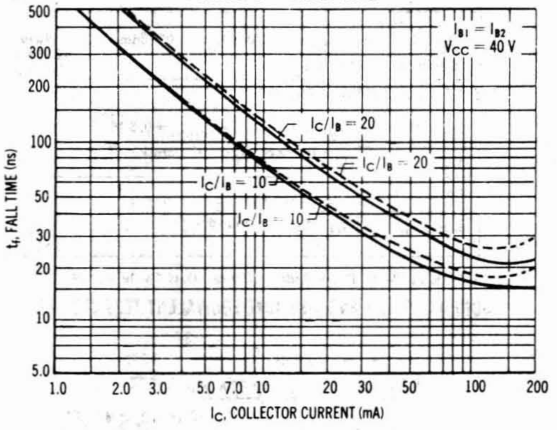


FIGURE 8 — FALL TIME



AUDIO SMALL SIGNAL CHARACTERISTICS

NOISE FIGURE VARIATIONS

$V_{CE} = 5.0$ Vdc, $T_A = 25°C$

FIGURE 9

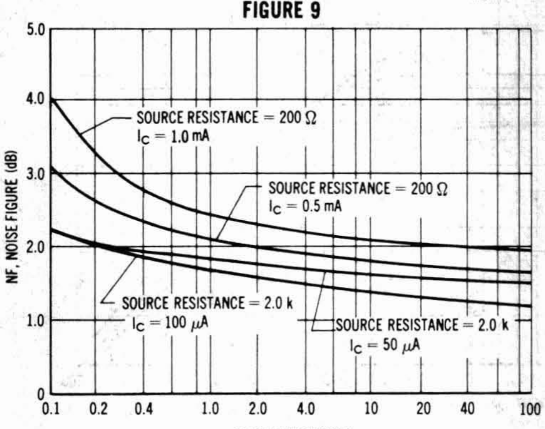
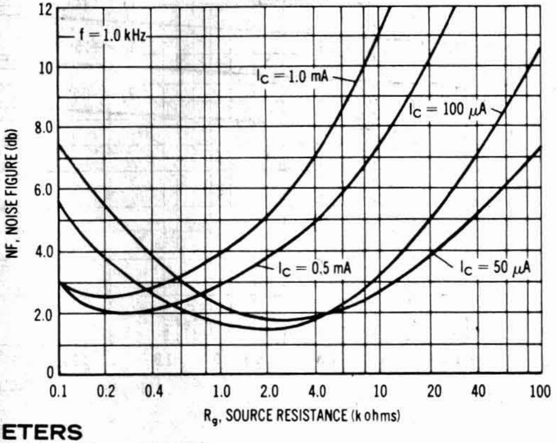


FIGURE 10



h PARAMETERS

($V_{CE} = 10$ Vdc, f = 1.0 kHz, $T_A = 25°C$)

FIGURE 11 — CURRENT GAIN

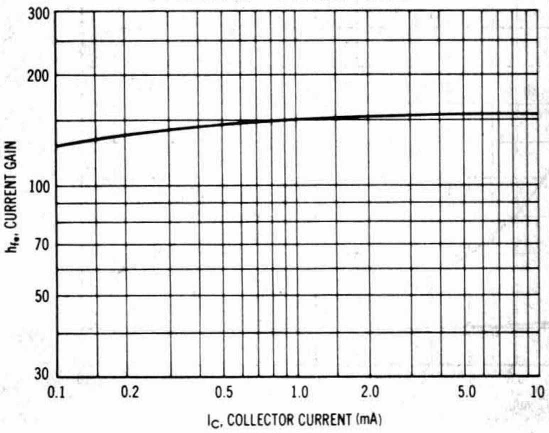


FIGURE 12 — OUTPUT ADMITTANCE

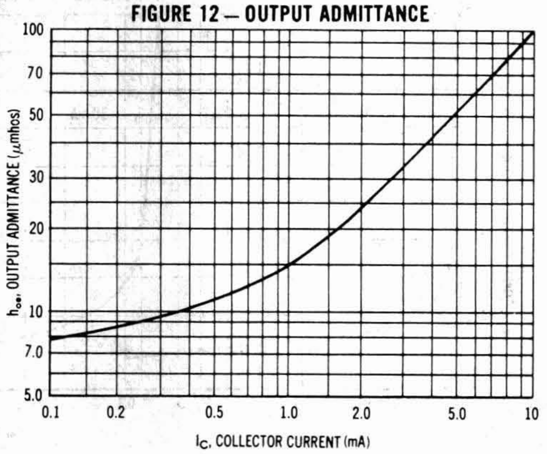


FIGURE 13 — INPUT IMPEDANCE

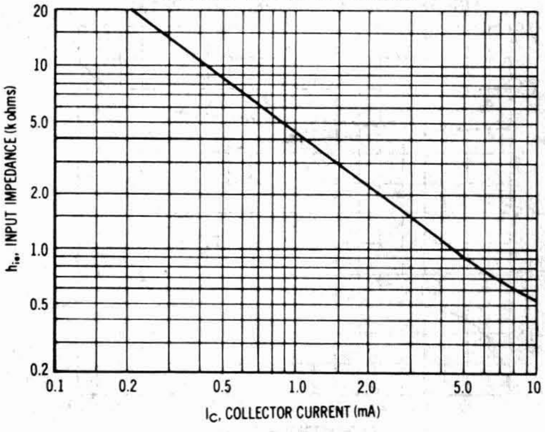
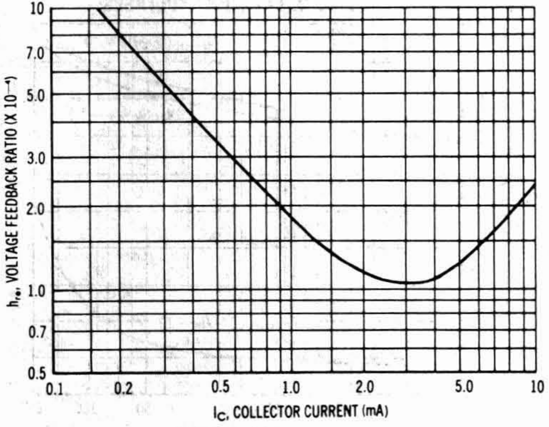


FIGURE 14 — VOLTAGE FEEDBACK RATIO



STATIC CHARACTERISTICS

FIGURE 15 — NORMALIZED CURRENT GAIN

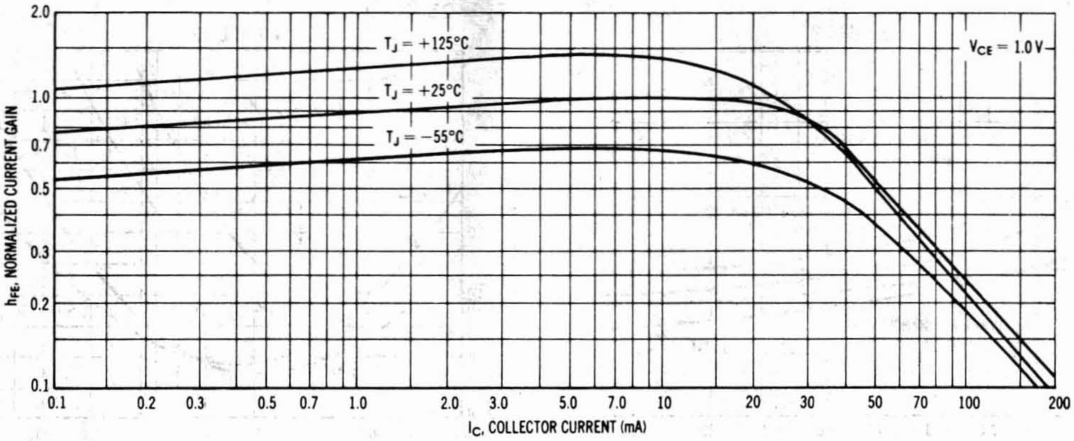


FIGURE 16 — COLLECTOR SATURATION REGION

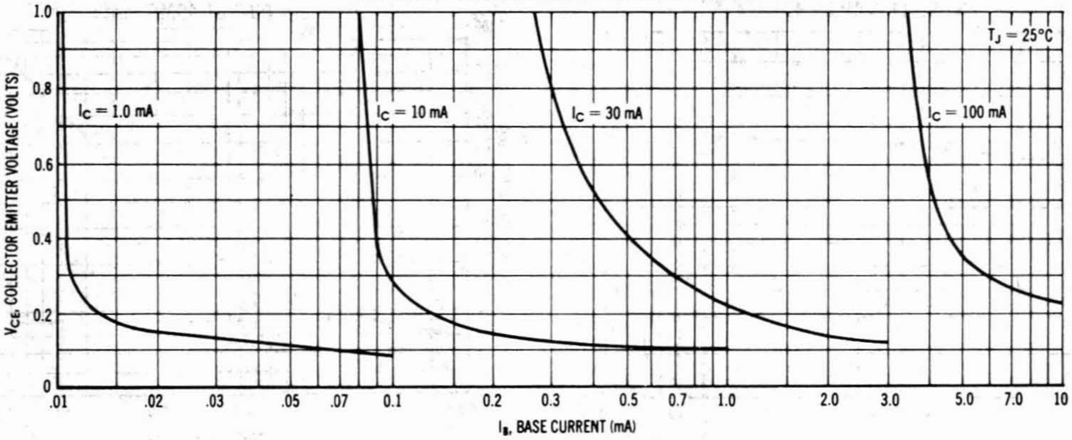


FIGURE 17 — "ON" VOLTAGES

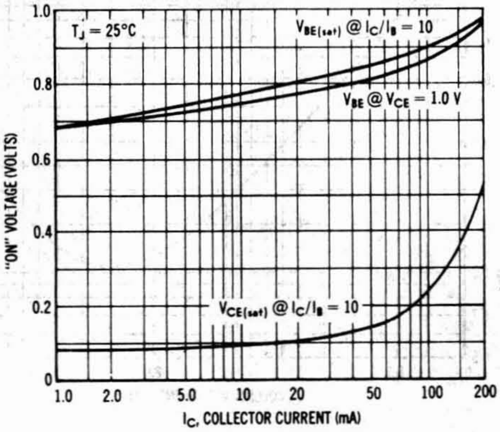
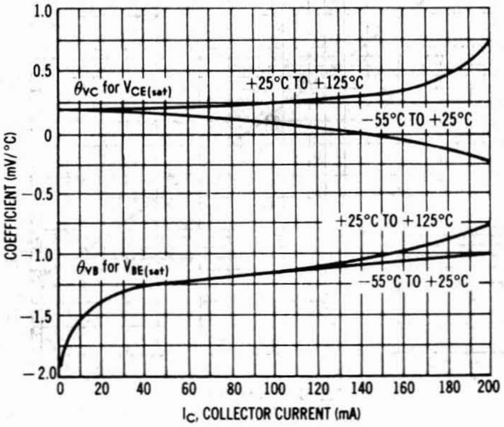
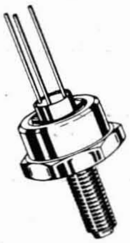


FIGURE 18 — TEMPERATURE COEFFICIENTS



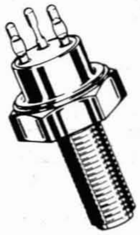
2N3924 (SILICON)
thru
2N3927

NPN silicon annular RF power transistors, optimized for large-signal power-amplifier and driver applications to 300 MHz.



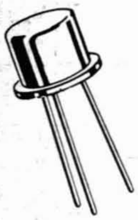
Collector electrically connected to case; stud electrically isolated from case

CASE 24
2N3925
(TO-102)



CASE 36
2N3926
2N3927
(TO-60)

Stud and case electrically connected to emitter



CASE 79
2N3924
(TO-39)

Collector connected to case

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	2N3924	2N3925	2N3926	2N3927	Unit
Collector-Emitter Voltage	V_{CEO}	18	18	18	18	Vdc
Collector-Base Voltage	V_{CB}	36	36	36	36	Vdc
Emitter-Base Voltage	V_{EB}	4.0	4.0	4.0	4.0	Vdc
Collector Current	I_C	0.5	1.0	1.5	3.0	Adc
Power Dissipation @ T_C = 25°C	P_D	7.0	10	11.6	23.2	Watts
Derate above 25°C		40	57.1	66.3	132.5	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →				°C

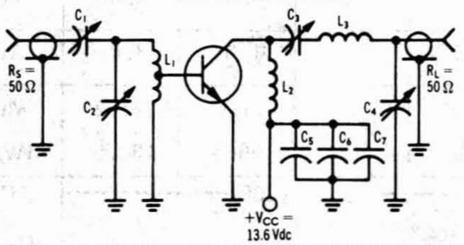
2N3924 thru 2N3927 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Conditions	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage	I_C = 200 mAdc	$BV_{CEO(sus)}$*	18	-	-	Vdc
Collector-Base Breakdown Voltage	I_C = 0.25 mAdc, I_E = 0 2N3924 thru 2N3926 I_C = 0.50 mAdc, I_E = 0 2N3927	BV_{CBO}	36 36	- -	- -	Vdc
Emitter-Base Breakdown Voltage	I_E = 1.0 mAdc, I_C = 0 2N3924 thru 2N3926 I_E = 2.0 mAdc, I_C = 0 2N3927	BV_{EBO}	4.0 4.0	- -	- -	Vdc
Collector Cutoff Current	V_{CB} = 15 Vdc, I_E = 0 2N3924 thru 2N3926 2N3927 V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C 2N3924 thru 2N3926 2N3927	I_{CBO}	- - -	- - -	0.1 0.25 5.0 10	mAdc
DYNAMIC CHARACTERISTICS						
Current-Gain – Bandwidth Product	I_C = 100 mAdc, V_{CE} = 13.6 Vdc, f = 100 MHz 2N3924 thru 2N3926 I_C = 200 mAdc, V_{CE} = 13.6 Vdc, f = 100 MHz 2N3927	f_T	 - -	 350 350	 - -	MHz
Output Capacitance	V_{CB} = 13.6 Vdc, I_E = 0, f = 100 kHz 2N3924 thru 2N3926 2N3927	C_{ob}	 - -	 12.5 25	 20 45	pF
FUNCTIONAL TESTS **2N3924**						
Power Input	Test Circuit Figure 1	P_{in}	-	-	1.0	Watt
Common-Emitter Amplifier Power Gain	V_{CE} = 13.6 Vdc, R_S = 50 ohms, R_L = 50 ohms, f = 175 MHz	G_{pe}	6.0	7.3	-	dB
Collector Efficiency	P_{out} = 4.0 Watts	η	70	-	-	%
2N3925						
Power Input	Test Circuit Figure 1	P_{in}	-	-	1.3	Watts
Common-Emitter Amplifier Power Gain	V_{CE} = 13.6 Vdc, R_S = 50 ohms, R_L = 50 ohms, f = 175 MHz	G_{pe}	5.84	6.5	-	dB
Collector Efficiency	P_{out} = 5.0 Watts	η	70	-	-	%
2N3926						
Power Input	Test Circuit Figure 1	P_{in}	-	-	2.0	Watts
Common-Emitter Amplifier Power Gain	V_{CE} = 13.6 Vdc, R_S = 50 ohms, R_L = 50 ohms, f = 175 MHz	G_{pe}	5.44	6.0	-	dB
Collector Efficiency	P_{out} = 7.0 Watts	η	70	-	-	%
2N3927						
Power Input	Test Circuit Figure 1	P_{in}	-	-	4.0	Watts
Common-Emitter Amplifier Power Gain	V_{CE} = 13.6 Vdc, R_S = 50 ohms, R_L = 50 ohms, f = 175 MHz	G_{pe}	4.77	5.0	-	dB
Collector Efficiency	P_{out} = 12 Watts	η	80	-	-	%

* Pulsed thru a 25-mH inductor (See Figure 2)

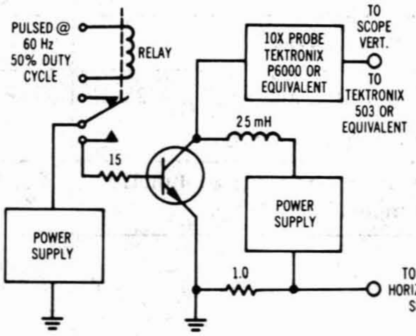
FIGURE 1 — 175 MHz TEST CIRCUIT


C1
C2
C3
C4
C5
C6
C7
L1
L2
L3
RS = 50 Ω
RL = 50 Ω
+VCC = 13.6 Vdc

C_1, C_2, C_4 .... 5-50 pF (Air variable)
C_3 .... 7-100 pF (Air variable)
C_5 .... 470 pF (Disc ceramic)
C_6 .... 0.01 μF (Disc ceramic)
C_7 .... 0.001 μF (Disc ceramic)

L_1 – 1 1/2 turns #14 AWG tinned wire; 3/8" ID Air wound; winding length 3/16"; base tapped 1 turn from ground
L_2 – RFC
L_3 – 2 turns #14 AWG tinned wire; 1/4" ID Air wound; winding length 3/16"

FIGURE 2 — PULSE TEST CIRCUIT


PULSED @ 60 Hz 50% DUTY CYCLE
RELAY
10X PROBE TEKTRONIX P6000 OR EQUIVALENT
TO SCOPE VERT.
TO TEKTRONIX 503 OR EQUIVALENT
25 mH
15
POWER SUPPLY
POWER SUPPLY
1.0
TO SCOPE HORIZONTAL SENSING

CLASS C DESIGN DATA FOR $V_{CE} = 13.6$ Vdc, $T_C = 25°C$

(Emitter Grounded Directly to the Chassis — No Tuned-Emitter Techniques Used)

2N3924

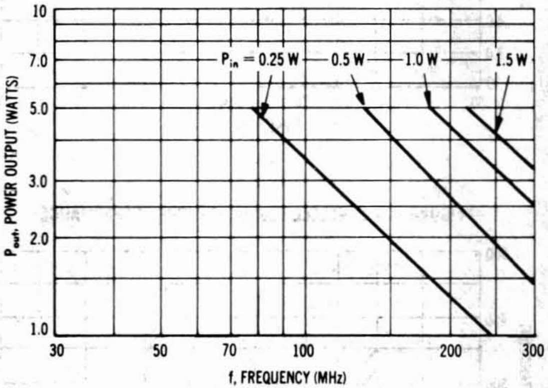


FIGURE 3 — POWER OUTPUT vs FREQUENCY

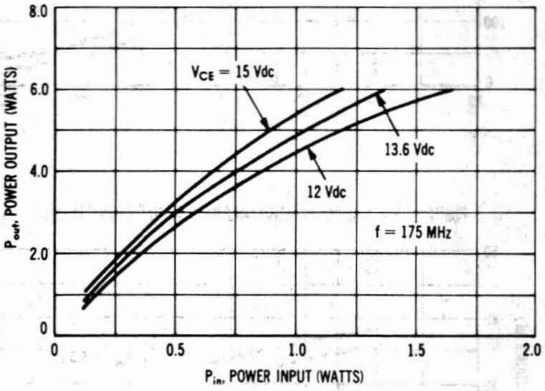


FIGURE 4 — POWER OUTPUT vs POWER INPUT

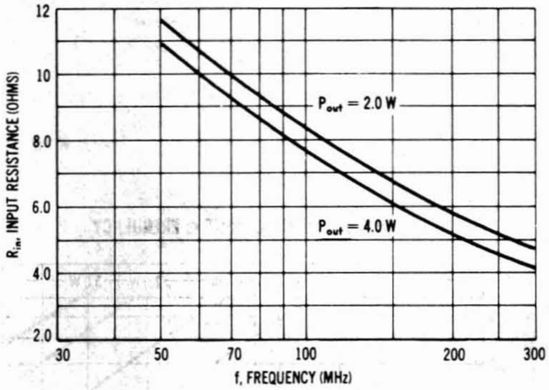


FIGURE 5 — PARALLEL EQUIVALENT INPUT RESISTANCE

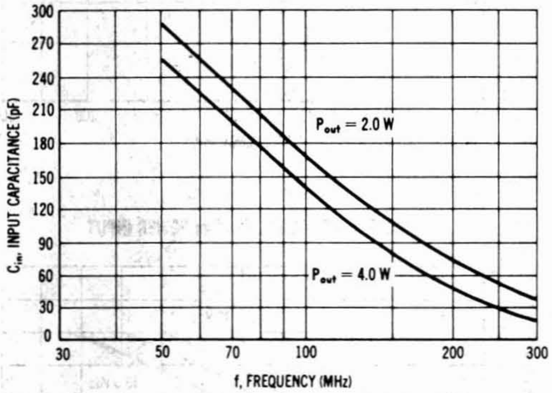


FIGURE 6 — PARALLEL EQUIVALENT INPUT CAPACITANCE

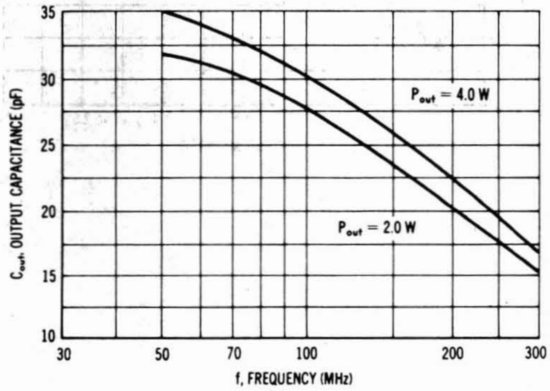


FIGURE 7 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE

2N3925

FIGURE 8 — POWER OUTPUT vs FREQUENCY

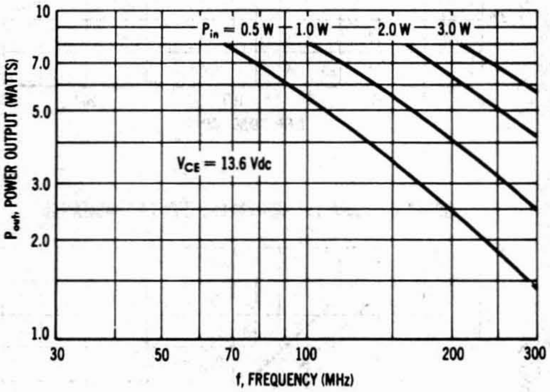


FIGURE 9 — POWER OUTPUT vs POWER INPUT

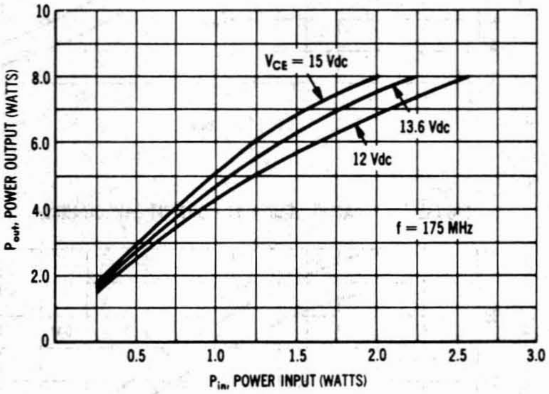


FIGURE 10 — PARALLEL EQUIVALENT INPUT RESISTANCE

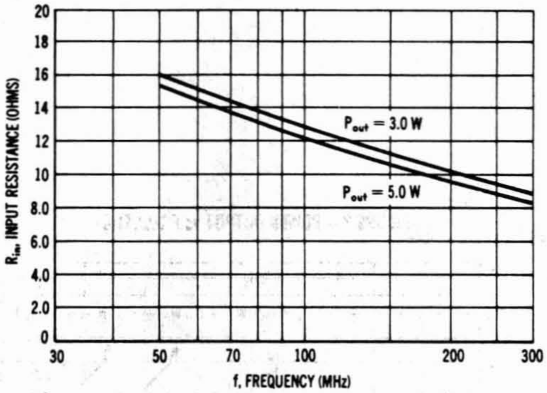


FIGURE 11 — PARALLEL EQUIVALENT INPUT CAPACITANCE

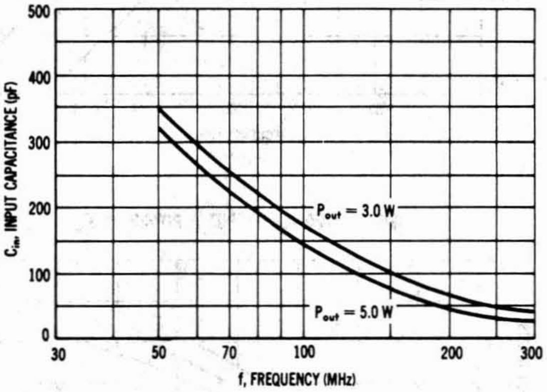
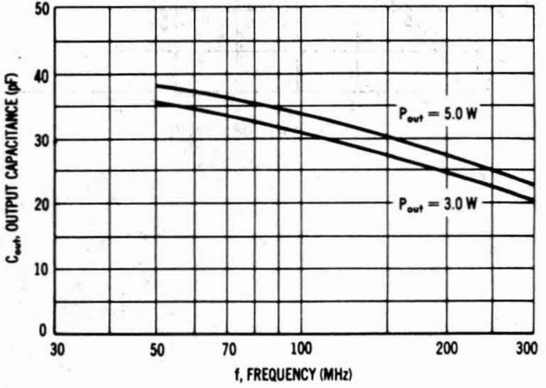


FIGURE 12 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE



2N3926

FIGURE 13 — POWER OUTPUT vs FREQUENCY

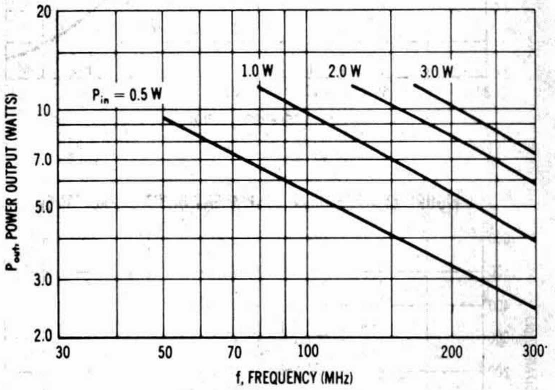


FIGURE 14 — POWER OUTPUT vs POWER INPUT

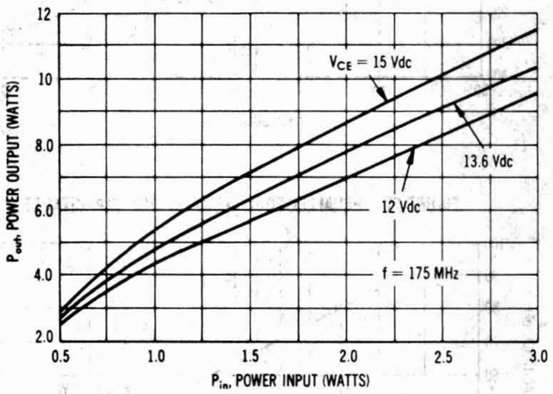


FIGURE 15 — PARALLEL EQUIVALENT INPUT RESISTANCE

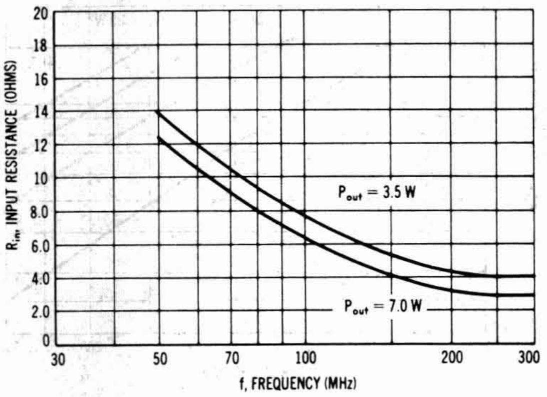


FIGURE 16 — PARALLEL EQUIVALENT INPUT CAPACITANCE

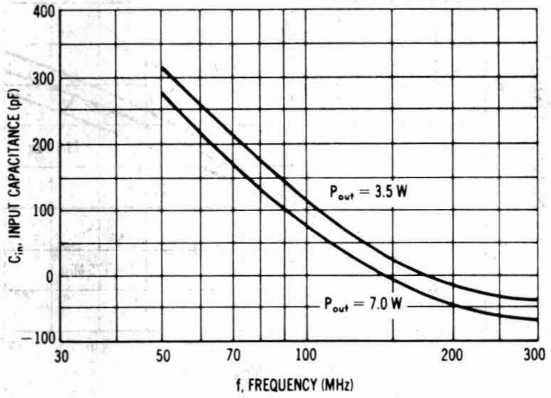
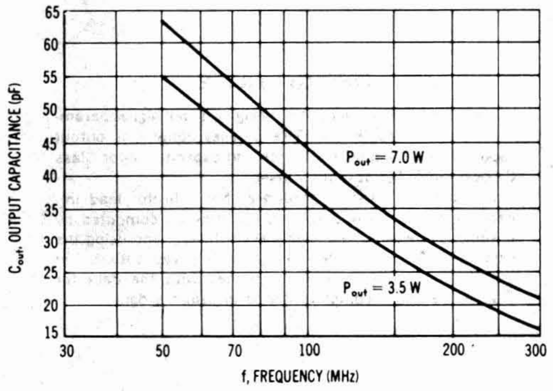


FIGURE 17 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE



2N3927

FIGURE 18 — POWER INPUT vs FREQUENCY

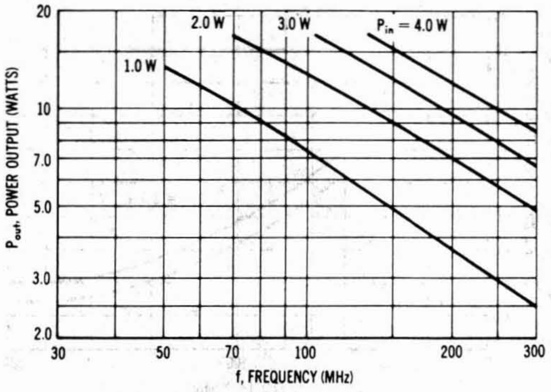


FIGURE 20 — PARALLEL EQUIVALENT INPUT RESISTANCE

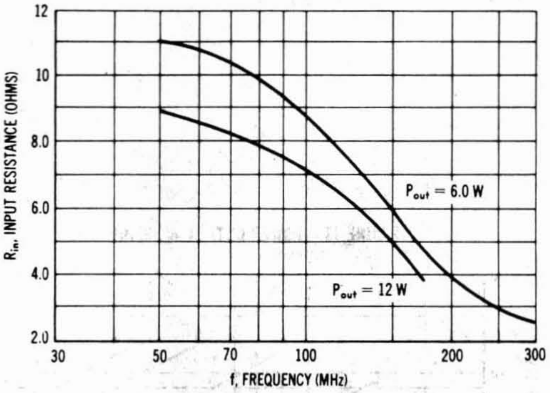


FIGURE 19 — POWER OUTPUT vs POWER INPUT

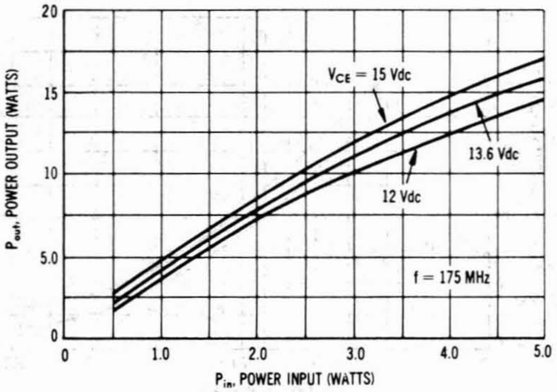


FIGURE 21 — PARALLEL EQUIVALENT INPUT CAPACITANCE

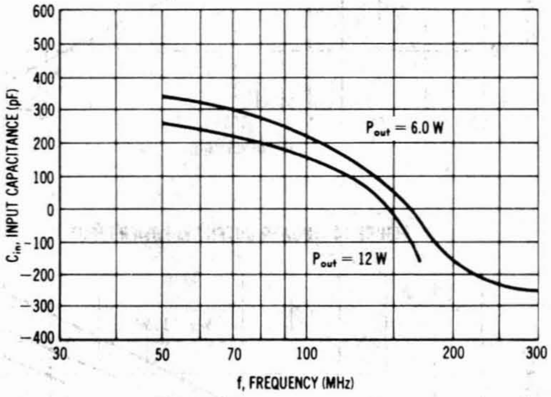
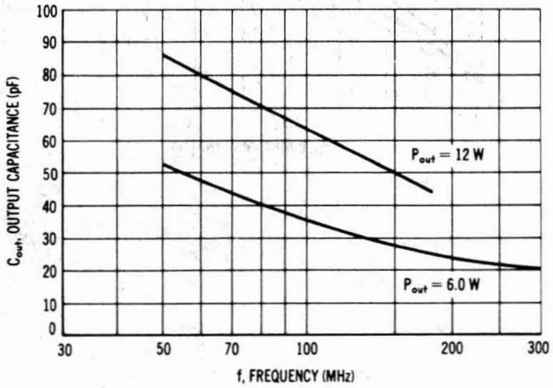


FIGURE 22 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE



DESIGN NOTE

For Class C power-amplifier designs, small-signal parameters are not applicable. The parallel equivalent output capacitance and input resistance and capacitance for Class C power-amplifier design are used.

The parallel resistive portion of the collector load impedance for a power amplifier, R_L', may be computed by assuming a peak voltage swing equal to V_{CC}, and using the expression $R_L' = V_{CC}^2/2P$ where P = RF power output. The computed R_L' may then be combined with the data for Class C design to complete device impedance data.

2N3946 (SILICON)
2N3947

CASE 22
(TO-18)

NPN silicon annular transistors, designed for general purpose switching and amplifier applications. The 2N3946 and 2N3947 are complementary with PNP types 2N3250 and 2N3251, respectively.

Collector connected to case

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Emitter-Base Voltage	V_{EB}	6	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ $T_C = 25°C$ Derating Factor Above 25°C	P_D	1.2 6.9	Watts mW/°C
Total Device Dissipation @ $T_A = 25°C$ Derating Factor Above 25°C	P_D	0.36 2.06	Watt mW/°C
Thermal Resistance Junction to Ambient Junction to Case	 θ_{JA} θ_{JC}	 0.49 0.15	 °C/mW °C/mW
Junction Operating Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc)	BV_{CEO}*	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	6	—	Vdc
Collector-Cutoff Current (V_{CE} = 40 Vdc, V_{OB} = 3 Vdc) (V_{CE} = 40 Vdc, V_{OB} = 3 Vdc, T_A = 150°C)	I_{CEX}	 — —	 .010 15	μAdc
Base Cutoff Current (V_{CE} = 40 Vdc, V_{OB} = 3 Vdc)	I_{BL}	—	.025	μAdc

*Pulse Test: PW ≦ 300 μs , Duty Cycle ≦ 2% V_{OB} = Base-Emitter Reverse Bias

ELECTRICAL CHARACTERISTICS (continued)

(T_A = 25°C unless otherwise noted)

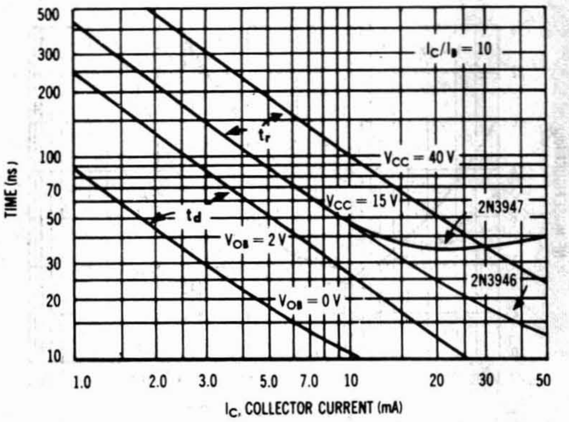
Characteristic			Symbol	Min	Max	Unit
ON CHARACTERISTICS						
DC Current Gain*			h_{FE}*			—
(I_C = 0.1 mAdc, V_{CE} = 1 Vdc)		2N3946		30	—	
		2N3947		60	—	
(I_C = 1.0 mAdc, V_{CE} = 1 Vdc)		2N3946		45	—	
		2N3947		90	—	
(I_C = 10 mAdc, V_{CE} = 1 Vdc)		2N3946		50	150	
		2N3947		100	300	
(I_C = 50 mAdc, V_{CE} = 1 Vdc)		2N3946		20	—	
		2N3947		40	—	
Collector Saturation Voltage*			$V_{CE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)				—	0.2	
(I_C = 50 mAdc, I_B = 5 mAdc)				—	0.3	
Base-Emitter Saturation Voltage*			$V_{BE(sat)}$*			Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)				0.6	0.9	
(I_C = 50 mAdc, I_B = 5 mAdc)				—	1.0	
TRANSIENT CHARACTERISTICS						
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)			C_{ob}	—	4	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 100 kHz)			C_{ib}	—	8	pF
Current-Gain - Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		2N3946	f_T	250	—	MHz
		2N3947		300	—	
Delay Time	V_{CC} = 3 Vdc, V_{OB} = 0.5 Vdc I_C = 10 mAdc, I_{B1} = 1 mA		t_d	—	35	ns
Rise Time			t_r	—	35	ns
Storage Time	V_{CC} = 3 V, I_C = 10 mA, I_{B1} = $-I_{B2}$ = 1 mAdc	2N3946	t_s	—	300	ns
		2N3947		—	375	
Fall Time			t_f	—	75	ns
SMALL SIGNAL CHARACTERISTICS						
Small-Signal Current Gain (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)		2N3946	h_{fe}	50	250	—
		2N3947		100	700	
Voltage Feedback Ratio (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)		2N3946	h_{re}	—	10	$X10^{-4}$
		2N3947		—	20	
Input Impedance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)		2N3946	h_{ie}	0.5	6	kohms
		2N3947		2	12	
Output Admittance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)		2N3946	h_{oe}	1	30	µmhos
		2N3947		5	50	
Collector-Base Time Constant (I_C = 10 mA, V_{CE} = 20 V, f = 31.8 MHz)			r'_bC_C	—	200	ps
Wide Band Noise Figure (I_C = 100 µA, V_{CE} = 5 V, R_g = 1 kΩ, f = 10 Hz to 15.7 kHz)			NF	—	5	dB

*Pulse Test: PW ≤ 300 µs, Duty Cycle ≤ 2% V_{OB} = Base-Emitter Reverse Bias

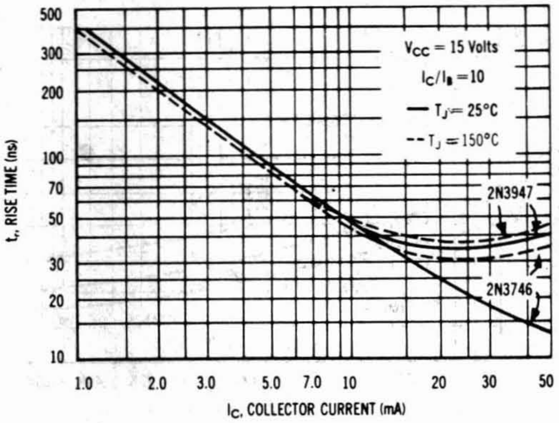
TYPICAL SWITCHING CHARACTERISTICS

($T_J = 25°C$ unless otherwise noted)

DELAY AND RISE TIME

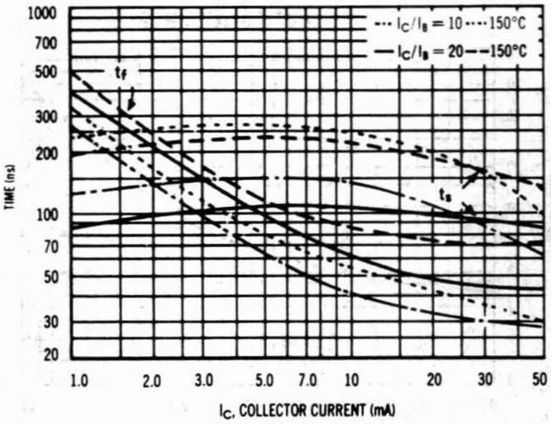


RISE TIME

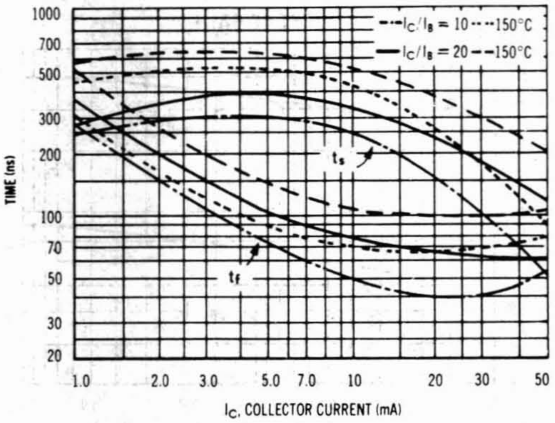


STORAGE AND FALL TIMES

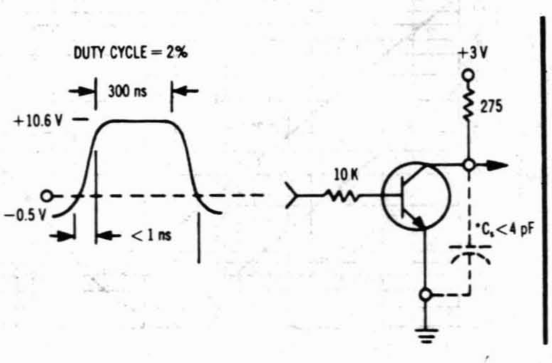
2N3946



2N3947

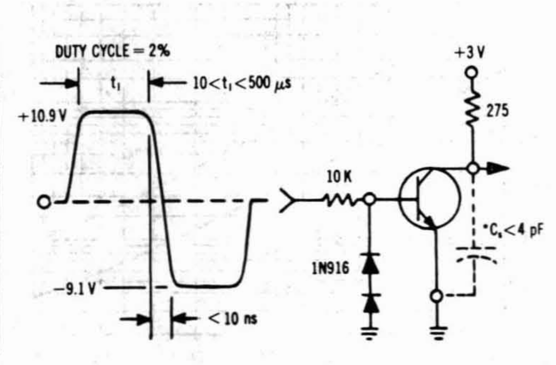


TURN-ON TIME EQUIVALENT TEST CIRCUIT



DUTY CYCLE = 2%
300 ns
+10.6 V
−0.5 V
< 1 ns
10 K
+3 V
275
$^*C_s < 4$ pF

TURN-OFF TIME EQUIVALENT TEST CIRCUIT



DUTY CYCLE = 2%
t_1
$10 < t_1 < 500$ μs
+10.9 V
−9.1 V
< 10 ns
10 K
1N916
+3 V
275
$^*C_s < 4$ pF

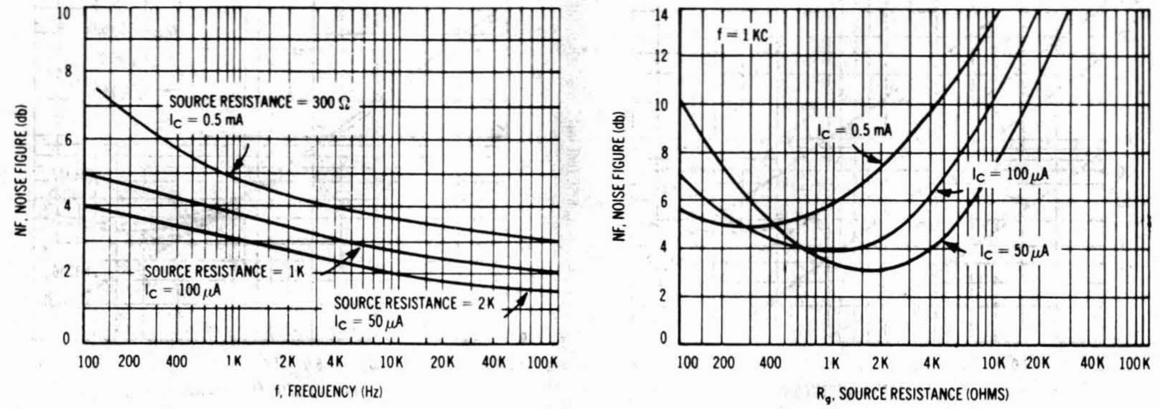
*TOTAL SHUNT CAPACITANCE OF TEST JIG AND CONNECTORS

2N3946, 2N3947 (continued)

AUDIO SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE VARIATIONS

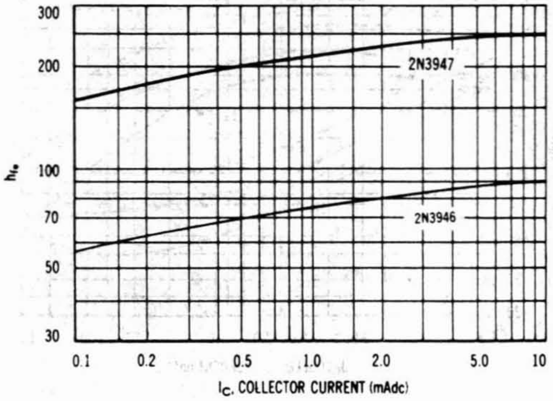
$V_{CE} = 5$ V, $T_A = 25°C$



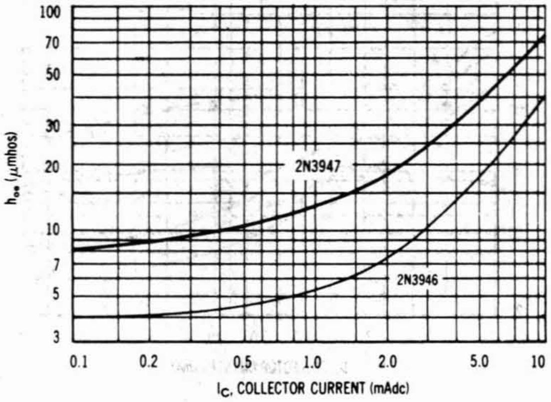
h PARAMETERS

$V_{CE} = 10$ V, $T_A = 25°C$, f = 1 Kc

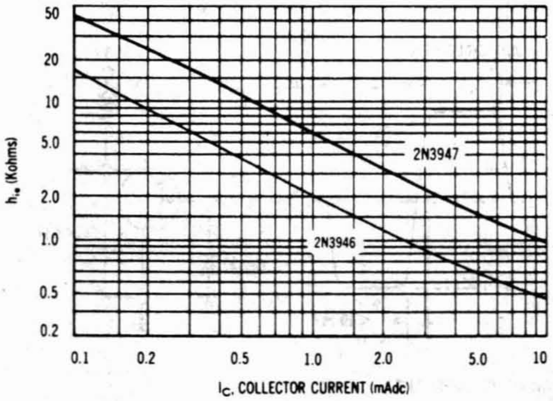
CURRENT GAIN



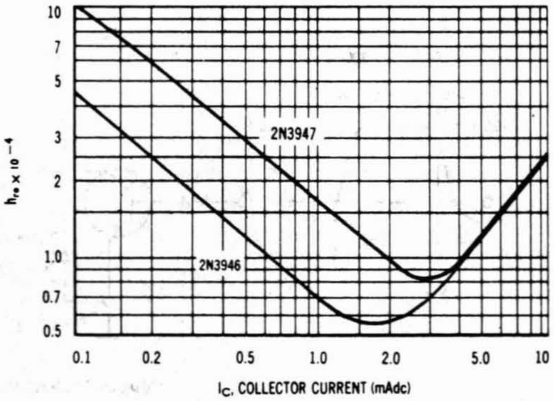
OUTPUT ADMITTANCE



INPUT IMPEDANCE

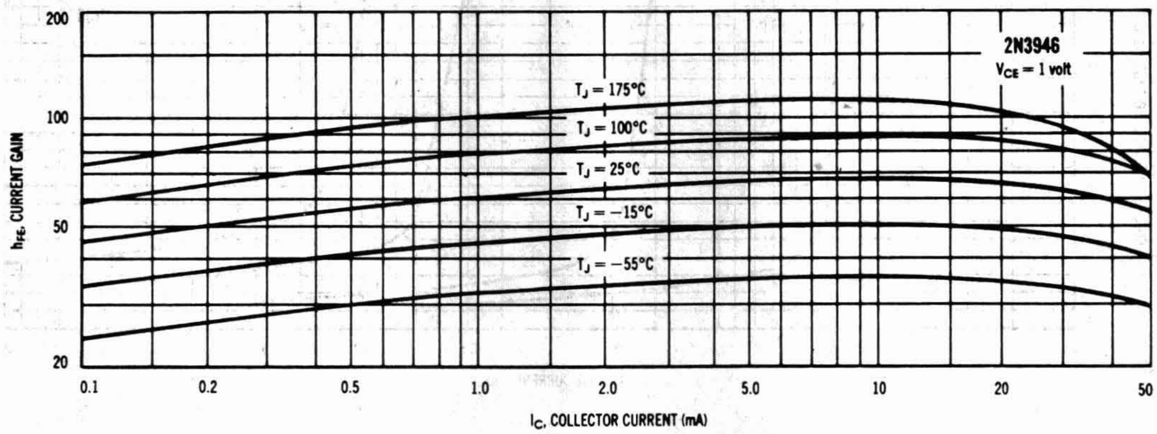


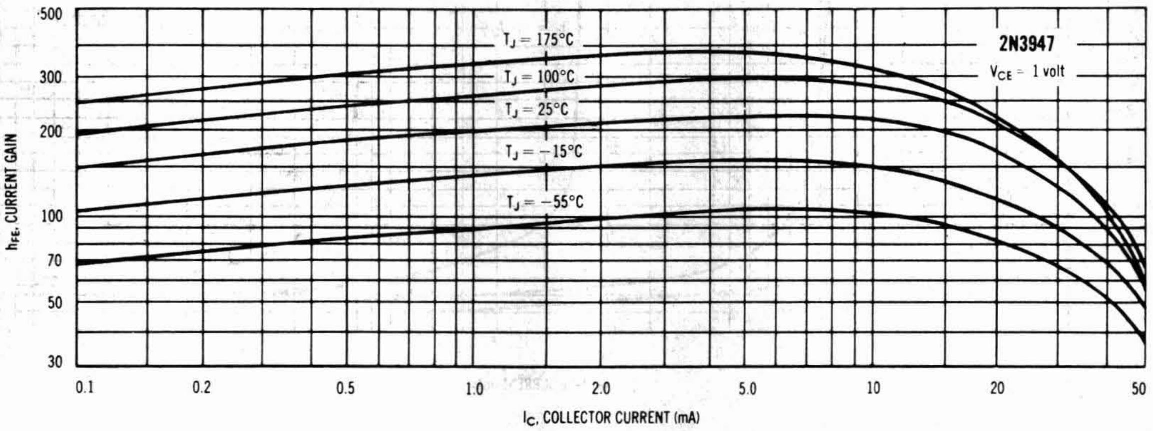
VOLTAGE FEEDBACK RATIO



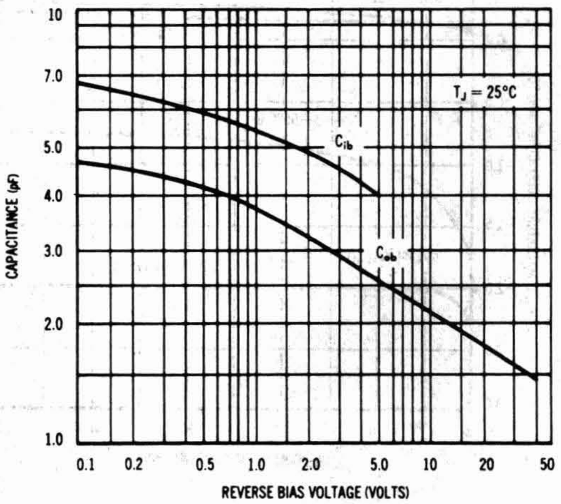
2N3946, 2N3947 (continued)

CURRENT GAIN CHARACTERISTICS

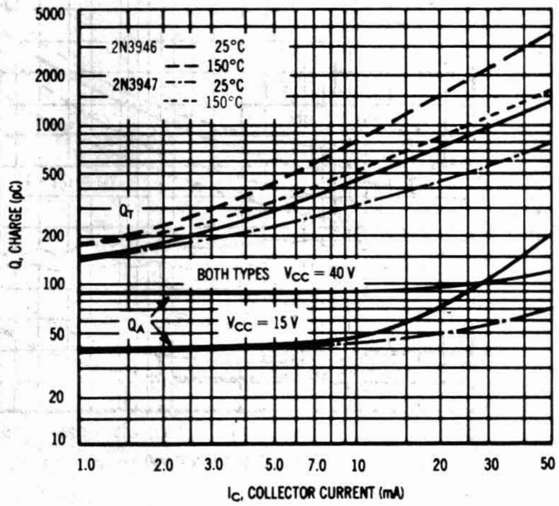




CAPACITANCE

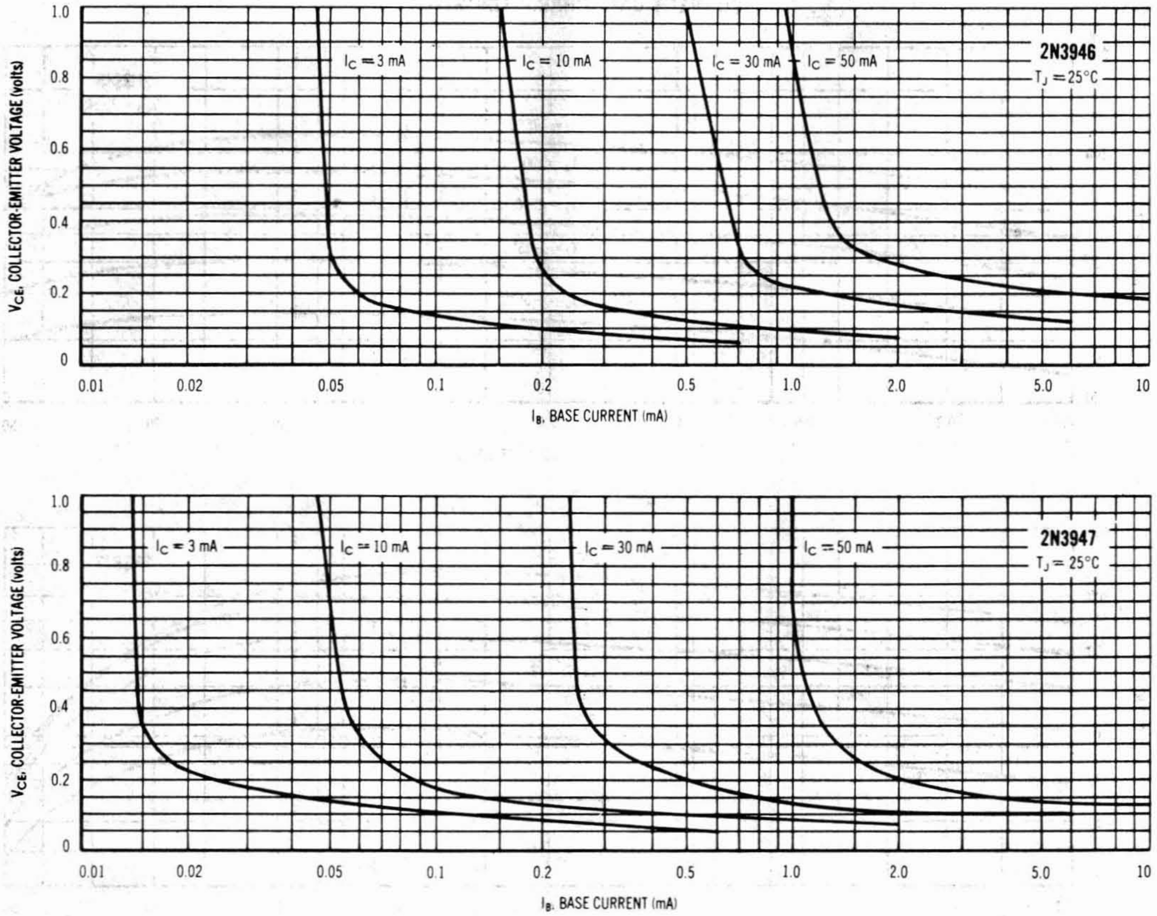


CHARGE DATA

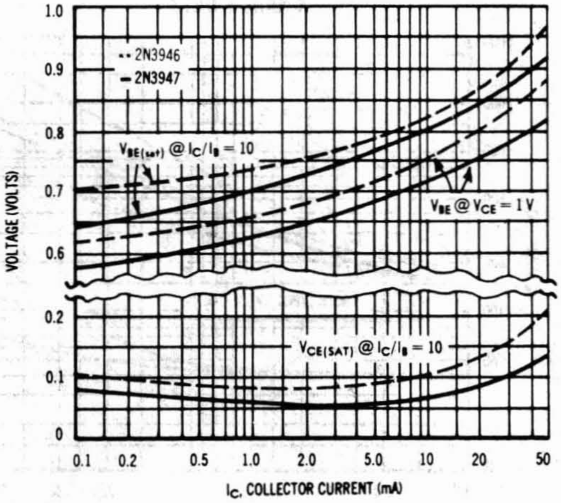


2N3946, 2N3947 (continued)

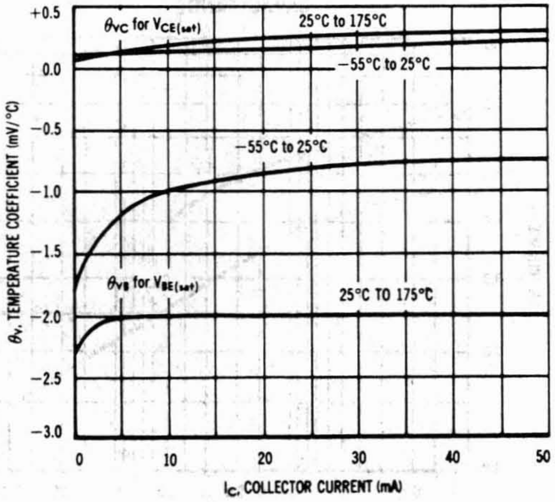
COLLECTOR SATURATION REGION



"ON" VOLTAGES



TEMPERATURE COEFFICIENTS



2N3948 (SILICON)

CASE 79
(TO-39)

NPN silicon RF power transistor designed for amplifier, frequency multiplier, or oscillator applications in military and industrial equipment. Suitable for use as output, driver, or pre-driver stages in VHF and UHF equipment. Ideal for CATV applications.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	36	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector Current — Continuous	I_C	400	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1 5.71	Watt mW/°C
Operating Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	35	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	175	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (I_C = 5 mAdc, I_B = 0)		$BV_{CEO(sus)}$	20	—	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)		BV_{CBO}	36	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)		BV_{EBO}	3.5	—	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)		I_{CBO}	 — —	 0.1 100	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 50 mAdc, V_{CE} = 5 Vdc)		h_{FE}	15	—	—
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_E = 50 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)		f_T	700	—	MHz
Output Capacitance (V_{CB} = 15 Vdc, I_E = 0, f = 1 MHz)		C_{ob}	—	4.5	pF
FUNCTIONAL TEST					
Power Gain	V_{CE} = 13.6 Vdc, R_S = 50 ohms, R_L = 50 ohms, f = 400 MHz, P_{in} = 0.25 W	G_{PE}	6	—	dB
Power Output		P_{out}	1	—	Watt
Collector Efficiency		η	45	—	%

SMALL-SIGNAL ADMITTANCE PARAMETERS VERSUS FREQUENCY

(I_C = 80 mAdc, V_{CE} = 15 Vdc, T_A = 25°C)

FIGURE 1 — y_{ie}

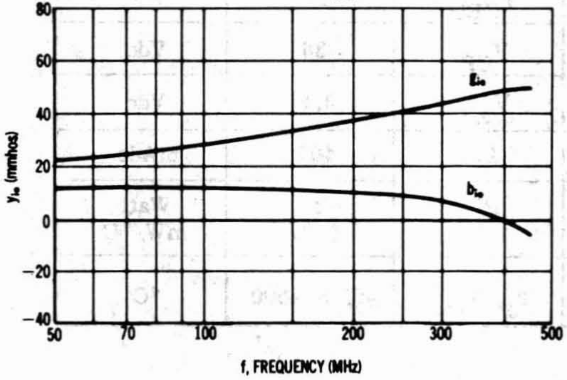


FIGURE 2 — y_{re}

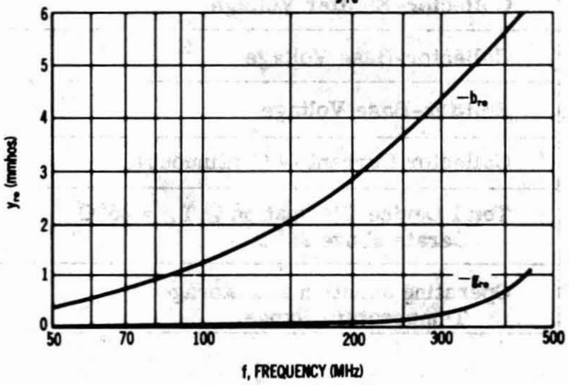


FIGURE 3 — y_{fe}

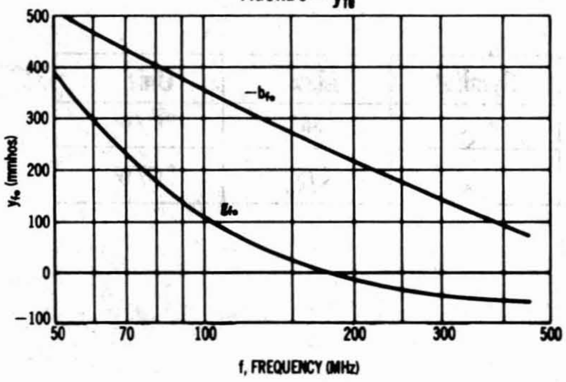


FIGURE 4 — y_{oe}

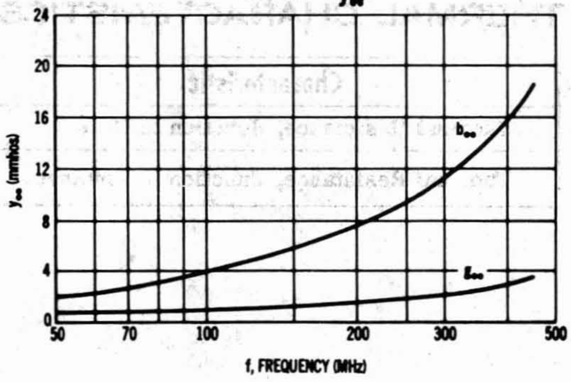


FIGURE 5 — SMALL-SIGNAL CURRENT GAIN

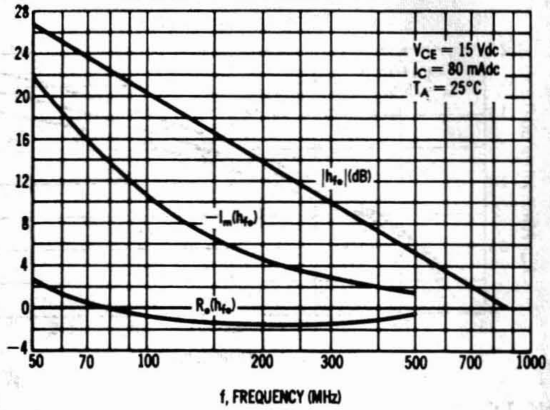
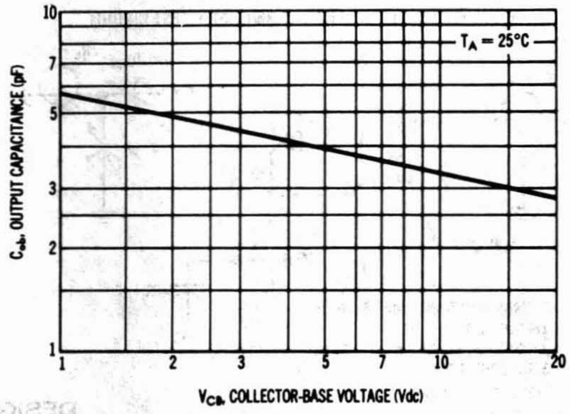


FIGURE 6 — OUTPUT CAPACITANCE



SMALL-SIGNAL ADMITTANCE PARAMETERS VERSUS COLLECTOR CURRENT

(f = 200 MHz, $T_A = 25°C$)

— $V_{CE} = 10$ V — $V_{CE} = 15$ V

FIGURE 7 — y_{ie}

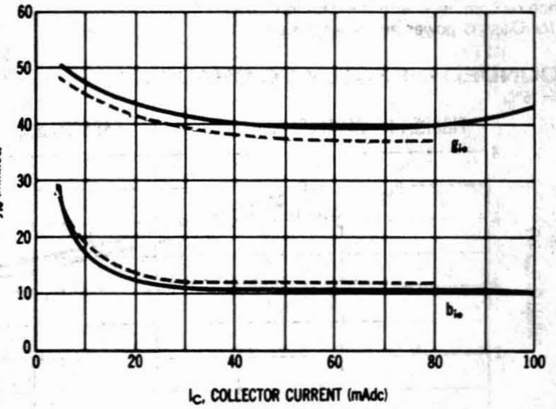


FIGURE 8 — y_{re}

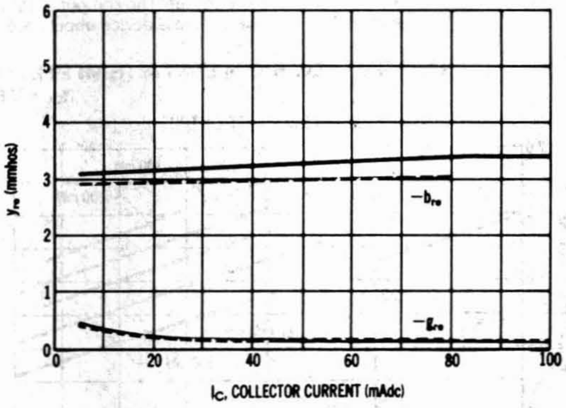


FIGURE 9 — y_{fe}

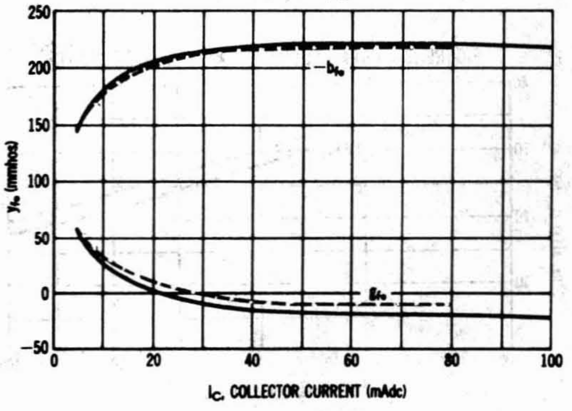
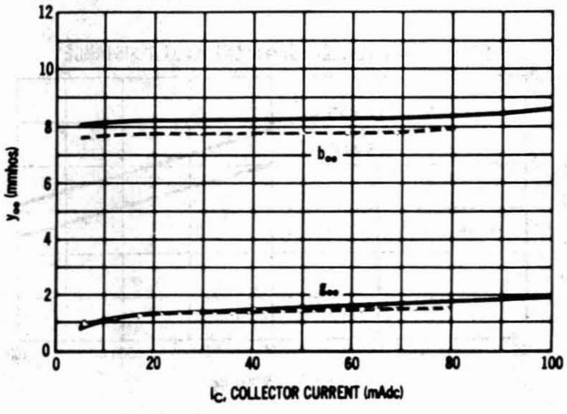
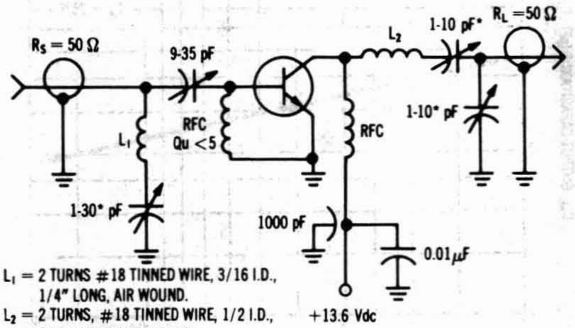


FIGURE 10 — y_{oe}



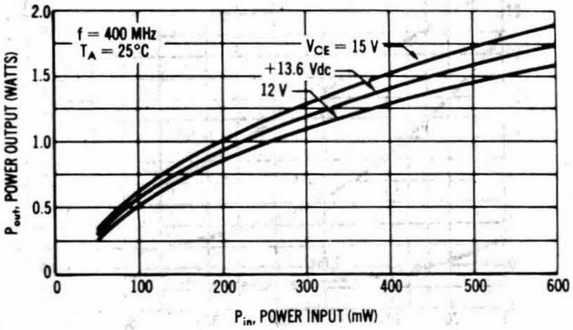
2N3948 (continued)

FIGURE 11 — 400 MHz RF AMPLIFIER TEST CIRCUIT



L_1 = 2 TURNS #18 TINNED WIRE, 3/16 I.D., 1/4" LONG, AIR WOUND.
L_2 = 2 TURNS, #18 TINNED WIRE, 1/2 I.D., 3/16" LONG, AIR WOUND.
*AIR VARIABLE CAPACITORS

FIGURE 12 — POWER GAIN



DESIGN NOTE

Figures 1 through 4 and 7 through 10 show small-signal admittance-parameter data. This data can be used for Class A amplifier designs.

For Class C power-amplifier designs, the small-signal parameters are not applicable. The parallel equivalent output capacitance and input resistance and capacitance for Class C power-amplifier operation are used

The parallel resistive portion of the collector load impedance for a power amplifier, R_L', may be computed by assuming a peak voltage swing equal to V_{CC}, and using the expression $R_L' = V_{CC}^2/2P$ where P = RF power output. The computed R_L' may then be combined with the data in Figures 14, 15 and 16 to comprise complete device impedance data for Class C power amplifier design.

CLASS C DESIGN DATA (EMITTER GROUNDED DIRECTLY TO CHASSIS)

($V_{CE} = 13.6$ V, $T_A = 25°C$)

FIGURE 13 — POWER OUTPUT

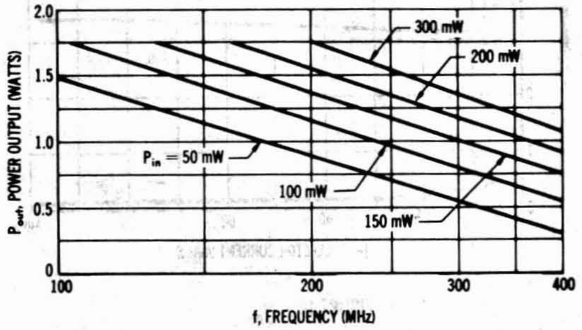


FIGURE 14 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE

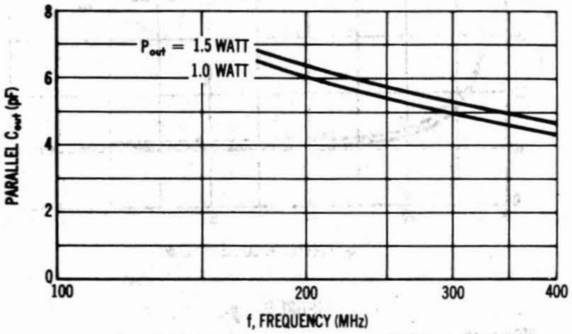


FIGURE 15 — PARALLEL EQUIVALENT INPUT RESISTANCE

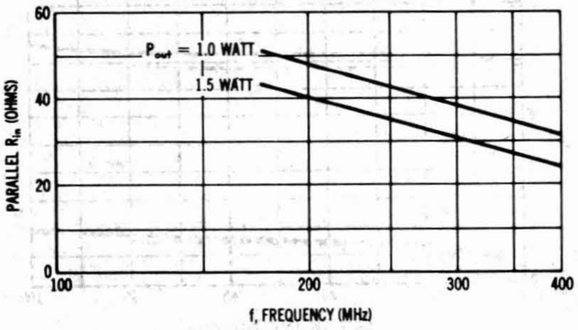
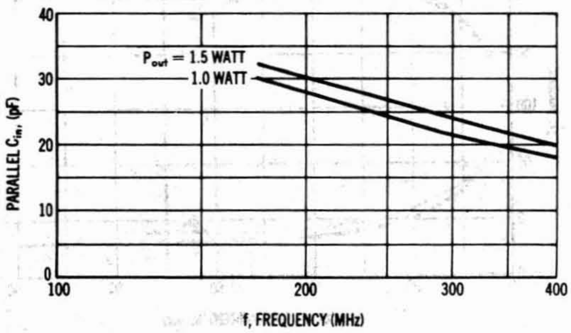


FIGURE 16 — PARALLEL EQUIVALENT INPUT CAPACITANCE



2N3950 (SILICON)

CASE 36
(TO-60)

NPN silicon RF power transistor designed for high-power RF amplifier applications in military and industrial equipment.

Emitter common to stud and case

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	35	Vdc
Collector-Base Voltage	V_{CB}	65	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector-Current — Continuous	I_C	3.3	Amp
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	2.8 16	Watts mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	70 0.4	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

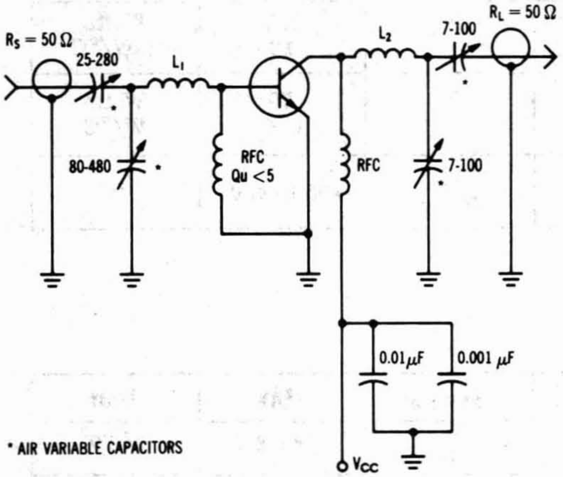
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	62.5	°C/W
Thermal Resistance, Junction to Case	θ_{JC}	2.5	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage* (I_C = 200 mAdc, I_B = 0)		$BV_{CEO(sus)}$*	35	—	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, V_{BE} = 0)		BV_{CES}	65	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 mAdc, I_C = 0)		BV_{EBO}	4	—	—	Vdc
Collector Cutoff Current (V_{CB} = 65 Vdc, I_E = 0) (V_{CB} = 28 Vdc, I_E = 0, T_A = 150°C)		I_{CBO}	 — —	 — —	 10 10	mAdc
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_E = 500 mAdc, V_{CE} = 28 Vdc, f = 50 MHz)		f_T	—	150	—	MHz
Output Capacitance (V_{CB} = 28 Vdc, I_E = 0, f = 1 MHz)		C_{ob}	—	80	120	pF
FUNCTIONAL TEST						
Power Gain	Test Circuit — Figure 1, P_{out} = 50 W, V_{CC} = 28 Vdc, R_S = 50 ohms, f = 50 MHz	G_{PE}	8	—	—	dB
Collector-Efficiency		η	60	—	—	%

*Pulsed through a 25 mH inductor; Duty factor = 50%, Rep. Rate ≤ 60 Hz.

FIGURE 1 — 50 MHz TEST CIRCUIT

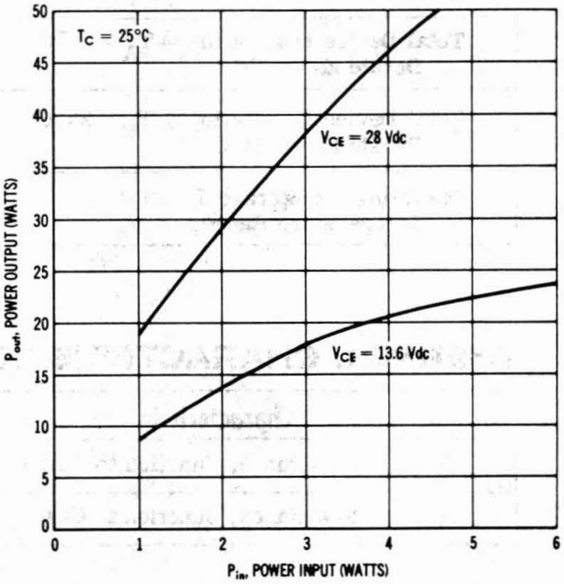


* AIR VARIABLE CAPACITORS

L_1 = 2 TURNS #18 TINNED WIRE, ¼" I.D., AIR WOUND, WINDING LENGTH ⅛".

L_2 = 5 TURNS #16 TINNED WIRE, ⅜" I.D., AIR WOUND, WINDING LENGTH ¾".

FIGURE 2 — 50 MHz POWER GAIN



CLASS C DESIGN DATA FOR $V_{CE} = 28$ Vdc, $T_C = 25°C$

(EMITTER GROUNDED DIRECTLY TO THE CHASSIS — NO TUNED-EMITTER TECHNIQUES USED)

FIGURE 3 — POWER OUTPUT

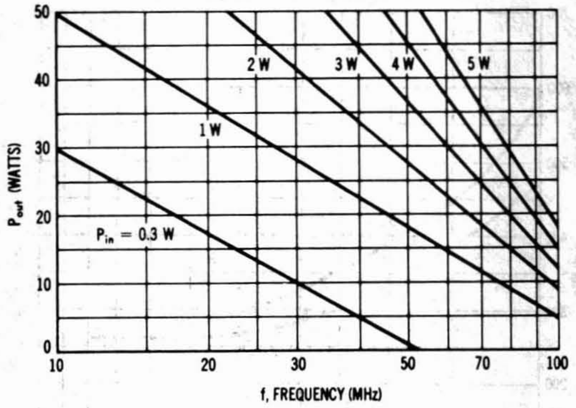


FIGURE 4 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE

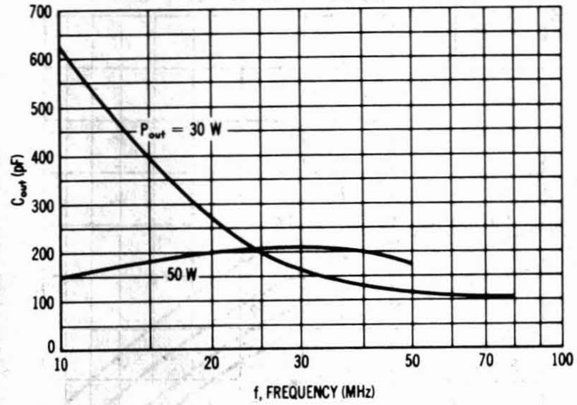


FIGURE 5 — PARALLEL EQUIVALENT INPUT RESISTANCE

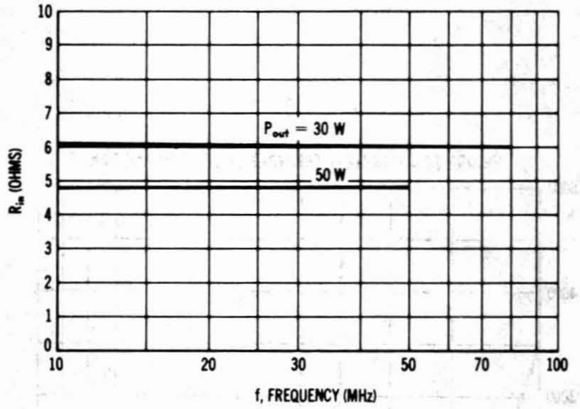
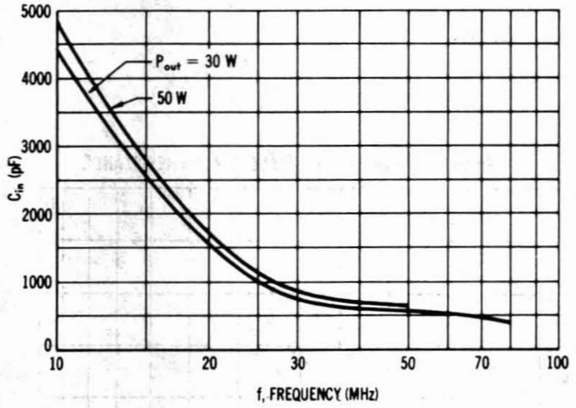


FIGURE 6 — PARALLEL EQUIVALENT INPUT CAPACITANCE



DESIGN NOTES

For Class-C power-amplifier designs, the small-signal parameters are not applicable. Figures 4 thru 6 and 8 thru 10 give the parallel equivalent output capacitance and input capacitance and resistance for Class-C power-amplifier operation.

The parallel resistive portion of the collector load impedance for a power amplifier, R_L' may be computed by assuming a peak voltage swing equal to V_{CC}, and using the expression $R_L' = V_{CC}^2/2P$ where P = RF power output. The computed R_L' may then be combined with the data in Figures 4 through 10 to comprise complete device impedance data for Class-C power-amplifier design.

Due to the high performance capabilities of the 2N3950, care should be exercised during initial tuning of prototype circuits.

Input power should be increased gradually, while stopping at intermediate levels to tune. If tuning difficulties are experienced, or if the power or collector current are abnormal at any intermediate power input level, the difficulties should be resolved before increasing power levels further.

The 2N3950 is designed to provide maximum ruggedness commensurate with its high performance. Operation at loads with high SWR may produce dangerous voltage and current excursions, a condition which should be avoided. In addition, disconnecting the load at full power output could increase device dissipation to over 70 watts which could result in device failure due to dissipation beyond safe limits set by the junction to ambient thermal resistance, regardless of the internal construction and safe area of the device.

CLASS C DESIGN DATA FOR $V_{CE} = 13.6$ Vdc, $T_C = 25°C$

(EMITTER GROUNDED DIRECTLY TO THE CHASSIS — NO TUNED-EMITTER TECHNIQUES USED)

FIGURE 7 — POWER OUTPUT

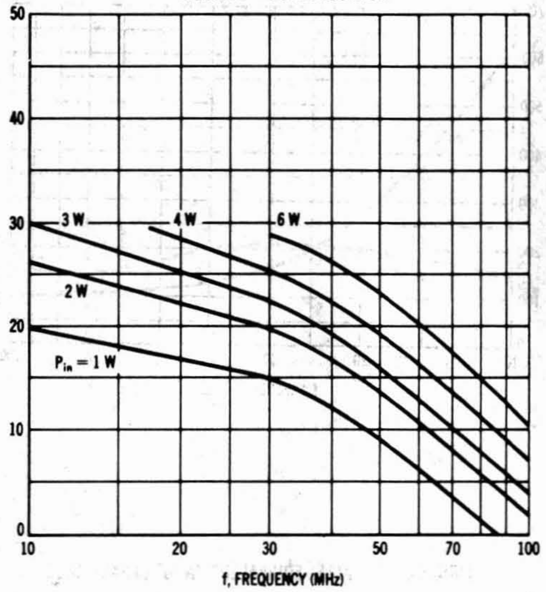


FIGURE 8 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE

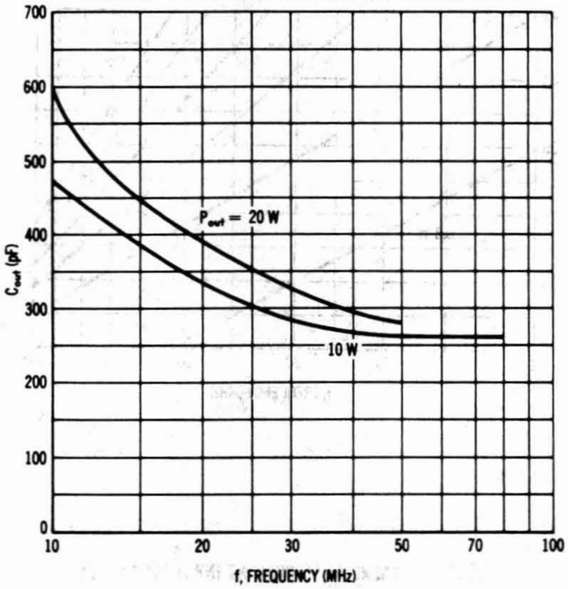


FIGURE 9 — PARALLEL EQUIVALENT INPUT RESISTANCE

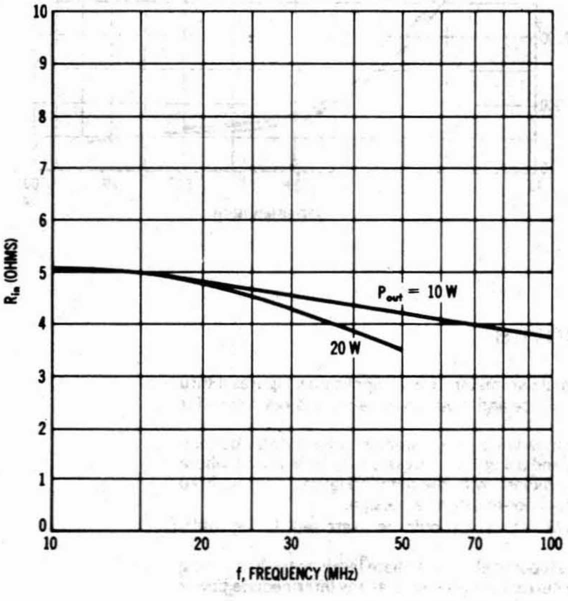
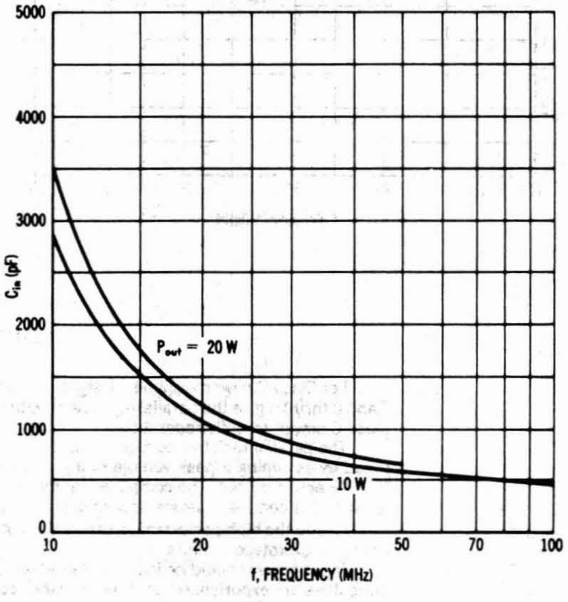


FIGURE 10 — PARALLEL EQUIVALENT INPUT CAPACITANCE



2N3959 (SILICON)
2N3960

CASE 22
(TO-18)

NPN silicon annular transistors particularly well suited for high-speed current-mode logic switching applications.

Collector connected to case

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	20	Vdc
Collector-Emitter Voltage (1 to 30 mA)	V_{CEO}	12	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	750 4.3	mW mW/°C
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	400 2.3	mW mW/°C
Thermal Resistance Junction to Case Junction to Ambient	 θ_{JC} θ_{JA}	 0.233 0.436	°C/mW
Junction Operating Temperature Range	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	20	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	12	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	4.5	—	Vdc
Collector Reverse Current (V_{CE} = 10 Vdc, V_{EB} = 2 Vdc) (V_{CE} = 10 Vdc, V_{EB} = 2 Vdc, T_A = 150°C)	9	I_{CEX}	 — —	 .005 5	μAdc
Base Cutoff Current (V_{CE} = 10 Vdc, V_{EB} = 2 Vdc)	9	I_{BL}	—	.005	μAdc
Collector Forward Current (V_{CE} = 5 Vdc, V_{BE} = 0.4 Vdc)	9	I_{CEX}	—	0.10	μAdc

ELECTRICAL CHARACTERISTICS (continued)

ON CHARACTERISTICS

Characteristic	Fig. No.	Symbol	Min	Max	Unit
DC Current Gain (I_C = 1.0 mAdc, V_{CE} = 1 Vdc) (I_C = 10 mAdc, V_{CE} = 1 Vdc) (I_C = 30 mAdc, V_{CE} = 1 Vdc)	1	h_{FE}	 25 40 25	 — 200 —	—
Collector-Emitter Saturation Voltage (I_C = 1.0 mAdc, I_B = 0.1 mAdc) (I_C = 30 mAdc, I_B = 3 mAdc)	2, 3, 4	$V_{CE(sat)}$	 — —	 0.2 0.3	Vdc
Base-Emitter "ON" Voltage (I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc) (I_C = 30 mAdc, V_{CE} = 1.0 Vdc)	3,4	$V_{BE(ON)}$	 — —	 0.8 1.0	Vdc

TRANSIENT CHARACTERISTICS

Characteristic	Fig. No.	Symbol	Min	Max	Unit
Output Capacitance (V_{CB} = 4 Vdc, I_E = 0, f = 1 kHz)	8	C_{ob}	—	2.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	8	C_{ib}	—	2.5	pF
High-Frequency Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N3959 2N3960		$\lvert h_{fe} \rvert$	 13 16	 — —	—
Current-Gain - Bandwidth Product (I_C = 5 mAdc, V_{CE} = 4 Vdc, f = 100 MHz) 2N3959 2N3960 (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N3959 2N3960 (I_C = 30 mAdc, V_{CE} = 4 Vdc, f = 100 MHz) 2N3959 2N3960	5	f_T	 1000 1300 1300 1600 1000 1200	 — — — — — —	MHz
Collector-Base Time Constant (I_C = 5 mAdc, V_{CE} = 4 Vdc) 2N3959 2N3960 (I_C = 10 mAdc, V_{CE} = 10 Vdc) 2N3959 2N3960 (I_C = 30 mAdc, V_{CE} = 4 Vdc) 2N3959 2N3960	6	$r'_b C_c$	 — — — — — —	 30 50 25 40 30 50	ps

TYPICAL SWITCHING TIMES

			Typical Performance (v_{out} = 1 V)		
			@ 10 mA	@ 30 mA	
Turn-On Delay Time	7	$t_{on(delay)}$	2.4	2	ns
Rise Time 2N3959		t_r	3	2.2	ns
2N3960			3	1.7	ns
Turn-Off Delay Time	7	$t_{off(delay)}$	1.6	1.6	ns
Fall-Time 2N3959		t_f	3.3	2.3	ns
2N3960			3.3	1.9	ns

2N3959, 2N3960 (continued)

FIGURE 1

MINIMUM DC CURRENT GAIN

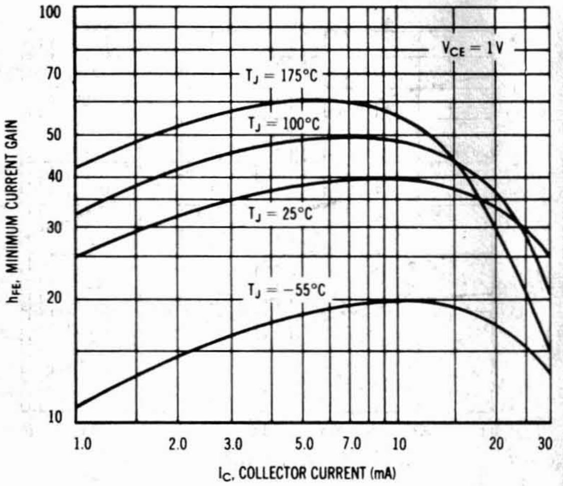
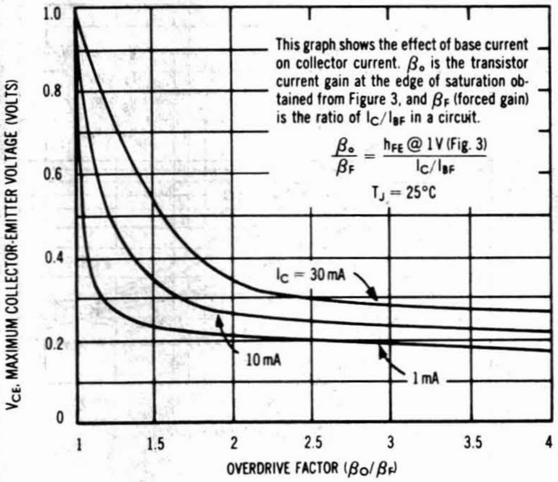


FIGURE 2

COLLECTOR SATURATION REGION



This graph shows the effect of base current on collector current. β_o is the transistor current gain at the edge of saturation obtained from Figure 3, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit.

$$\frac{\beta_o}{\beta_F} = \frac{h_{FE} @ 1\,V \text{ (Fig. 3)}}{I_C/I_{BF}}$$

$T_J = 25°C$

FIGURE 3

"ON" VOLTAGE LIMITS

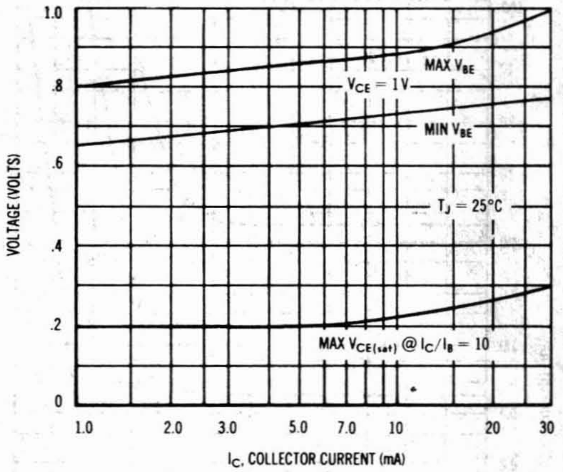


FIGURE 4

MAXIMUM COLLECTOR-BASE TIME CONSTANT

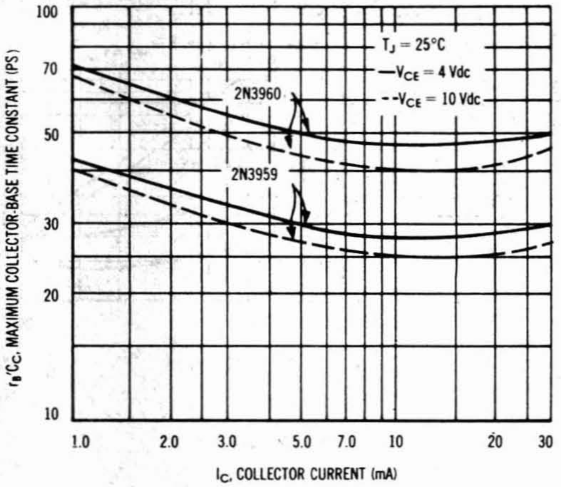


FIGURE 5

TYPICAL TEMPERATURE COEFFICIENTS

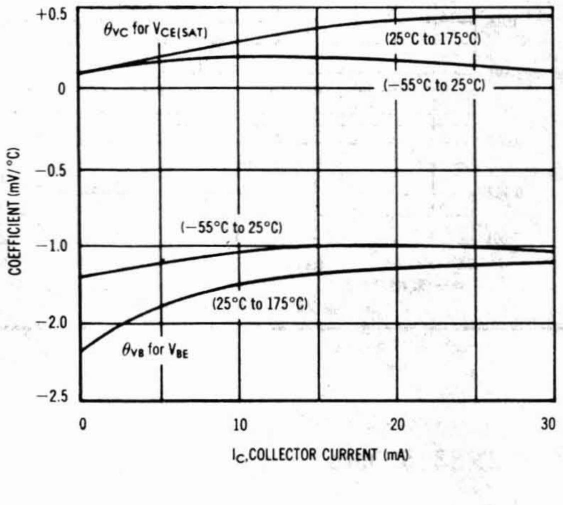
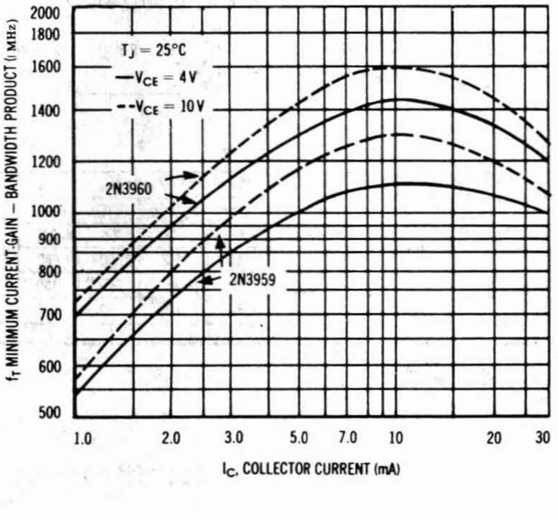


FIGURE 6

MINIMUM CURRENT GAIN-BANDWIDTH PRODUCT



2N3959, 2N3960 (continued)

FIGURE 7
TYPICAL SWITCHING TIMES

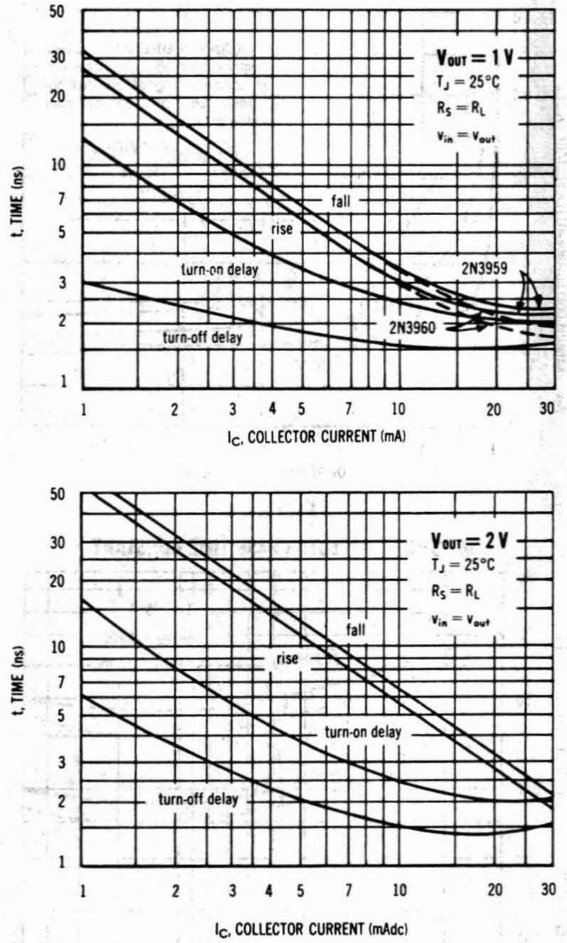


FIGURE 8
JUNCTION CAPACITANCE

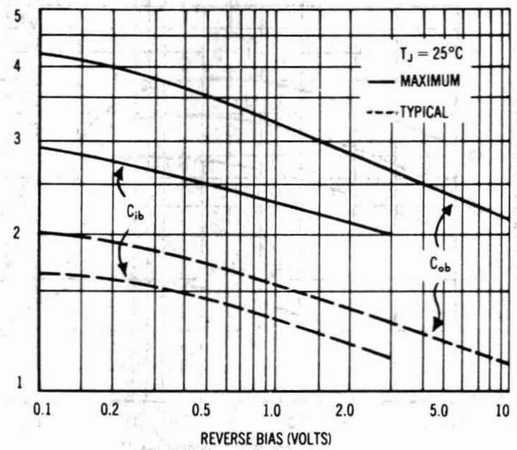
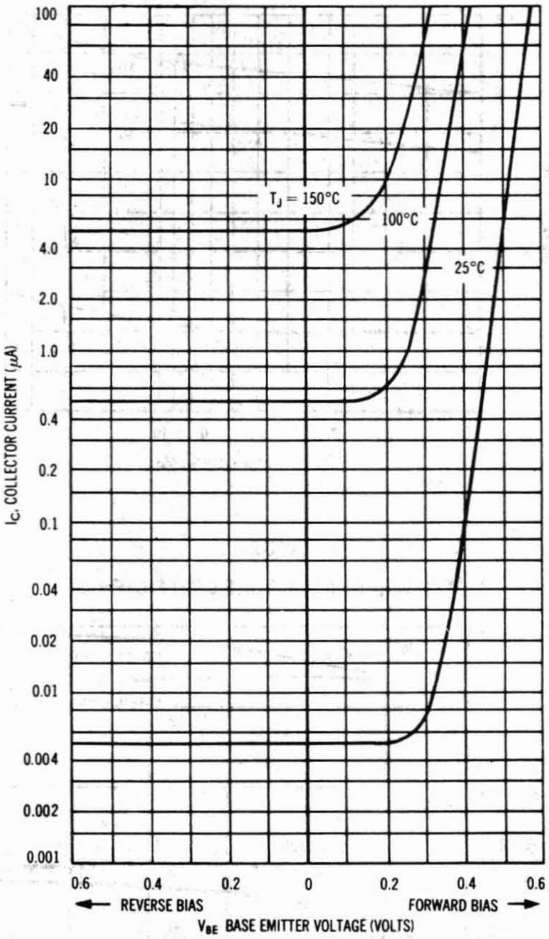
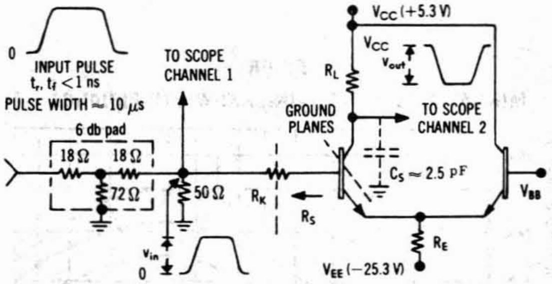


FIGURE 9
MAXIMUM CUT-OFF CHARACTERISTICS



TEST CIRCUIT


0
INPUT PULSE
tr, tf < 1 ns
PULSE WIDTH ≈ 10 µs
6 db pad
18 Ω
18 Ω
72 Ω
TO SCOPE CHANNEL 1
50 Ω
Vin
0
RK
RS
GROUND PLANES
VCC (+5.3 V)
VCC
Vout
RL
TO SCOPE CHANNEL 2
CS ≈ 2.5 pF
VBB
RE
VEE (−25.3 V)

THIS TEST SET UP IS DESIGNED TO SIMULATE A CASCADE OF IDENTICAL STAGES. ∴ THE SOURCE RESISTANCE (R_S) EQUALS THE LOAD RESISTANCE (R_L). VALUES USED IN THE TEST ARE SHOWN IN THE TABLE.

FOR $V_{in} = V_{out} = 1V$, $V_{BB} = +0.5V$, R_L & R_K VALUES APPROPRIATELY REDUCED

$V_{in} = V_{out} = 2$ volts, $V_{BB} = +1.0V$			
I_C (mA)	R_E (KΩ)	R_L (Ω)	R_K (Ω)
1.0	24.0	2 K	2 K
3.0	8.2	680	680
10	2.4	200	180
30	0.8	68	36

2N3961

For Specifications, See 2N3375 Data.

2N3980 (SILICON)

CASE 22 A
(TO-18 Modified)
(Lead 3 connected to case)

Silicon annular PN unijunction transistor designed for military and industrial use in pulse, timing, sensing, and oscillator circuits.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	P_D	360*	mW
RMS Emitter Current	I_e	50	mA
Peak Pulse Emitter Current**	i_e	1.0**	Amp
Emitter Reverse Voltage	V_{B2E}	30	Volts
Interbase Voltage	V_{B2B1}	35	Volts
Storage Temperature Range	T_{stg}	-65 to +200	°C

* Derate 2.4 mW/°C increase in ambient temperature. Total power dissipation (available power to Emitter and Base-Two) must be limited by external circuitry.

**Capacitance discharge current must fall to 0.37 Amp within 3.0 ms and PRR ≤ 10 PPS.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Intrinsic Standoff Ratio (V_{B2B1} = 10 V) Note 1	η	0.68	—	0.82	—
Interbase Resistance (V_{B2B1} = 3.0 V, I_E = 0)	R_{BB}	4.0	6.0	8.0	k ohms
Interbase Resistance Temperature Coefficient (V_{B2B1} = 3.0 V, I_E = 0, T_A = -65°C to +100°C)	αR_{BB}	0.4	—	0.9	%/°C
Emitter Saturation Voltage (V_{B2B1} = 10 V, I_E = 50 mA) Note 2	$V_{EB1(sat)}$	—	2.5	3.0	Volts
Modulated Interbase Current (V_{B2B1} = 10 V, I_E = 50 mA)	$I_{B2(mod)}$	12	15	—	mA
Emitter Reverse Current (V_{B2E} = 30 V, I_{B1} = 0) (V_{B2E} = 30 V, I_{B1} = 0, T_A = 125°C)	I_{EO}	— —	5.0 —	10 1.0	nA μA
Peak Point Emitter Current (V_{B2B1} = 25 V)	I_P	—	0.6	2.0	μA
Valley Point Current (V_{B2B1} = 20 V, R_{B2} = 100 ohms) Note 2	I_V	1.0	4.0	10	mA
Base-One Peak Pulse Voltage (Note 3, Figure 3)	V_{OB1}	6.0	8.0	—	Volts
Maximum Oscillation Frequency (Figure 4)	f(max)	1.0	1.25	—	MHz

NOTES

1. Intrinsic standoff ratio, η, is defined by equation:

$$\eta = \frac{V_P - V_{(EB1)}}{V_{B2B1}}$$

Where V_P = Peak Point Emitter Voltage
V_{B2B1} = Interbase Voltage
$V_{(EB1)}$ = Emitter to Base-One Junction Diode Drop ($\approx$0.5 V @ 10 μA)

2. Use pulse techniques: PW $\approx$ 300 μs duty cycle $\leq$2% to avoid internal heating due to interbase modulation which may result in erroneous readings.

3. Base-One Peak Pulse Voltage is measured in circuit of Figure 3. This specification is used to ensure minimum pulse amplitude for applications in SCR firing circuits and other types of pulse circuits.

FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

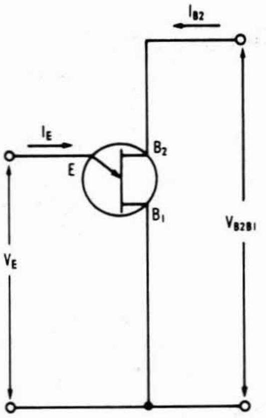


FIGURE 2 — STATIC EMITTER CHARACTERISTICS CURVES

(Exaggerated to Show Details)

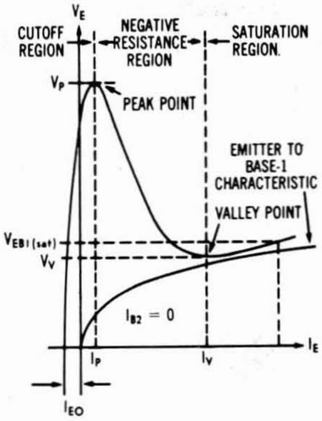


FIGURE 3 — V_{OB1} TEST CIRCUIT

(Typical Relaxation Oscillator)

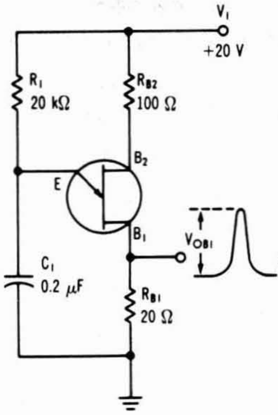
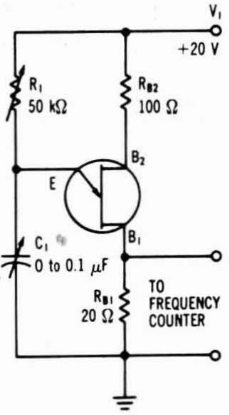


FIGURE 4 — F(max) MAXIMUM FREQUENCY TEST CIRCUIT



2N4012 (SILICON)

stud isolated from case

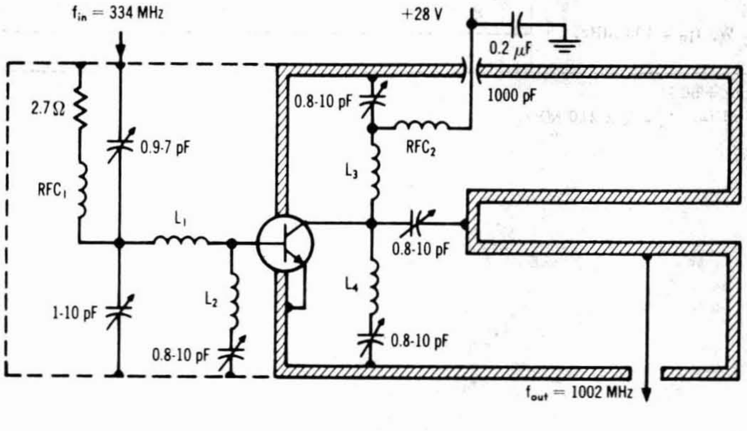
CASE 36
(TO-60)

NPN silicon annular transistor, designed for frequency-multiplication applications.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Emitter Voltage ($V_{EB(off)} = 1.5$ Vdc)	V_{CEV}	65	Vdc
Collector-Base Voltage	V_{CB}	65	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector Current	I_C	1.5	Amps
Total Device Dissipation @ $T_A = 25°C$ Derate Above 25°C	P_D	11.6 66.3	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

FIGURE 1 – TRIPLER TEST CIRCUIT


f_{in} = 334 MHz
+28 V
0.2 µF
1000 pF
2.7 Ω
0.9-7 pF
RFC_1
0.8-10 pF
L_3
RFC_2
L_1
0.8-10 pF
L_2
L_4
1-10 pF
0.8-10 pF
0.8-10 pF
f_{out} = 1002 MHz

RFC_1 = 0.22 µH
RFC_2 = 0.33 OHMS, W. W. RESISTOR
L_1 = 2 TURNS, ⅜″ DIAMETER, NO. 16 WIRE
L_2 = 1/16″ WIDTH COPPER STRIP, ⅜″ LONG
L_3 = 2 TURNS, ⅜″ DIAMETER, NO. 18 WIRE
L_4 = 1½ TURNS, ⅜″ DIAMETER, 1/16″ COPPER STRIP
OUTPUT CAVITY = 1¼″ X 1¼″ X 2¼″
CENTER CONDUCTOR = ¼″ OD TUBE
OUTPUT DIRECT COUPLE = 1″ FROM SHORTED END

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 0 to 200 mAdc, I_B = 0)	BV_{CEO}^{*}	40	-	-	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 0 to 200 mAdc, $V_{EB(off)}$ = 1.5 Vdc)	BV_{CEV}^{*}	65	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	65	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	4	-	-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, I_B = 0)	I_{CEO}	-	-	0.1	mAdc
ON CHARACTERISTICS					
Collector-Emitter Saturation Voltage (I_C = 500 mAdc, I_B = 100 mAdc)	$V_{CE(sat)}$	-	-	1	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 150 mAdc, V_{CE} = 28 Vdc, f = 100 MHz)	f_T	-	500	-	MHz
Collector-Base Cutoff Frequency † (V_{CE} = 28 Vdc, I_C = 0)	f_c	-	25	-	GHz
Output Capacitance (V_{CB} = 30 Vdc, I_E = 0)	C_{ob}	-	-	10	pF
Base-Spreading Resistance (I_C = 250 mAdc, V_{CE} = 28 Vdc, f = 400 MHz)	r_{bb}'	-	10	-	Ohms

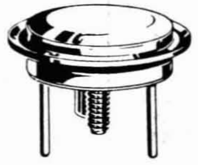
FUNCTIONAL TEST

Power Output	Tripler (Test Circuit Figure 1) V_{CE} = 28 Vdc, P_{in} = 1 W, f_{in} = 334 MHz, f_{out} = 1002 MHz	P_{out}	2.5	-	-	Watts
Efficiency		η	25	-	-	%
Power Output	Doubler V_{CE} = 28 Vdc, P_{in} = 1 W, f_{in} = 400 MHz, f_{out} = 800 MHz	P_{out}	-	3.0	-	Watts
Efficiency		η	-	35	-	%

*Pulsed through a 25 mH inductor; duty cycle = 50%

† f_c is determined from Q measured at 210 MHz. f_c = Q x 210 MHz.

2N4048 thru 2N4053 (GERMANIUM)



Collector connected to case

PNP germanium power transistors designed for high-current applications requiring high gain and extremely low saturation voltage.

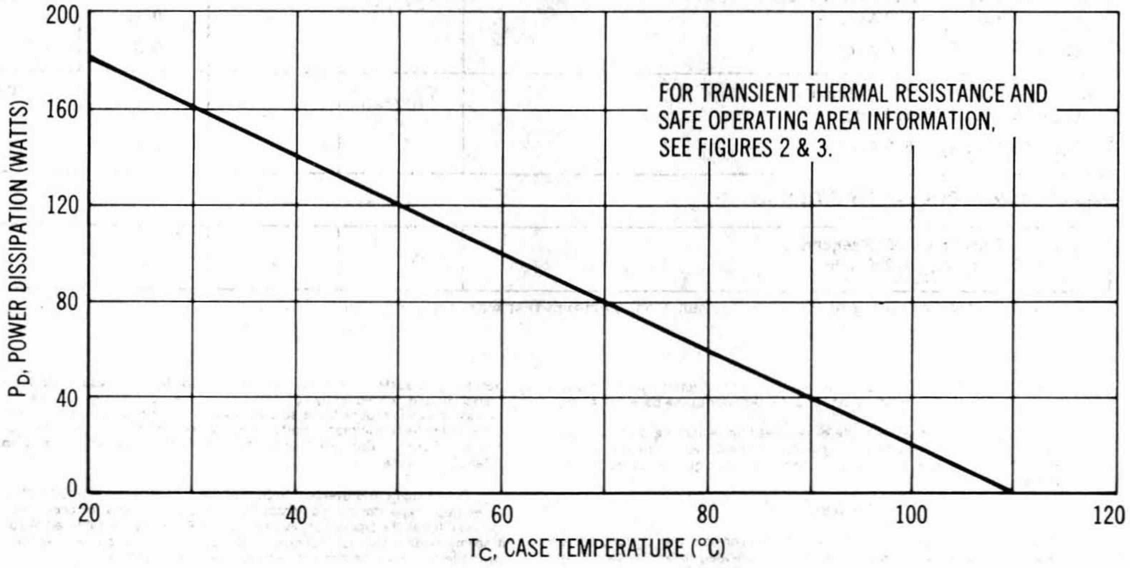
MAXIMUM RATINGS

Rating	Symbol	2N4048 2N4051	2N4049 2N4052	2N4050 2N4053	Unit
Collector-Emitter Voltage	V_{CEO}	30	45	60	Vdc
Collector-Emitter Voltage	V_{CES}	45	60	75	Vdc
Collector-Base Voltage	V_{CB}	45	60	75	Vdc
Emitter-Base Voltage	V_{EB}	25	30	40	Vdc
Collector Current — Continuous	I_C*	← 60 →			Adc
Total Device Dissipation @ $T_C = 25°C$	P_D	← 170 →			Watts
Derate above 25°C		← 2.0 →			W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +110 →			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.5	°C/W

FIGURE 1 — AVERAGE POWER-TEMPERATURE DERATING CURVE



* JEDEC Registered Values, For True Capability See Figure 3

2N4048 thru 2N4053 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage† (I_C = 1.0 Adc, I_B = 0)	2N4048, 2N4051	BV_{CEO}†	30	-	Vdc
	2N4049, 2N4052		45	-	
	2N4050, 2N4053		60	-	
Collector-Emitter Breakdown Voltage (I_C = 300 mAdc, V_{BE} = 0)	2N4048, 2N4051	BV_{CES}	45	-	Vdc
	2N4049, 2N4052		60	-	
	2N4050, 2N4053		75	-	
Floating Potential (V_{CB} = 45 Vdc, I_E = 0)	2N4048, 2N4051	V_{EBF}	-	0.5	Vdc
(V_{CB} = 60 Vdc, I_E = 0)	2N4049, 2N4052		-	0.5	
(V_{CB} = 75 Vdc, I_E = 0)	2N4050, 2N4053		-	0.5	
Collector Cutoff Current (V_{CE} = 30 Vdc, $V_{BE(off)}$ = 2.0 Vdc, T_C = +71°C)	2N4048, 2N4051	I_{CEX}	-	15	mAdc
(V_{CE} = 45 Vdc, $V_{BE(off)}$ = 2.0 Vdc, T_C = +71°C)	2N4049, 2N4052		-	15	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 2.0 Vdc, T_C = +71°C)	2N4050, 2N4053		-	15	
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)		I_{CBO}	-	0.2	mAdc
(V_{CB} = 45 Vdc, I_E = 0)	2N4048, 2N4051		-	4.0	
(V_{CB} = 60 Vdc, I_E = 0)	2N4049, 2N4052		-	4.0	
(V_{CB} = 75 Vdc, I_E = 0)	2N4050, 2N4053		-	4.0	
Emitter Cutoff Current (V_{BE} = 25 Vdc, I_C = 0)	2N4048, 2N4051	I_{EBO}	-	4.0	mAdc
(V_{BE} = 25 Vdc, I_C = 0, T_C = +71°C)			-	15	
(V_{BE} = 30 Vdc, I_C = 0)	2N4049, 2N4052		-	4.0	
(V_{BE} = 30 Vdc, I_C = 0, T_C = +71°C)			-	15	
(V_{BE} = 40 Vdc, I_C = 0)	2N4050, 2N4053		-	4.0	
(V_{BE} = 40 Vdc, I_C = 0, T_C = +71°C)			-	15	
ON CHARACTERISTICS					
DC Current Gain† (I_C = 15 Adc, V_{CE} = 2.0 Vdc)	2N4048, 2N4049, 2N4050	h_{FE}†	60	120	-
	2N4051, 2N4052, 2N4053		80	180	
(I_C = 60 Adc, V_{CE} = 2.0 Vdc)			15	-	
Collector-Emitter Saturation Voltage† (I_C = 15 Adc, I_B = 1.0 Adc)		$V_{CE(sat)}$†	-	0.15	Vdc
(I_C = 60 Adc, I_B = 6.0 Adc)			-	0.3	
Base-Emitter Saturation Voltage† (I_C = 15 Adc, I_B = 1.0 Adc)		$V_{BE(sat)}$†	-	0.6	Vdc
(I_C = 60 Adc, I_B = 6.0 Adc)			-	1.0	
SMALL SIGNAL CHARACTERISTICS					
Common-Emitter Cutoff Frequency (I_C = 15 Adc, V_{CE} = 2.0 Vdc)		$f_{\alpha e}$	2.0	-	kHz

† To avoid excessive heating of the collector junction, perform test with pulse method.

The switching performance of this transistor is determined primarily by the gain-bandwidth product, f_T*, and the behavior of the base-spreading resistance, r_B'.

In the case of rise time, the base-spreading resistance plays a small part, and the test circuit delivers a constant current step of turn-on current to the transistor (I_{B1}). Therefore, the curve of t_r on Figure 6 follows theory closely, i.e.:

$$t_r = 0.8\,\frac{I_C}{I_{B1}} \cdot \frac{1}{2\pi f_T}$$

From the curve, it can be seen that f_T is roughly constant with current; using the equation, its large signal value can be calculated to be approximately 120 kHz at the 20-Amp level. A lower supply voltage will increase rise time slightly.

Turn-off time is slow because of conductivity modulation which occurs in the base region. When the transistor is held "on" in saturation, the base region becomes filled with excess charge; i.e., charge in excess of that necessary to sustain the circuit limited value of I_C. As a result, the base resistivity and consequently r_B' become very low. During turn off, as the excess charge is reduced, the accompanying increase in resistivity causes a marked reduction in the turn-off current, i_{B2}, as can be seen from the waveforms of Figure 5. During fall time, the i_{B2} current is very low causing an extended fall time.

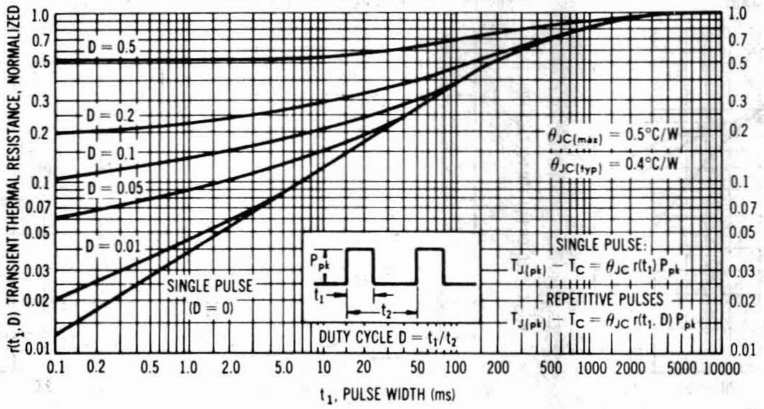
Only a slight improvement in turn-off performance is achieved with a "speed-up" capacitor placed across R_B. This unusual behavior occurs because r_B' limits the amount of reverse current which can be achieved. Also, it seems evident that r_B' increases with applied reverse current, so that efforts to speed up the turn-off behavior are somewhat futile.

In most applications, switching time will be close to the values shown on Figure 6. Delay time is not shown as it is negligible in comparison to the other times.

---

* $f_T = f_{\alpha e} \times h_{fe}$

FIGURE 2 — TRANSIENT THERMAL RESISTANCE



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate I_C-V_{CE} limits of the transistor that must be observed for reliable operation; i.e. the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 3 is based on $T_{J(pk)} = 110°C$; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 110°C$. $T_{J(pk)}$ may be calculated from the data in Figure 2. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 3 — ACTIVE REGION SAFE-OPERATING AREA

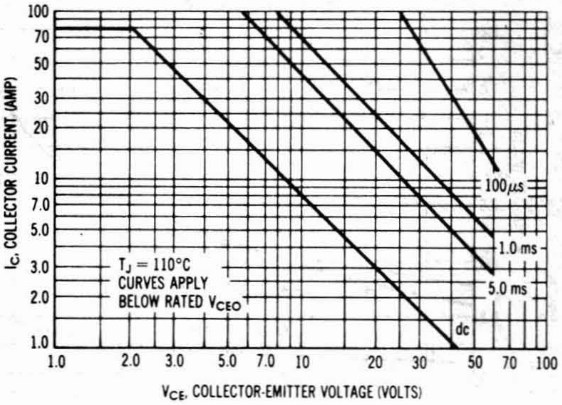
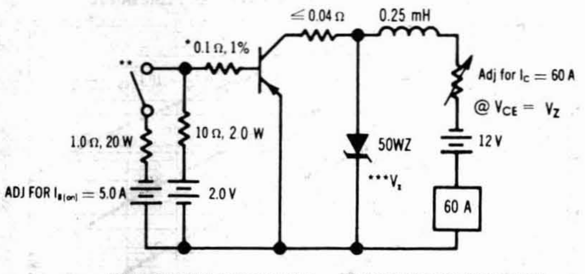


FIGURE 4 — SAFE OPERATING AREA TEST CIRCUIT


≤ 0.04 Ω
0.25 mH
*0.1 Ω, 1%
**
Adj for IC = 60 A
@ VCE = VZ
1.0 Ω, 20 W
10 Ω, 2.0 W
50WZ
***VZ
12 V
ADJ FOR IB(on) = 5.0 A
2.0 V
60 A

*NOT REQUIRED IF CURRENT PROBE USED TO READ $I_{B(on)}$

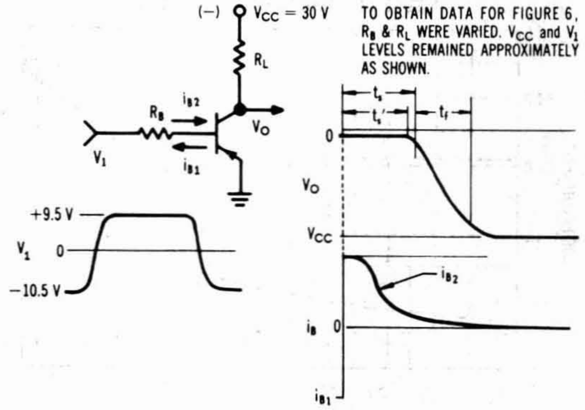
**PRF ≈ 60 Hz

SERIES IMPEDANCE & INDUCTANCE MUST BE KEPT TO A MINIMUM.

***ZENER SELECTED TO ESTABLISH SAFE OPERATING AREA VOLTAGE.

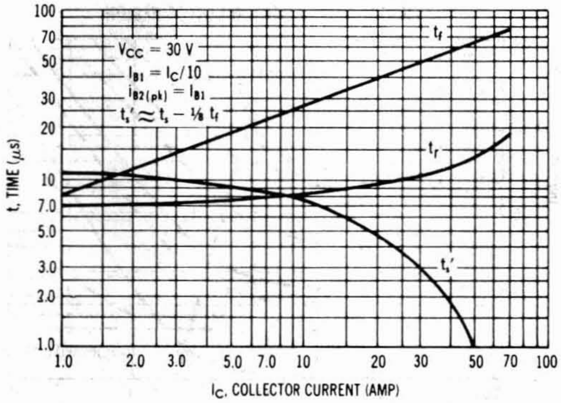
@ I_C = 60 Adc:
2N4048, 2N4051 = 35 Vdc
2N4049, 2N4052 = 40 Vdc
2N4050, 2N4053 = 45 Vdc

FIGURE 5 — SWITCHING TEST CIRCUIT


(−) VCC = 30 V
RL
RB
iB2
iB1
V1
VO
+9.5 V
V1
0
−10.5 V
ts
ts'
tf
0
VO
VCC
iB2
iB 0
iB1

TO OBTAIN DATA FOR FIGURE 6, R_B & R_L WERE VARIED. V_{CC} and V_1 LEVELS REMAINED APPROXIMATELY AS SHOWN.

FIGURE 6 — SWITCHING TIMES



TYPICAL DC CHARACTERISTICS

FIGURE 7 — DC CURRENT GAIN

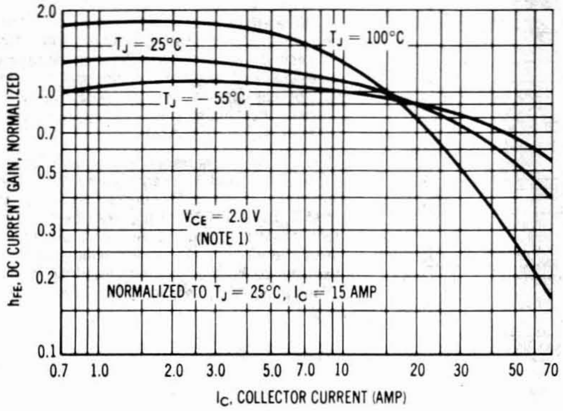


FIGURE 8 — COLLECTOR SATURATION REGION

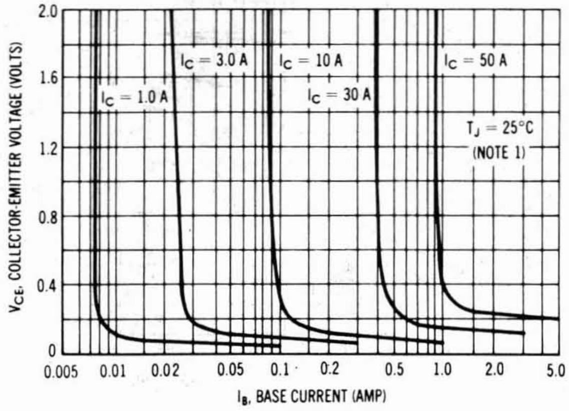


FIGURE 9 — EFFECTS OF BASE-EMITTER RESISTANCE

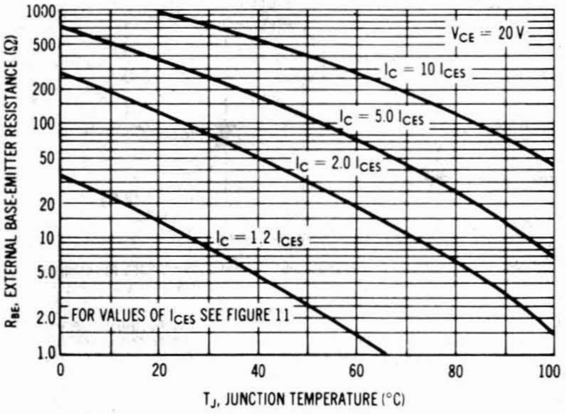


FIGURE 10 — "ON" VOLTAGES

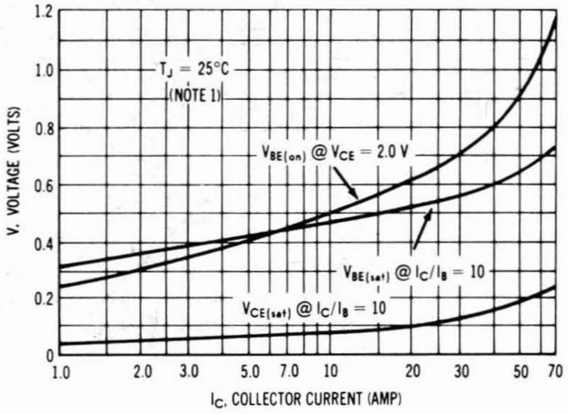


FIGURE 11 — COLLECTOR CUTOFF REGION

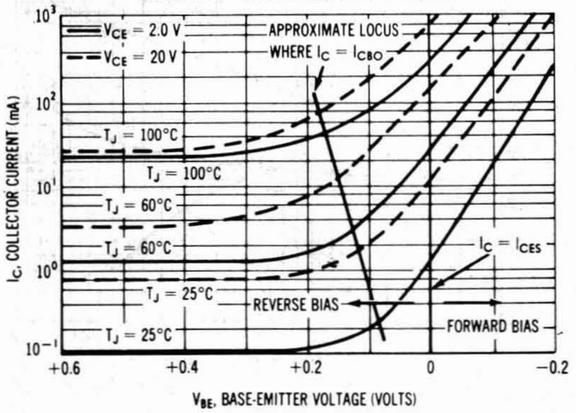
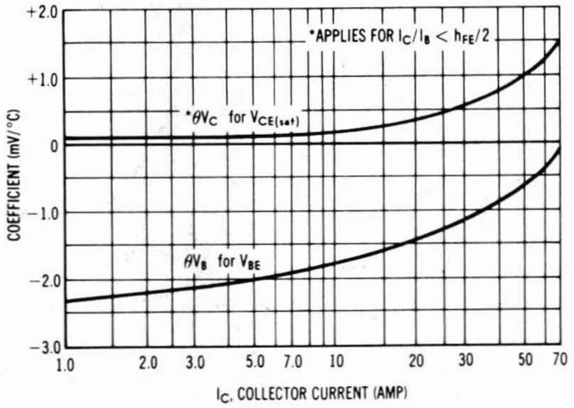


FIGURE 12 — TEMPERATURE COEFFICIENTS



NOTE 1: Data is obtained from pulse tests and adjusted to nullify the effect of I_{CBO}.

2N4072 (SILICON)
2N4073

CASE 22
(TO-18)
2N4072

CASE 31
(TO-5)
2N4073

NPN silicon annular transistors designed as amplifiers and drivers for large-signal VHF and UHF applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4072	2N4073	Unit
Collector-Emitter Voltage	V_{CEO}	20		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	4.0		Vdc
Collector Current-Continuous	I_C	100	150	mAdc
Total Device Dissipation @ T_A = 25°C Derate Above 25°C	P_D	0.35 2.0	- -	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	- -	1.5 8.57	Watts mW/°C
Operating Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +200		°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
STATIC CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (I_C = 15 mAdc, I_B = 0)	$BV_{CEO(sus)}$	20	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	40	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	4.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	- -	0.1 100	μAdc
DC Current Gain (I_C = 25 mAdc, V_{CE} = 2 Vdc)	h_{FE}	10	-	-	-
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 25 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	-	550	-	MHz
Output Capacitance (V_{CB} = 15 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	3.0	4.0	pF

2N4072, 2N4073 (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Typ	Max	Unit
FUNCTIONAL TEST						
Power Gain	2N4072 Test Circuit - Figure 5 P_{in} = 25 mW, V_{CE} = 13.6 Vdc, f = 175 MHz	G_{PE}	10	-	-	dB
Power Output		P_{out}	250	-	-	mW
Collector Effecency		η	50	60	-	%
Power Gain	2N4073 Test Circuit - Figure 5 P_{in} = 50 mW, V_{CE} = 13.6 Vdc, f = 175 MHz	G_{PE}	10	-	-	dB
Power Output		P_{out}	500	650	-	mW
Collector Efficiency		η	50	65	-	%

2N4072

FIGURE 1 — POWER OUTPUT versus FREQUENCY

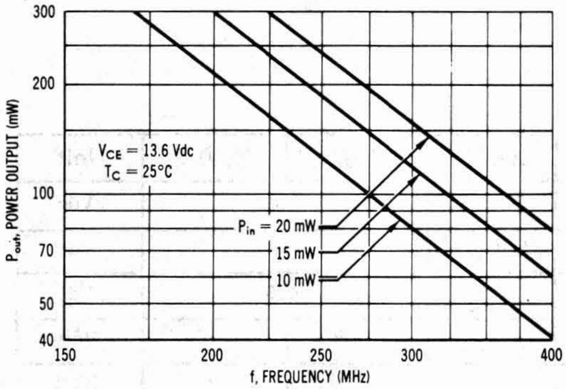
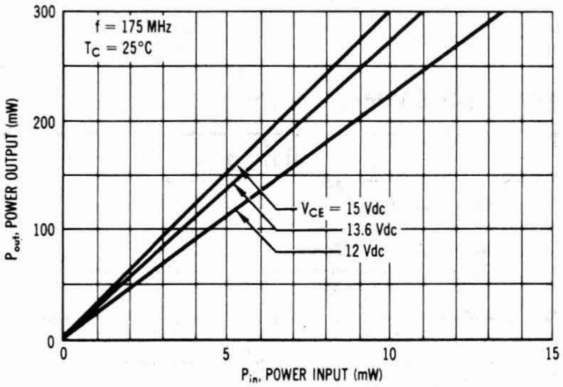


FIGURE 2 — POWER OUTPUT versus POWER INPUT



2N4073

FIGURE 3 — POWER OUTPUT versus FREQUENCY

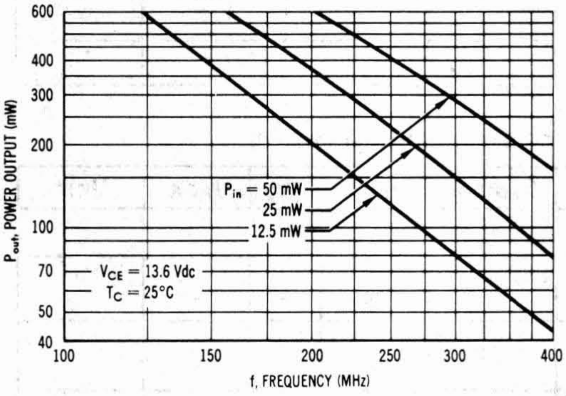


FIGURE 4 — POWER OUTPUT versus POWER INPUT

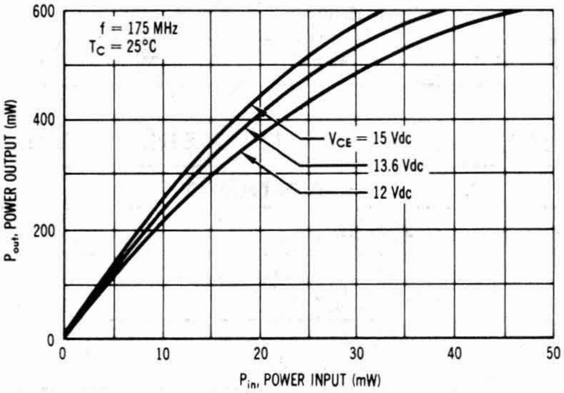
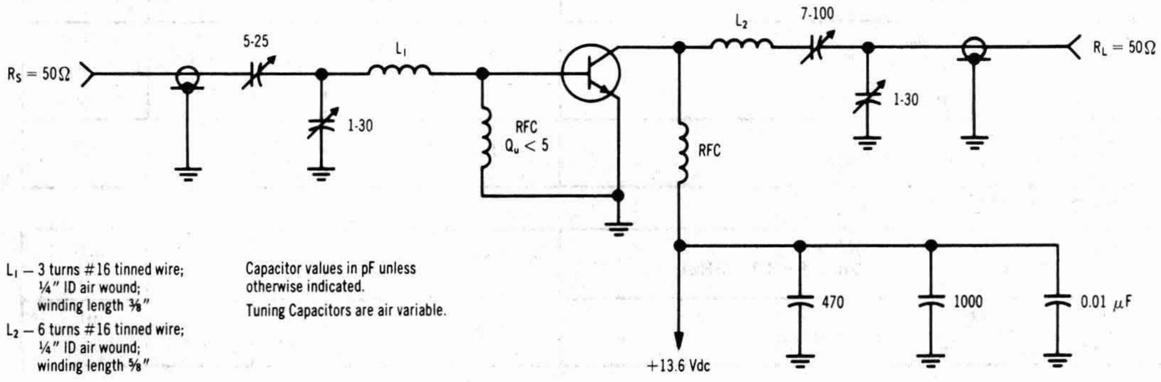


FIGURE 5 — 175 MHz TEST CIRCUIT



L_1 — 3 turns #16 tinned wire;
1/4" ID air wound;
winding length 3/8"

L_2 — 6 turns #16 tinned wire;
1/4" ID air wound;
winding length 5/8"

Capacitor values in pF unless otherwise indicated.

Tuning Capacitors are air variable.

2N4091 (SILICON)
2N4092
2N4093

SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

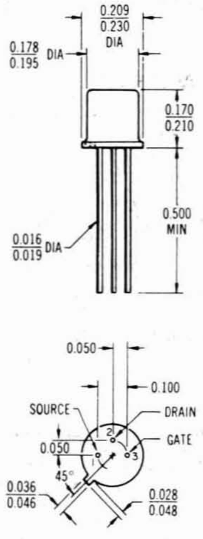
Depletion Mode (Type A) Junction Field-Effect Transistors designed for chopper and high-speed switching applications.

- Low Drain-Source "On" Resistance — $r_{ds(on)}$ = 30 Ohms (Max) @ f = 1.0 kHz (2N4091)
- Low Source Reverse Current — I_{SGO} = 0.2 nAdc (Max) @ V_{SG} = 20 Vdc
- Guaranteed Switching Characteristics

N-CHANNEL

JUNCTION FIELD-EFFECT TRANSISTORS

(Type A)

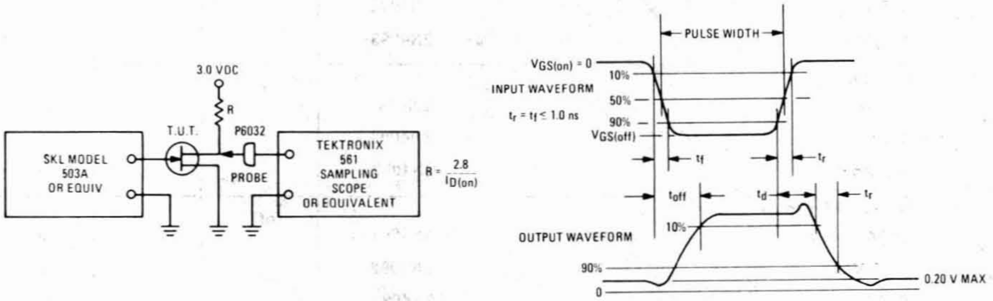

0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
SOURCE
DRAIN
GATE
0.050
45°
1
2
3
0.036
0.046
0.028
0.048

CASE 22 (3)
(TO-18)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	40	Vdc
Drain-Gate Voltage	V_{DG}	40	Vdc
Gate-Source Voltage	V_{GS}	40	Vdc
Gate Current	I_G	10	mAdc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.8 10	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 — SWITCHING TIMES TEST CIRCUIT


3.0 VDC
R
T.U.T.
P6032
SKL MODEL 503A OR EQUIV
PROBE
TEKTRONIX 561 SAMPLING SCOPE OR EQUIVALENT
R = 2.8 / $I_{D(on)}$
PULSE WIDTH
$V_{GS(on)}$ = 0
INPUT WAVEFORM
$t_r = t_f \leq 1.0$ ns
10%
50%
90%
$V_{GS(off)}$
t_f
t_r
t_{off}
t_d
t_r
OUTPUT WAVEFORM
10%
90%
0
0.20 V MAX

2N4091, 2N4092, 2N4093 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 1.0 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	40	-	Vdc
Drain-Gate Breakdown Voltage (I_D = 1.0 μAdc, I_S = 0)		$V_{(BR)DGO}$	40	-	Vdc
Gate-Source Cutoff Voltage (V_{DS} = 20 Vdc, I_D = 1.0 nAdc)	2N4091	$V_{GS(off)}$	5.0	10	Vdc
	2N4092		2.0	7.0	
	2N4093		1.0	5.0	
Source Reverse Current (V_{SG} = 20 Vdc, I_D = 0)		I_{SGO}	-	0.2	nAdc
Drain Reverse Current (V_{DG} = 20 Vdc, I_S = 0)		I_{DGO}	-	0.2	nAdc
(V_{DG} = 20 Vdc, I_D = 0, T_A = 150°C)			-	0.4	μAdc
Drain-Cutoff Current (V_{DS} = 20 Vdc, V_{GS} = 12 Vdc)	2N4091	$I_{D(off)}$	-	0.2	nAdc
(V_{DS} = 20 Vdc, V_{GS} = 8.0 Vdc)	2N4092		-	0.2	
(V_{DS} = 20 Vdc, V_{GS} = 6.0 Vdc)	2N4093		-	0.2	
(V_{DS} = 20 Vdc, V_{GS} = 12 Vdc, T_A = 150°C)	2N4091		-	0.4	μAdc
(V_{DS} = 20 Vdc, V_{GS} = 8.0 Vdc, T_A = 150°C)	2N4092		-	0.4	
(V_{DS} = 20 Vdc, V_{GS} = 6.0 Vdc, T_A = 150°C)	2N4093		-	0.4	
ON CHARACTERISTICS					
Zero-Gate Voltate Drain Current* (V_{DS} = 20 Vdc, V_{GS} = 0)	2N4091	I_{DSS}*	30	-	mAdc
	2N4092		15	-	
	2N4093		8.0	-	
Drain-Source "ON" Voltage (I_D = 6.6 mAdc, V_{GS} = 0)	2N4091	$V_{DS(on)}$	-	0.2	Vdc
(I_D = 4.0 mAdc, V_{GS} = 0)	2N4092		-	0.2	
(I_D = 2.5 mAdc, V_{GS} = 0)	2N4093		-	0.2	
Static Drain-Source "ON" Resistance (I_D = 1.0 mAdc, V_{GS} = 0)	2N4091	$r_{DS(on)}$	-	30	Ohms
	2N4092		-	50	
	2N4093		-	80	
SMALL-SIGNAL CHARACTERISTICS					
Drain-Source "ON" Resistance (V_{GS} = 0, I_D = 0, f = 1.0 kHz)	2N4091	$r_{ds(on)}$	-	30	Ohms
	2N4092		-	50	
	2N4093		-	80	
Input Capacitance (V_{DS} = 20 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{iss}	-	16	pF
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 20 Vdc, f = 1.0 MHz)		C_{rss}	-	5.0	pF
SWITCHING CHARACTERISTICS					
Delay Time (See Figure 1) ($I_{D(on)}$ = 6.6 mAdc)	2N4091	t_d	-	15	ns
($I_{D(on)}$ = 4.0 mAdc)	2N4092		-	15	
($I_{D(on)}$ = 2.5 mAdc)	2N4093		-	20	
Rise Time (See Figure 1) ($I_{D(on)}$ = 6.6 mAdc)	2N4091	t_r	-	10	ns
($I_{D(on)}$ = 4.0 mAdc)	2N4092		-	20	
($I_{D(on)}$ = 2.5 mAdc)	2N4093		-	40	
Turn-Off Time (See Figure 1) ($V_{GS(off)}$ = 12 Vdc)	2N4091	t_{off}	-	40	ns
($V_{GS(off)}$ = 8.0 Vdc)	2N4092		-	60	
($V_{GS(off)}$ = 6.0 Vdc)	2N4093		-	80	

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 3.0%.

2N4123 (SILICON)
2N4124

CASE 29(1)
(TO-92)

NPN silicon transistors designed for general purpose switching and amplifier applications and for complementary circuitry with PNP types 2N4125 and 2N4126. Features one-piece, injection-molded plastic package for high reliability.

MAXIMUM RATINGS

Rating	Symbol	2N4123	2N4124	Unit
Collector-Emitter Voltage	V_{CEO}	30	25	Vdc
Collector-Base Voltage	V_{CB}	40	30	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	200		mAdc
Total Device Dissipation @ $T_A = 60°C$	P_D	210		mW
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

FIGURE 1 — CAPACITANCE

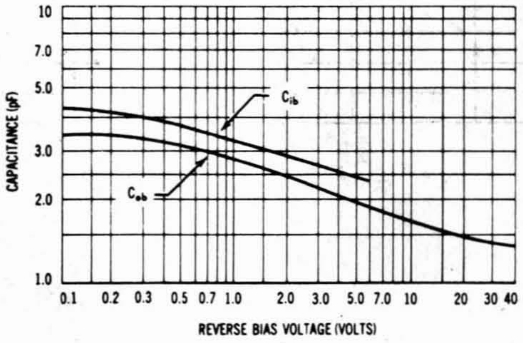
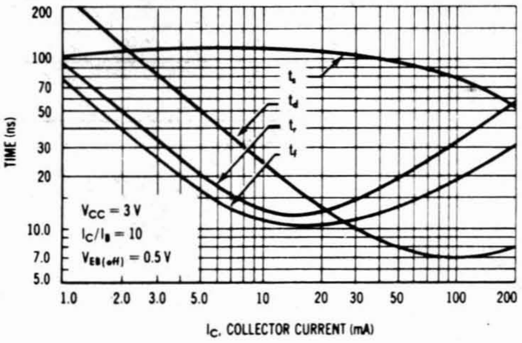


FIGURE 2 — SWITCHING TIMES



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage* (I_C = 1 mAdc, I_E = 0)	2N4123 2N4124		BV_{CEO}*	30 25	– –	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N4123 2N4124		BV_{CBO}	40 30	– –	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)			BV_{EBO}	5.0	–	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)			I_{CBO}	–	50	nAdc
Emitter Cutoff Current (V_{BE} = 3 Vdc, I_C = 0)			I_{EBO}	–	50	nAdc
ON CHARACTERISTICS						
DC Current Gain* (I_C = 2 mAdc, V_{CE} = 1 Vdc)	2N4123 2N4124	9	h_{FE}*	50 120	150 360	–
(I_C = 50 mAdc, V_{CE} = 1 Vdc)	2N4123 2N4124			25 60	– –	
Collector-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5 mAdc)		10, 11	$V_{CE(sat)}$*	–	0.3	Vdc
Base-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5 mAdc)		11	$V_{BE(sat)}$*	–	0.95	Vdc
SMALL SIGNAL CHARACTERISTICS						
High-Frequency Current Gain (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N4123 2N4124		$\lvert h_{fe} \rvert$	2.5 3.0	– –	–
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N4123 2N4124		f_T	250 300	– –	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz)		1	C_{ob}	–	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		1	C_{ib}	–	8.0	pF
Small-Signal Current Gain (I_C = 2 mAdc, V_{CE} = 1 Vdc, f = 1 kHz)	2N4123 2N4124	5	h_{fe}	50 120	200 480	–
Noise Figure (I_C = 100 μAdc, V_{CE} = 5 Vdc, R_S = 1 k ohm, Noise Bandwidth = 10 Hz to 15.7 kHz)	2N4123 2N4124	3, 4	NF	– –	6.0 5.0	dB

SWITCHING CHARACTERISTICS

Characteristic		Fig. No.	Symbol	Typ	Unit
Delay Time	V_{CC} = 3 Vdc, $V_{EB(off)}$ = 0.5 Vdc, I_C = 10 mAdc, I_{B1} = 1 mAdc	2	t_d	24	ns
Rise Time		2	t_r	13	ns
Storage Time	V_{CC} = 3 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 1 mAdc	2	t_s	125	ns
Fall Time		2	t_f	11	ns

*Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2%

AUDIO SMALL SIGNAL CHARACTERISTICS

NOISE FIGURE

V_{CE} = 5 Vdc, T_A = 25°C

FIGURE 3 — FREQUENCY VARIATIONS

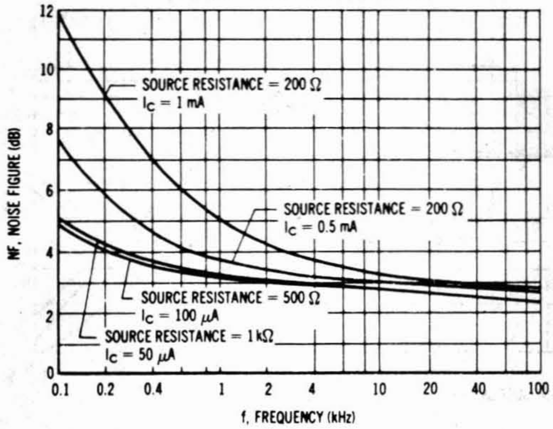
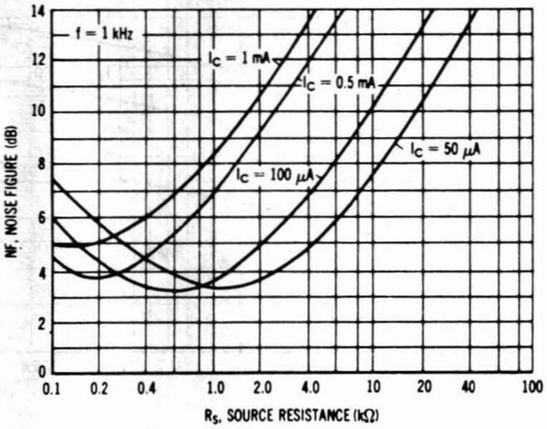


FIGURE 4 — SOURCE RESISTANCE



h PARAMETERS

V_{CE} = 10 V, f = 1 kHz, T_A = 25°C

FIGURE 5 — CURRENT GAIN

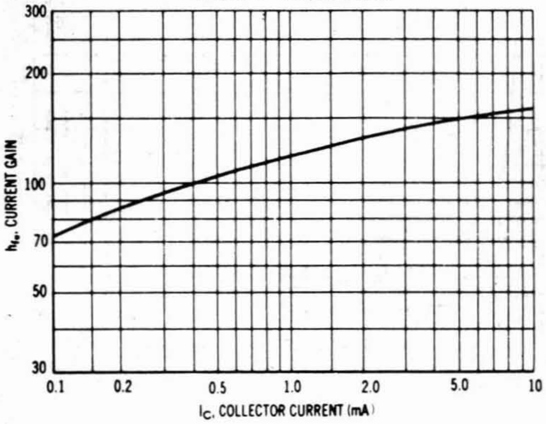


FIGURE 6 — OUTPUT ADMITTANCE

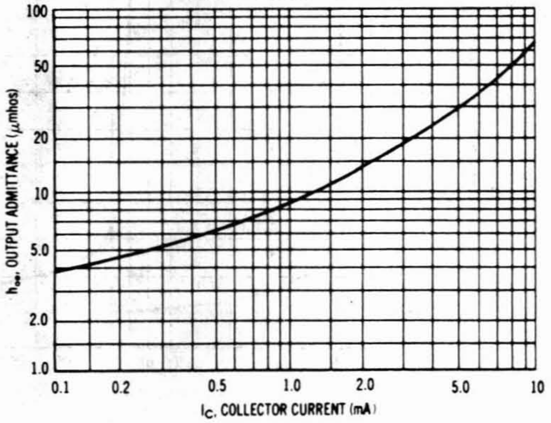


FIGURE 7 — INPUT IMPEDANCE

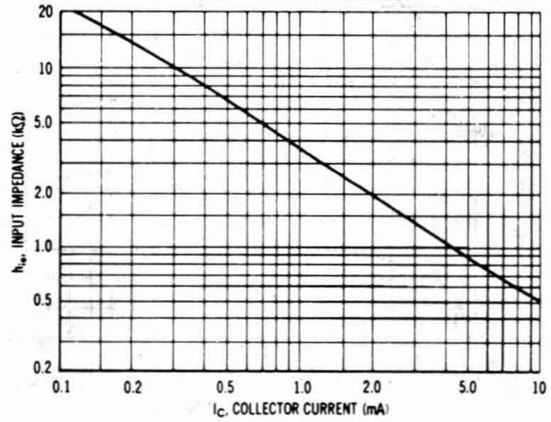
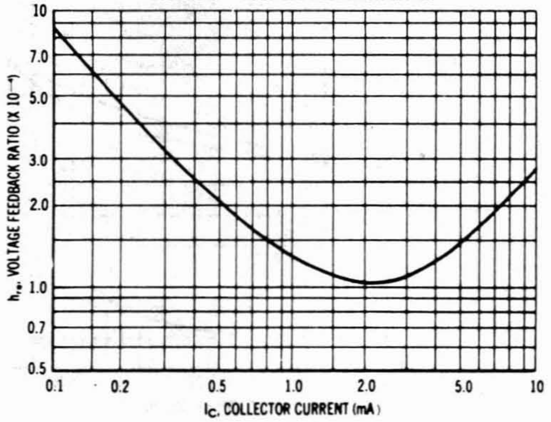


FIGURE 8 — VOLTAGE FEEDBACK RATIO



STATIC CHARACTERISTICS

FIGURE 9 — NORMALIZED CURRENT GAIN

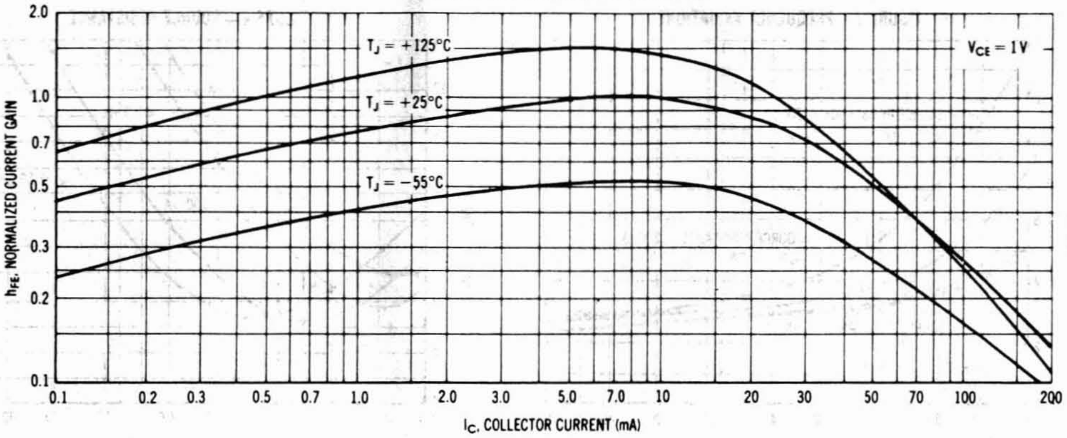


FIGURE 10 — COLLECTOR SATURATION REGION

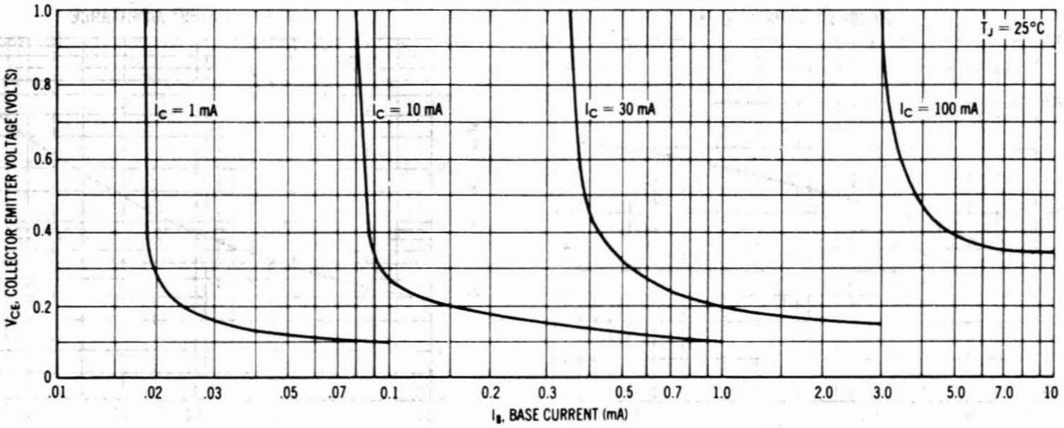


FIGURE 11 — "ON" VOLTAGES

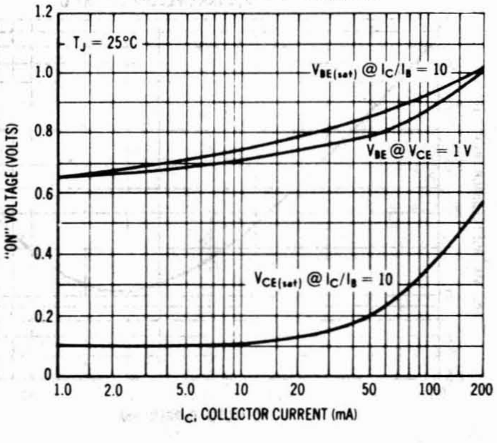
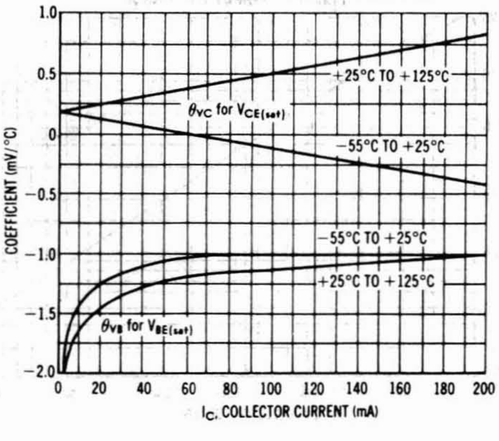
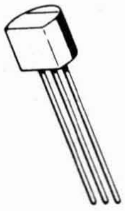


FIGURE 12 — TEMPERATURE COEFFICIENTS



2N4125 (SILICON)
2N4126



CASE 29(1)
(TO-92)

PNP silicon transistors designed for general purpose switching and amplifier applications and for complementary circuitry with NPN types 2N4123 and 2N4124 Features one-piece, injection-molded plastic package for high reliability.

MAXIMUM RATINGS

Rating	Symbol	2N4125	2N4126	Unit
Collector-Emitter Voltage	V_{CEO}	30	25	Vdc
Collector-Base Voltage	V_{CB}	30	25	Vdc
Emitter-Base Voltage	V_{EB}	4.0		Vdc
Collector Current	I_C	200		mAdc
Total Device Dissipation @ $T_A = 60°C$	P_D	210		mW
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

FIGURE 1 — CAPACITANCE

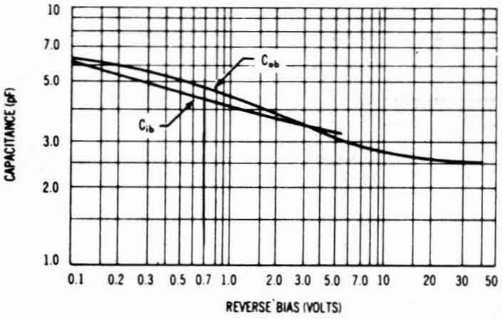
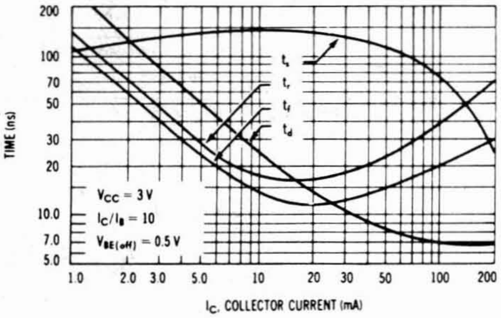


FIGURE 2 — SWITCHING TIMES



2N4125, 2N4126 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Fig. No.	Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage* (I_C = 1 mAdc, I_E = 0)	2N4125 2N4126		BV_{CEO}*	30 25	– –	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	2N4125 2N4126		BV_{CBO}	30 25	– –	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)			BV_{EBO}	4.0	–	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)			I_{CBO}	–	50	nAdc
Emitter Cutoff Current (V_{BE} = 3 Vdc, I_C = 0)			I_{EBO}	–	50	nAdc

ON CHARACTERISTICS

Characteristic		Fig. No.	Symbol	Min	Max	Unit
DC Current Gain* (I_C = 2 mAdc, V_{CE} = 1 Vdc)	2N4125 2N4126	9	h_{FE}*	50 120	150 360	–
(I_C = 50 mAdc, V_{CE} = 1 Vdc)	2N4125 2N4126			25 60	– –	
Collector-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5 mAdc)		10, 11	$V_{CE(sat)}$*	–	0.4	Vdc
Base-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5 mAdc)		11	$V_{BE(sat)}$*	–	0.95	Vdc

SMALL SIGNAL CHARACTERISTICS

Characteristic		Fig. No.	Symbol	Min	Max	Unit
High-Frequency Current Gain (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N4125 2N4126		$\lvert h_{fe} \rvert$	2.0 2.5	– –	–
Current-Gain – Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N4125 2N4126		f_T	200 250	– –	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz)		1	C_{ob}	–	4.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		1	C_{ib}	–	10	pF
Small-Signal Current Gain (I_C = 2 mAdc, V_{CE} = 1 Vdc, f = 1 kHz)	2N4125 2N4126	5	h_{fe}	50 120	200 480	–
Noise Figure (I_C = 100 μAdc, V_{CE} = 5 Vdc, R_S = 1 k ohm, Noise Bandwidth = 10 Hz to 15.7 kHz)	2N4125 2N4126	3, 4	NF	– –	5.0 4.0	dB

SWITCHING CHARACTERISTICS

Characteristic		Fig. No.	Symbol	Typ	Unit
Delay Time	V_{CC} = 3 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_C = 10 mAdc, I_{B1} = 1 mAdc	2	t_d	25	ns
Rise Time		2	t_r	18	ns
Storage Time	V_{CC} = 3 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 1 mAdc	2	t_s	140	ns
Fall Time		2	t_f	15	ns

*Pulse Test: Pulse Width = 300 μsec, Duty Cycle = 2%

AUDIO SMALL SIGNAL CHARACTERISTICS

NOISE FIGURE

V_{CE} = 5 Vdc, T_A = 25°C

FIGURE 3 — FREQUENCY VARIATIONS

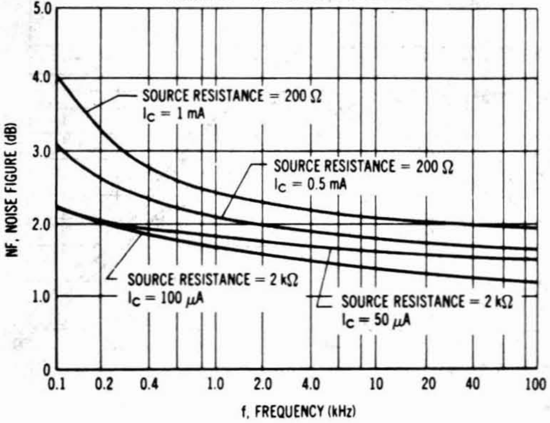
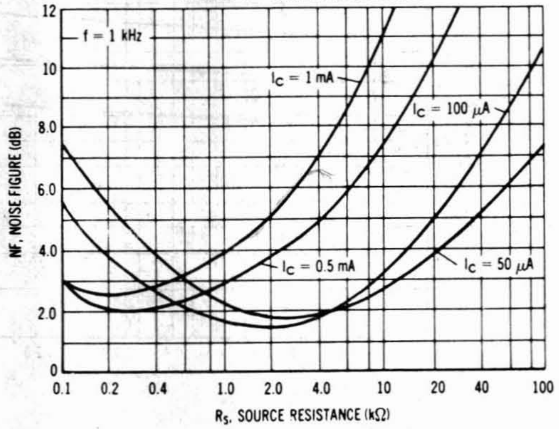


FIGURE 4 — SOURCE RESISTANCE



h PARAMETERS

V_{CE} = 10 V, f = 1 kHz, T_A = 25°C

FIGURE 5 — CURRENT GAIN

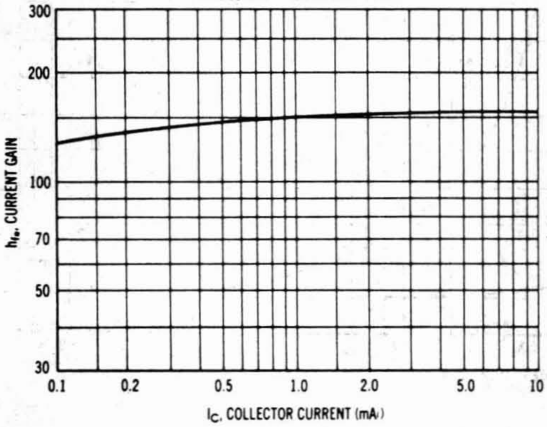


FIGURE 6 — OUTPUT ADMITTANCE

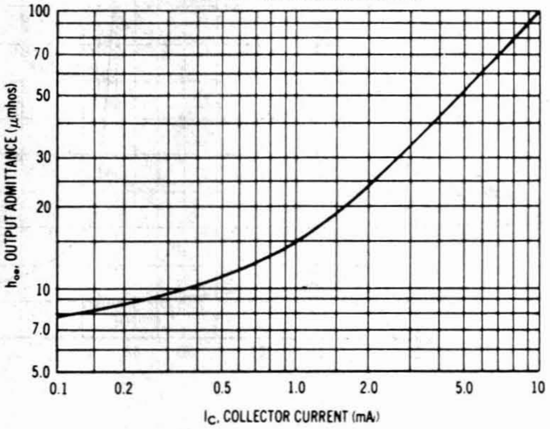


FIGURE 7 — INPUT IMPEDANCE

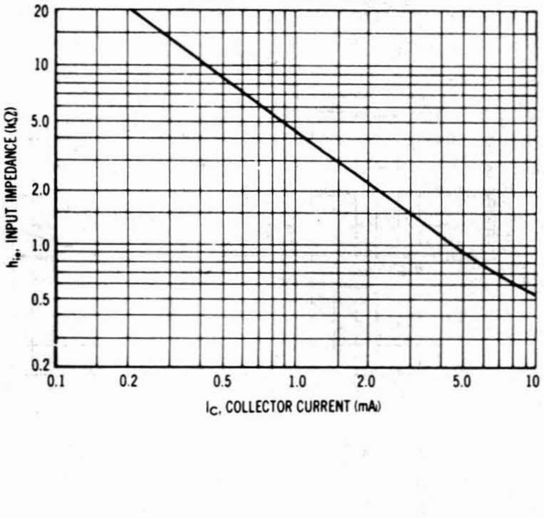
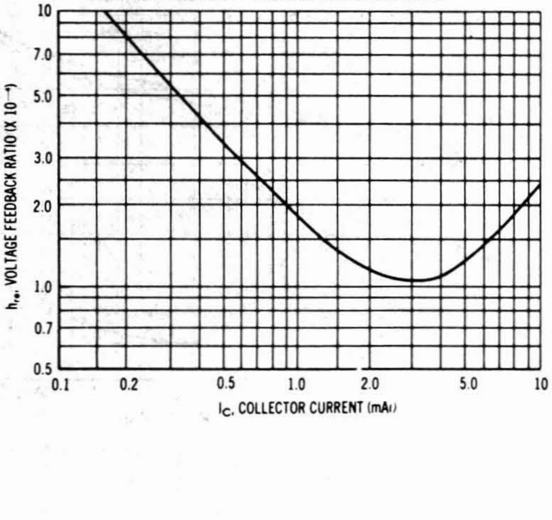


FIGURE 8 — VOLTAGE FEEDBACK RATIO



STATIC CHARACTERISTICS

FIGURE 9 — NORMALIZED CURRENT GAIN

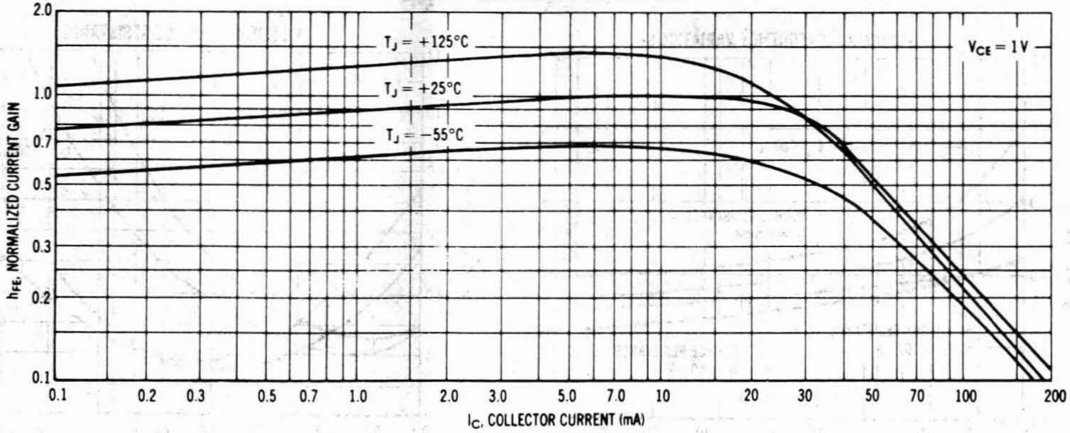


FIGURE 10 — COLLECTOR SATURATION REGION

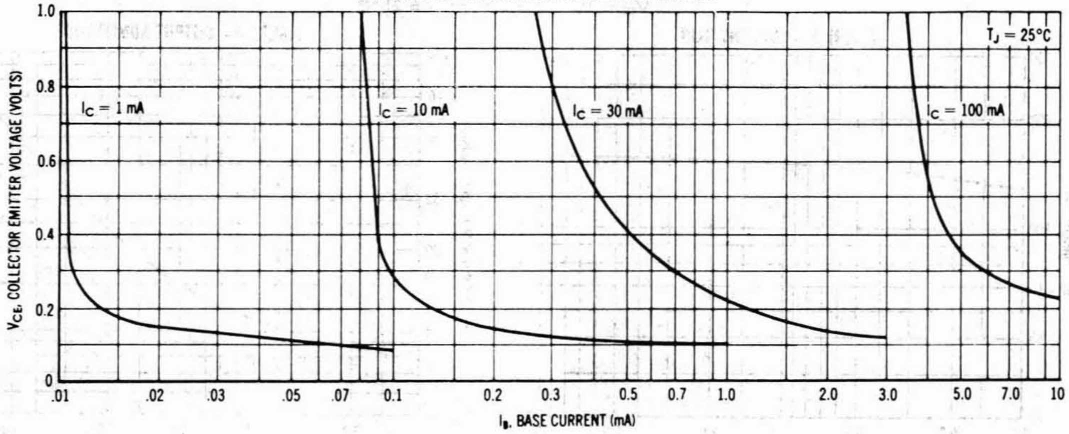


FIGURE 11 — "ON" VOLTAGES

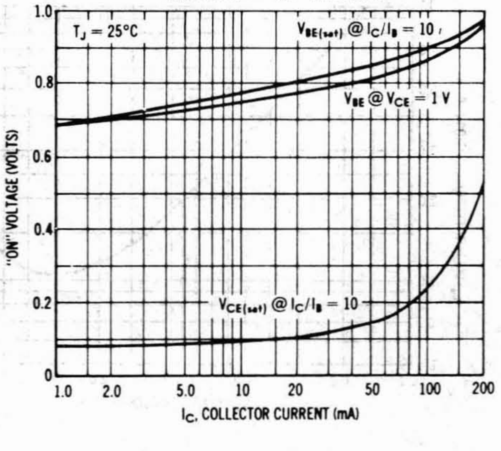
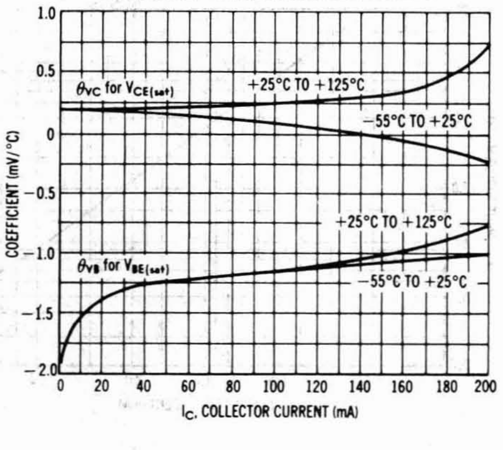
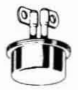
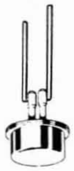


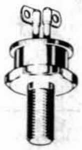
FIGURE 12 — TEMPERATURE COEFFICIENTS

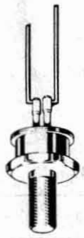


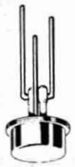
2N4151 thru 2N4198 (SILICON)

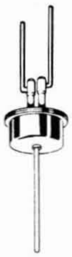

2N4151-58
CASE 85


2N4159-66
CASE 85L


2N4167-74
CASE 86


2N4175-82
CASE 86L


2N4183-90
CASE 87L


2N4191-98
CASE 88L

Multi-purpose silicon controlled rectifiers suited for industrial, consumer, and military applications. Offered in a choice of space-saving, economical packages for mounting versatility.

MAXIMUM RATINGS

(Apply over operating temperature range and for all case types unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*†	$V_{ROM(rep)}$*†		Volts
2N4151, 59, 67, 75, 83, 91		25	
2N4152, 60, 68, 76, 84, 92		50	
2N4153, 61, 69, 77, 85, 93		100	
2N4154, 62, 70, 78, 86, 94		200	
2N4155, 63, 71, 79, 87, 95		300	
2N4156, 64, 72, 80, 88, 96		400	
2N4157, 65, 73, 81, 89, 97		500	
2N4158, 66, 74, 82, 90, 98		600	
Non-repetitive Peak Reverse Blocking Voltage	$V_{ROM(non-rep)}$		Volts
2N4151, 59, 67, 75, 83, 91		75	
2N4152, 60, 68, 76, 84, 92		100	
2N4153, 61, 69, 77, 85, 93		150	
2N4154, 62, 70, 78, 86, 94		300	
2N4155, 63, 71, 79, 87, 95		400	
2N4156, 64, 72, 80, 88, 96		500	
2N4157, 65, 73, 81, 89, 97		600	
2N4158, 66, 74, 82, 90, 98		700	
Forward Current RMS	I_f	8.0	Amp
Circuit Fusing Considerations (T_J = -40 to +100°C; $t \le 8.3$ ms)	I^2t	40	A^2s
Peak Forward Surge Current † (One cycle, 60 Hz, T_J = -40 to +100°C)	$I_{FM(surge)}$†	100	Amp
Peak Forward Gate Power †	P_{GFM}†	5.0	Watt
Average Forward Gate Power †	$P_{GF(AV)}$†	0.5	Watt
Peak Forward Gate Current †	I_{GFM}†	2.0	Amp
Peak Gate Voltage — Forward**	V_{GFM}**	10	Volts
Reverse	V_{GRM}	10	
Operating Temperature Range †	T_J†	-40 to +100	°C
Storage Temperature Range †	T_{stg}†	-40 to +150	°C
Stud Torque 2N4167-2N4182		15	in. lb.

*$V_{ROM(rep)}$ for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for zero or negative gate voltage. Devices should not be tested for blocking capability in a manner such that the voltage applied exceeds the rated blocking voltage.

**Devices should not be operated with a positive bias applied to the gate concurrently with a negative potential applied to the anode.

†JEDEC Registered Values

THERMAL CHARACTERISTICS

Characteristic	Symbol	Typ	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.5	2.5 †	°C/W
Thermal Resistance, Case to Ambient (See Fig. 11) 2N4151-66, 2N4183-98	θ_{CA}	50	—	°C/W

† JEDEC Registered Values

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Peak Forward Blocking Voltage*† (T_J = 100°C)	2N4151, 59, 67, 75, 83, 91	V_{FOM}*†	25	—	Volts
	2N4152, 60, 68, 76, 84, 92		50	—	
	2N4153, 61, 69, 77, 85, 93		100	—	
	2N4154, 62, 70, 78, 86, 94		200	—	
	2N4155, 63, 71, 79, 87, 95		300	—	
	2N4156, 64, 72, 80, 88, 96		400	—	
	2N4157, 65, 73, 81, 89, 97		500	—	
	2N4158, 66, 74, 82, 90, 98		600	—	
Peak Forward Blocking Current† (Rated V_{FOM} @ T_J = 100°C, gate open)		I_{FOM}†	—	2.0	mA
Peak Reverse Blocking Current† (Rated V_{ROM} @ T_J = 100°C, gate open)		I_{ROM}†	—	2.0	mA
Gate Trigger Current (Continuous dc)** (Anode Voltage = 7.0 Vdc, R_L = 100 Ω)		I_{GT}**	—	20	mA
(Anode Voltage = 7.0 Vdc, R_L = 100 Ω T_C = -40°C)†			—	50†	
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7.0 Vdc, R_L = 100 Ω)		V_{GT}	—	1.5	Volts
(Anode Voltage = 7.0 Vdc, R_L = 100 Ω, T_C = -40°C)†			—	2.5†	
(Anode Voltage = 7.0 Vdc, R_L = 100 Ω, T_J = 100°C)†			0.2†	—	
Forward "On" Voltage (pulsed, 1.0 ms max, duty cycle ≤ 1%) (I_F = 5.0 A)		v_F	—	1.3	Volts
(I_F = 15.7 A)†			—	2.0†	
Holding Current (Anode Voltage = 7.0 Vdc, gate open)		I_{HO}	—	25	mA
(Anode Voltage = 7.0 Vdc, gate open, T_C = -40°C)†			—	60†	
			Typical		
Turn-On Time ($t_d + t_r$) (I_G = 20 mAdc, I_F = 5.0 Adc)		t_{on}	1.0		μs
Turn-Off Time (I_F = 5.0 Adc, I_R = 5.0 Adc)		t_{off}	15		μs
(I_F = 5.0 Adc, I_R = 5.0 Adc, T_J = 100°C) (V_{FXM} = rated voltage) (dv/dt = 30 V/μs)			25		
Forward Voltage Application Rate (Gate open, T_J = 100°C)		dv/dt	50		V/μs

---

*V_{FOM} for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for zero or negative gate voltage. These devices should not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

**For optimum operation, i.e. faster turn-on, lower switching losses, best di/dt capability, recommended I_{GT} = 200 mA.

† JEDEC Registered Values

EFFECT OF TEMPERATURE UPON TYPICAL TRIGGER CHARACTERISTICS

FIGURE 1 — GATE TRIGGER CURRENT

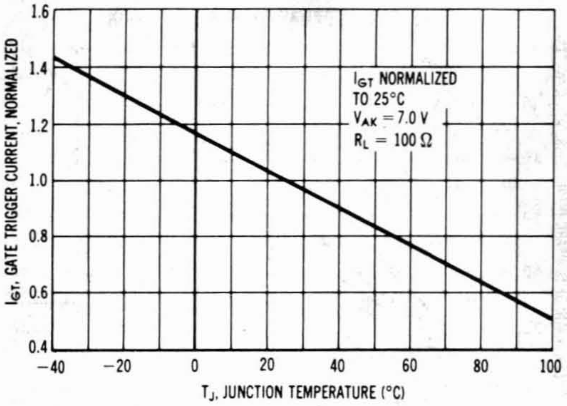
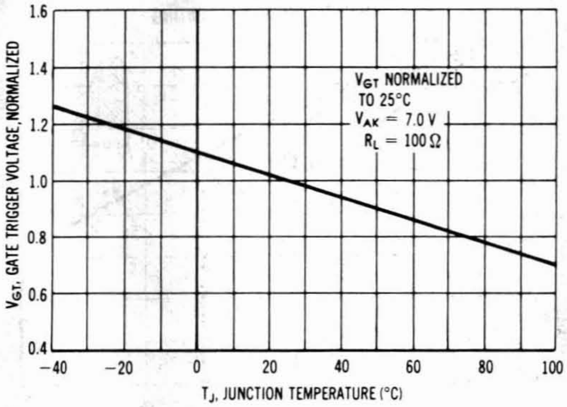


FIGURE 2 — GATE TRIGGER VOLTAGE



MAXIMUM ALLOWABLE NON-RECURRENT SURGE CURRENT

FIGURE 3 — 60 Hz SURGES

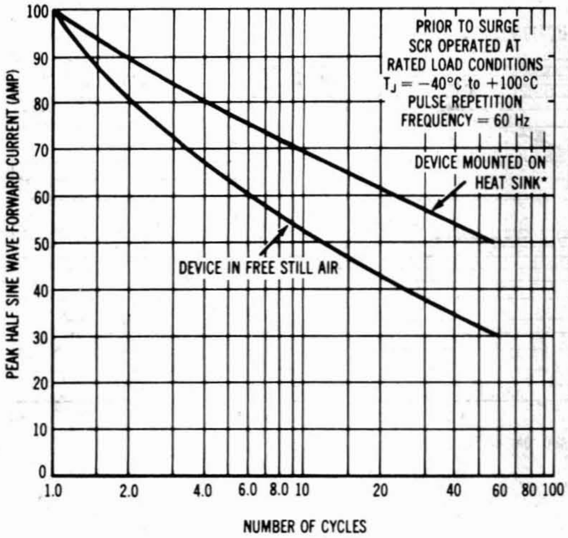


FIGURE 4 — SUB-CYCLE SURGES

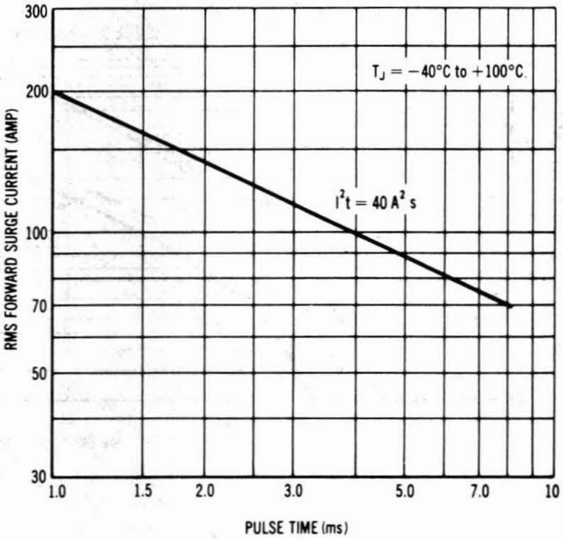


FIGURE 5 — GATE TRIGGER CHARACTERISTICS

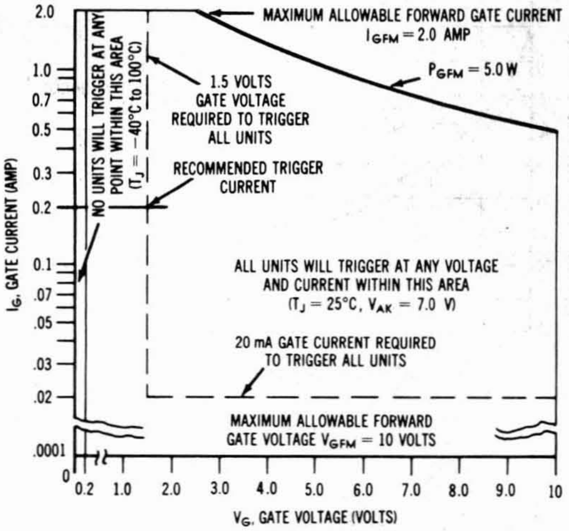
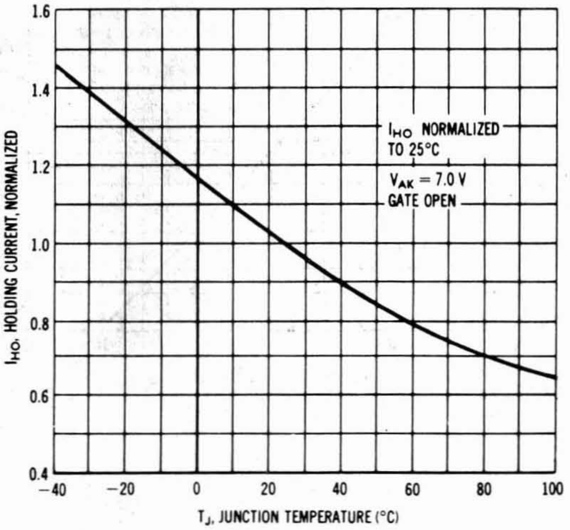


FIGURE 6 — TYPICAL HOLDING CURRENT



*Heat sink sufficient to maintain allowable case temperature for 180 degree conduction angle during normal operation, see Figure 7.

DERATING AND DISSIPATION FOR RESISTIVE AND INDUCTIVE LOADS (f = 60 to 400 Hz, SINE WAVE)

FIGURE 7 – CURRENT DERATING

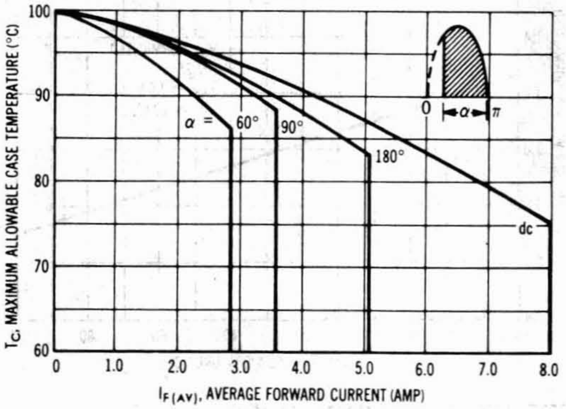


FIGURE 8 – FORWARD POWER DISSIPATION

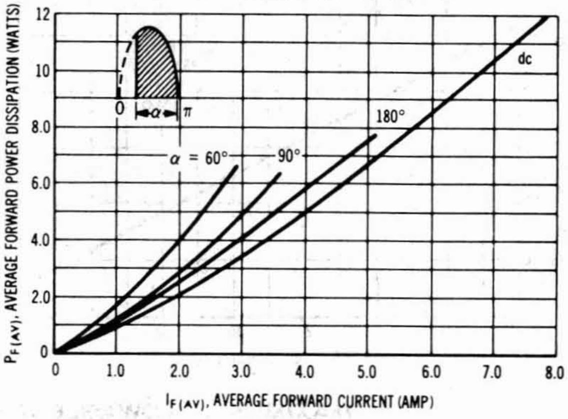


FIGURE 9 – FORWARD CONDUCTION CHARACTERISTICS

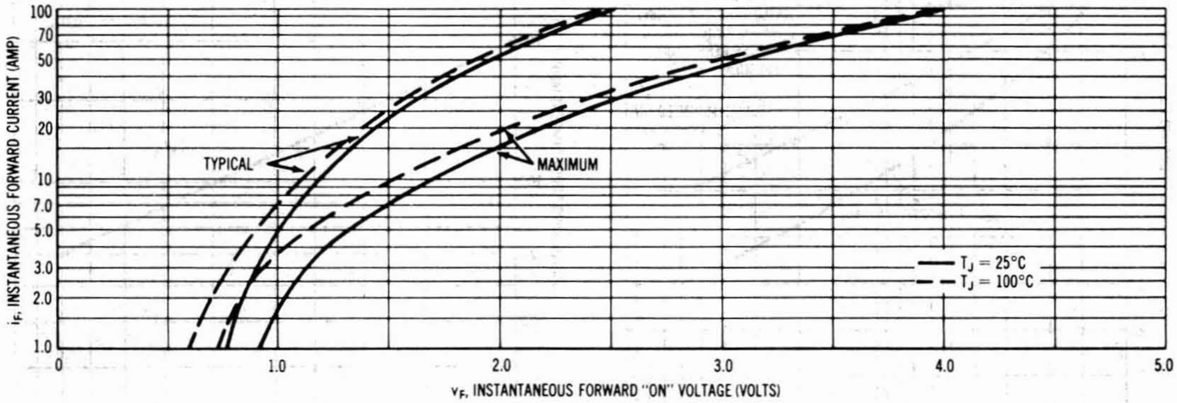


FIGURE 10 – TYPICAL THERMAL RESISTANCE OF PLATES

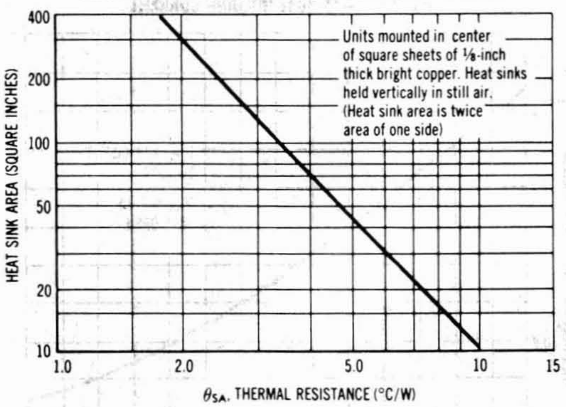
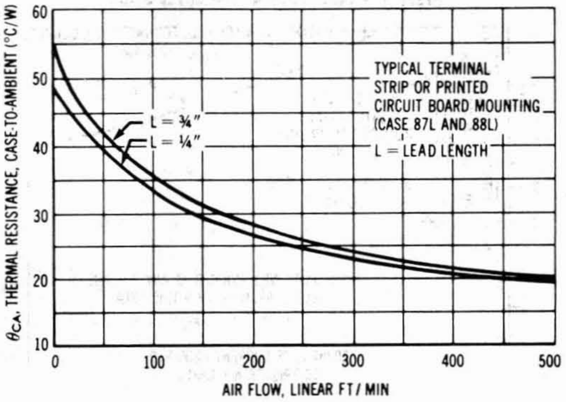
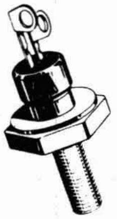


FIGURE 11 – CASE-TO-AMBIENT THERMAL RESISTANCE



2N4199 thru 2N4204 (SILICON)



CASE 63

Fast switching, high-voltage thyristors especially designed for pulse modulator applications in radar and other similar equipment.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage* (T_J=105°C)	$V_{ROM(rep)}$*	50	Volts
Repetitive Peak Forward Current (PW = 3.0 μs, Duty Cycle = 0.6%, T_C = 85°C max)	$I_{FM(rep)}$	100	Amp
Current Application Rate**	di/dt**	5000	A/μs
Peak Gate Power-Forward	P_{GFM}	20	Watts
Average Gate Power-Forward	$P_{GF(AV)}$	1.0	Watt
Peak Gate Current-Forward	I_{GFM}	5.0	Amp
Peak Gate Voltage-Forward Reverse ***	V_{GFM} V_{GRM} ***	10 10	Volts
Operating Junction Temperature Range Blocking State Conducting State	T_J	 -65 to +105 -65 to +200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Stud Torque	—	15	in. lb.

*Characterized for unilateral applications where reverse blocking capability is not important. Higher voltage units available upon request. $V_{ROM(rep)}$ may be applied as a continuous d c voltage for zero or negative gate voltage but positive gate voltage must not be applied concurrently with a negative potential on the anode. When checking blocking capability, do not permit the applied voltage to exceed the rated voltage.

**Minimum Gate Trigger Pulse: $i_G = 200$ mA, PW = 1 μs, $t_r = 20$ ns.

***Do not reverse bias gate during forward conduction if anode current exceeds 10 amperes.

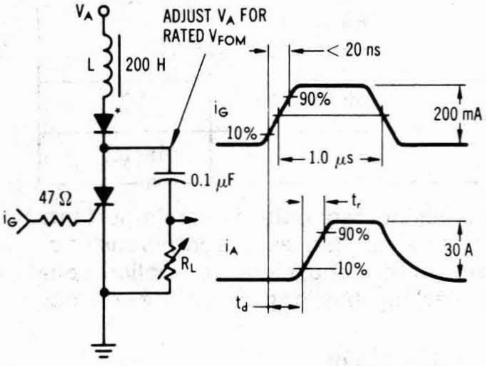
ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
Peak Forward Blocking Voltage* ($T_C = 105°C$)	2N4199 2N4200 2N4201 2N4202 2N4203 2N4204	15	V_{FOM}*	300 400 500 600 700 800	— — — — — —	Volts
Peak Forward and Reverse Blocking Current (Rated V_{FOM} and V_{ROM}, $T_C = 105°C$, gate open)		17	I_{FOM} I_{ROM}	— —	2.0 2.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7.0 Vdc, R_L = 100 ohms, $T_C = 25°C$) (Anode Voltage = 7.0 Vdc, R_L = 100 ohms, $T_C = -65°C$)		14	I_{GT}	— —	50 100	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = rated V_{FOM}, R_L = 100 ohms, $T_C = 105°C$) (Anode Voltage = 7.0 Vdc, R_L = 100 ohms, $T_C = 25°C$) (Anode Voltage = 7.0 Vdc, R_L = 100 ohms, $T_C = -65°C$)		12	V_{GT}	0.2 — —	— 1.5 2.0	Volts
Holding Current (Anode Voltage = 7.0 Vdc, gate open, $T_C = 105°C$)		18	I_{HO}	3.0	—	mA
Forward "On" Voltage (I_f = 2 Adc, PW = 1.0 ms max, Duty cycle ≤ 1%)		8	V_F	—	1.5	Volts
Dynamic Forward "On" Voltage (0.5 μs after 50% decay point on dynamic forward voltage waveform.) Forward Current: 30 A pulse (PFN discharge circuit.) Gate Pulse: at 200 mA, PW = 1.0 μs, t_r = 20 ns		7	$V_{F(on)}$	—	25	Volts
Turn-On Time						ns
Delay Time	All types	1, 9	t_d	—	200	
Rise Time	2N4199 and 2N4200 2N4201 2N4202 2N4203 and 2N4204	1, 11	t_r	— — — —	200 150 130 100	
Pulse Turn-Off Time Test Conditions: PFN discharge; Forward Current = 30 A pulse; Reverse Current = 5.0 A, $T_C = 85°C$, dv/dt = 250 V/μs to Rated V_{FOM}; Reverse anode voltage during turn-off interval = 0 V; Reverse gate bias during turn-off interval = 6.0 V.		2, 13	$t_{off(pulse)}$	—	20	μs
Forward Voltage Application Rate (Linear Rise of Voltage) ($T_C = 105°C$, gate open)		16	dv/dt	250	—	V/μs
Thermal Resistance (Junction to Case)		6	θ_{JC}	—	3.0	°C/W

*V_{FOM} for all types can be applied on a continous dc basis without incurring damage. Ratings apply for zero or negative gate voltage. When checking forward or reverse blocking capability, these devices should not be tested with a constant current source in a manner that the voltage applied exceeds the rated blocking voltage. Other voltage units available upon request.

TEST CIRCUITS

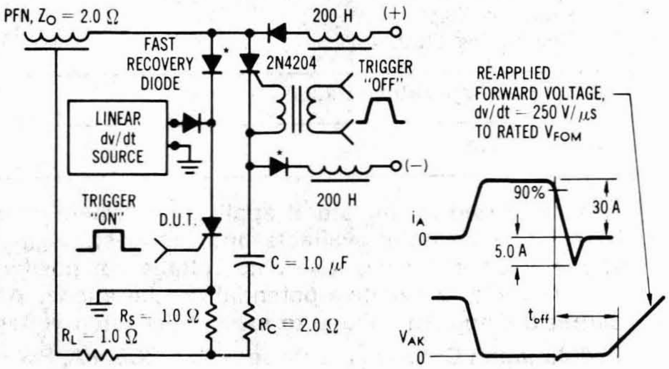
FIGURE 1 — TURN-ON TIME



V_A
ADJUST V_A FOR RATED V_{FOM}
L
200 H
*
0.1 μF
47 Ω
i_G
R_L
< 20 ns
i_G
90%
10%
200 mA
1.0 μs
t_r
i_A
90%
10%
30 A
t_d

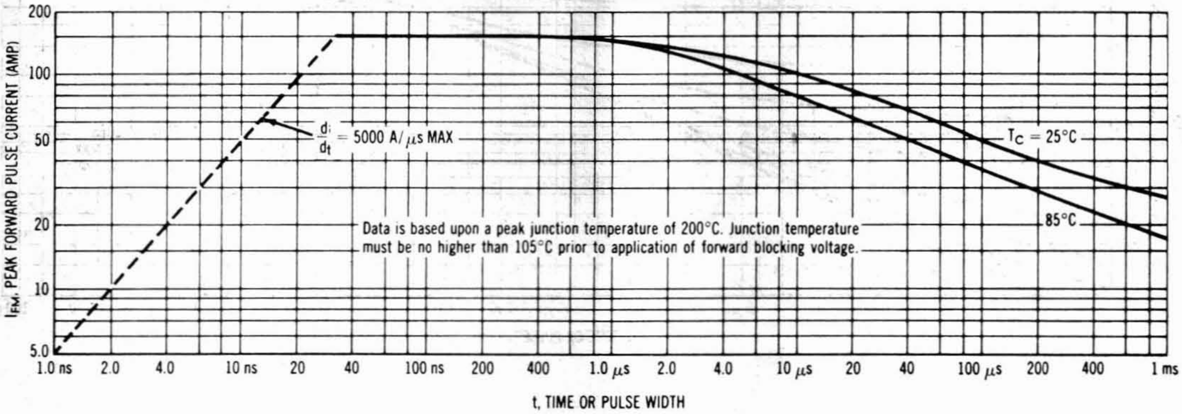
*Two MR1337-5 fast recovery diodes in series

FIGURE 2 — TURN-OFF TIME



PFN, Z_O = 2.0 Ω
FAST RECOVERY DIODE
*
2N4204
200 H
(+)
TRIGGER "OFF"
LINEAR dv/dt SOURCE
*
(−)
200 H
TRIGGER "ON"
D.U.T.
C = 1.0 μF
R_S = 1.0 Ω
R_L = 1.0 Ω
R_C = 2.0 Ω
RE-APPLIED FORWARD VOLTAGE, dv/dt = 250 V/μs TO RATED V_{FOM}
90%
30 A
i_A
0
5.0 A
t_{off}
V_{AK}
0

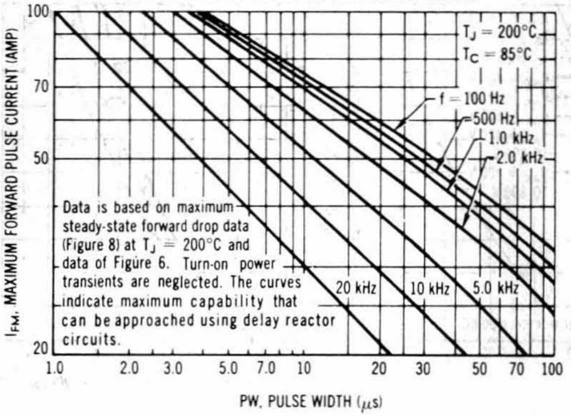
FIGURE 3 — MAXIMUM ALLOWABLE FORWARD PULSE CURRENT



Data is based upon a peak junction temperature of 200°C. Junction temperature must be no higher than 105°C prior to application of forward blocking voltage.

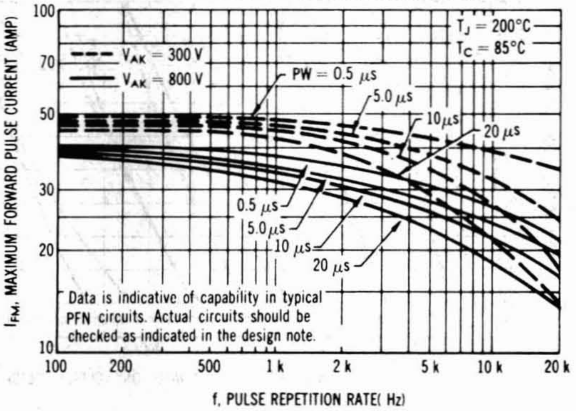
CURRENT DERATING DATA

FIGURE 4 — DERATING USING NO SWITCHING LOSSES



Data is based on maximum steady-state forward drop data (Figure 8) at T_J = 200°C and data of Figure 6. Turn-on power transients are neglected. The curves indicate maximum capability that can be approached using delay reactor circuits.

FIGURE 5 — DERATING USING TYPICAL SWITCHING LOSSES



Data is indicative of capability in typical PFN circuits. Actual circuits should be checked as indicated in the design note.

DESIGN NOTE

Use of Transient Thermal Resistance Data

A train of periodical power pulses can be represented by the model shown in Fig. A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Fig. 6 was calculated for various duty cycles from:

$$r(t) = D + (1 - D) \cdot r(t_A + t_P) + r(t_A) - r(t_P)$$

To find $\theta_{JC}(t)$ multiply the value obtained from Fig. 6 by the steady-state value $\theta_{JC}(\infty)$. Use 3°C/W for worst-case results; use 2°C/W for typical information.

DESIGN EXAMPLE

A 2N4199 discharging a PFN, transient power pulse shown in Fig. C.

Conditions: $V_{AK} = 150$ V., $I_{PK} = 44$ A., f = 5000 Hz.

Determine: $\triangle T$

Method 1: (See Fig. A) $P_A t_A$ is chosen to have the same energy as the actual power pulse, i.e.: the area under the curves are equal. P_A equals the peak of the actual power pulse. At a pulse repetition frequency of 5000 Hz and $T_A = 2.14\ \mu s$ ($D = 0.0107$): the reading on Fig. 6 is 0.039.

$$\therefore \triangle T = r(t)\theta_{JC}(\infty) P_A = (0.039)\,(3)\,(1000) = 120°C.$$

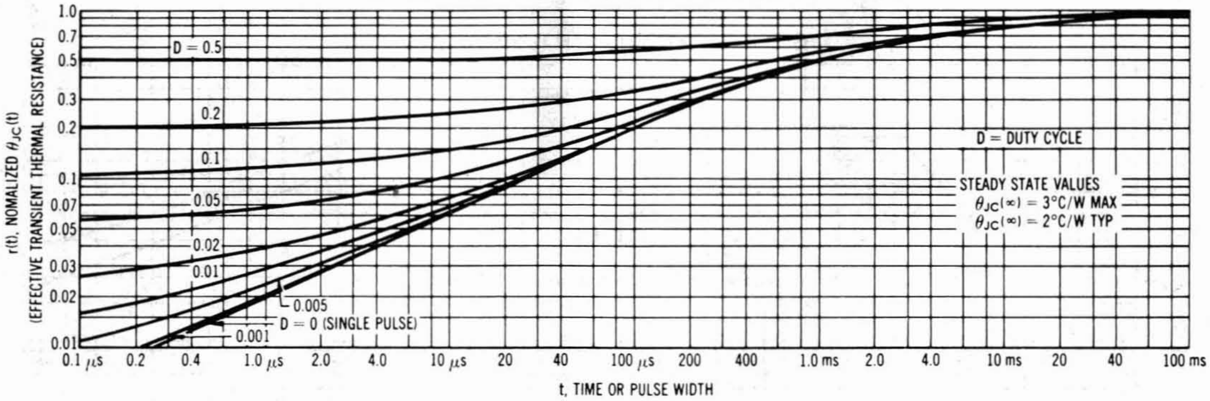
Method 2: For a power waveform where the time of the peak power is short compared to the total transient, the foregoing method results in an overly large safety factor. A pulse model closer to the real case is shown in Fig. B. Using the transient thermal resistance information for $D = 0$ in Fig. 6, $\triangle T(t_4)$ and $\triangle T(t_5)$ can be evaluated from

$$\triangle T(t_4) = \Big[P_1\,[r(T_1) + (1 - D_1) \cdot r(T + T_1) + D - r(T)] + P_2[(1 - D_2) \cdot r(T) + D_2 - r(T - T_2)]\Big]\,\theta_{JC}(\infty)$$

$$\triangle T(t_5) = \Big[P_1[r(T_1 + T_2) + (1 - D_1) \cdot r(T + T_1 + T_2) - r(T + T_2) - r(T_2)] + P_2\,[\,r(T_2) + (1 - D_2 \cdot r(T + T_2) + D_2 - r(T)]\Big]\,\theta_{JC}(\infty)$$

The two results are compared; the one with higher value is taken for worst-case design. For the problem, values for the equivalent pulses of Fig. B are $P_1 = 1000$ W, $P_2 = 700$ W, $T_1 = 1.05\ \mu s$, $T_2 = 1.55\ \mu s$, $D_1 = 5.25(10^{-3})$, $D_2 = 7.75(10^{-3})$.

FIGURE 6 — NORMALIZED EFFECTIVE TRANSIENT THERMAL RESISTANCE



FORWARD "ON" VOLTAGE DATA

FIGURE 7 — TYPICAL DYNAMIC FORWARD "ON" VOLTAGE

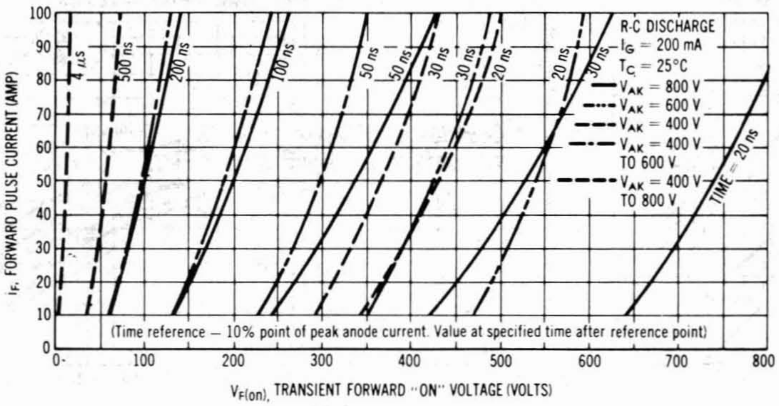
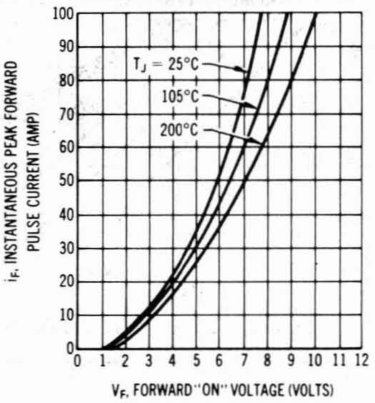


FIGURE 8 — MAXIMUM STEADY-STATE



$$\Delta T(t_4) = \Big[1000\,[0.0205 + (1-5.25\cdot 10^{-3})\,0.27 + 5.25\cdot 10^{-3} - 0.27]$$

$$+ 700\,[(1-7.75\cdot 10^{-3})\,0.27 + 7.75\cdot 10^{-3} - 0.27]\Big]\,3 = 93.51°\mathrm{C}$$

$$\Delta T(t_5) = \Big[1000\,[0.032 + (1-5.25\cdot 10^{-3})\,0.27 + 5.25\cdot 10^{-3} - 0.27 - 0.0205]$$

$$+ 700\,[0.025 + (1-7.75\cdot 10^{-3})\,0.27 + 7.75\cdot 10^{-3} - 0.27]\Big]\,3 = 105.6°\mathrm{C}$$

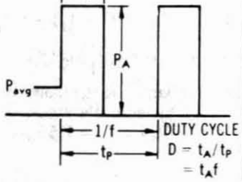

tA
PA
Pavg
1/f
tP
DUTY CYCLE
D = tA/tP
= tAf

FIGURE A — SIMPLE MODEL

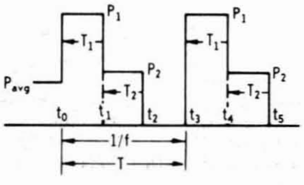

P1
T1
P2
T2
P1
T1
P2
T2
Pavg
t0
t1
t2
t3
t4
t5
1/f
T

FIGURE B — MORE ACCURATE MODEL

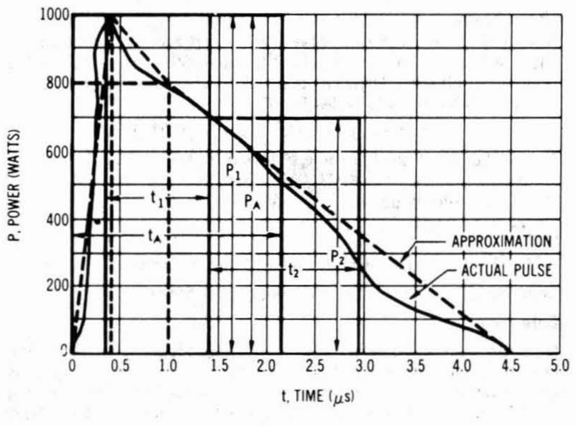


FIGURE C — AN ACTUAL TRANSIENT POWER PULSE

SWITCHING CHARACTERISTICS

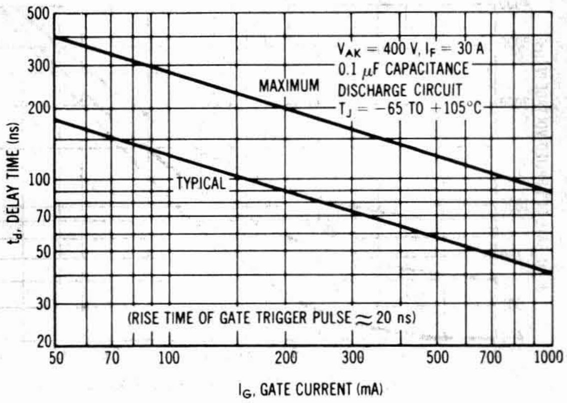


FIGURE 9 — DELAY TIME

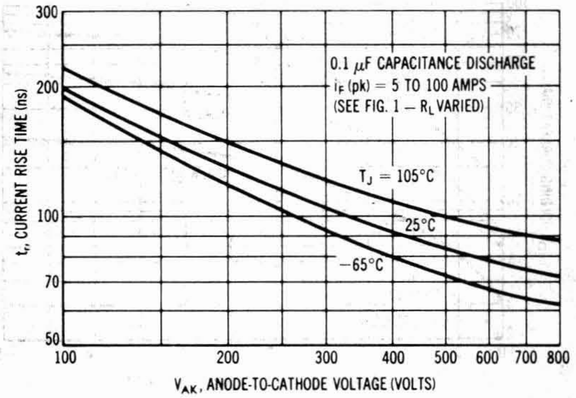


FIGURE 11 — CURRENT RISE TIME

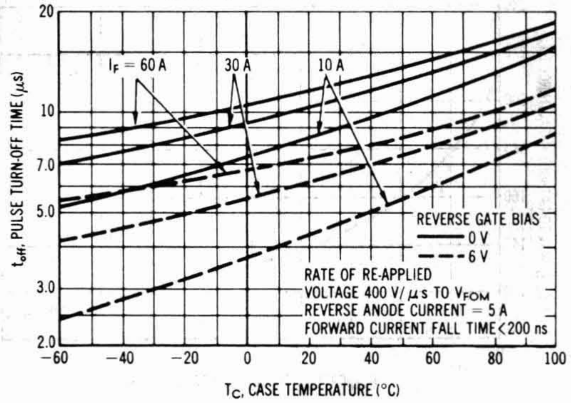


FIGURE 13 — TYPICAL TURN-OFF TIME

TRIGGERING CHARACTERISTICS

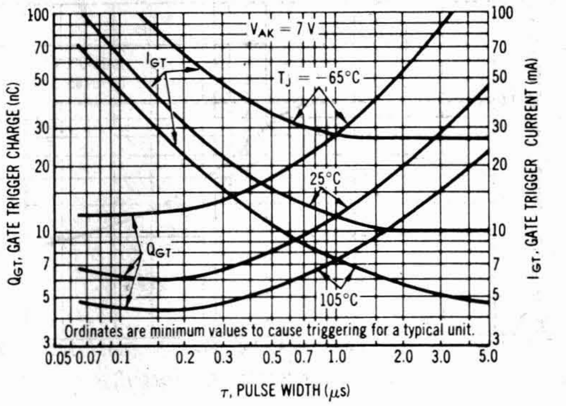


FIGURE 10 — TYPICAL PULSE TRIGGER CHARGE/CURRENT

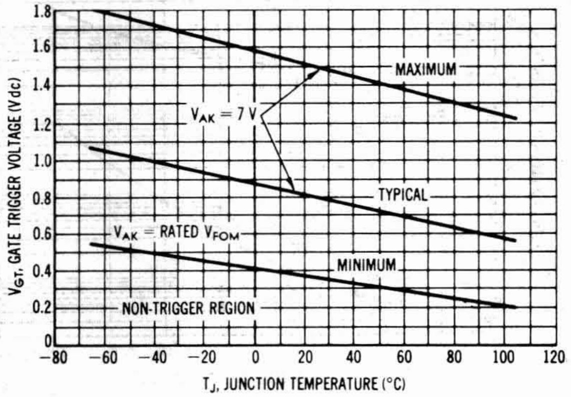


FIGURE 12 — DC GATE TRIGGER VOLTAGE

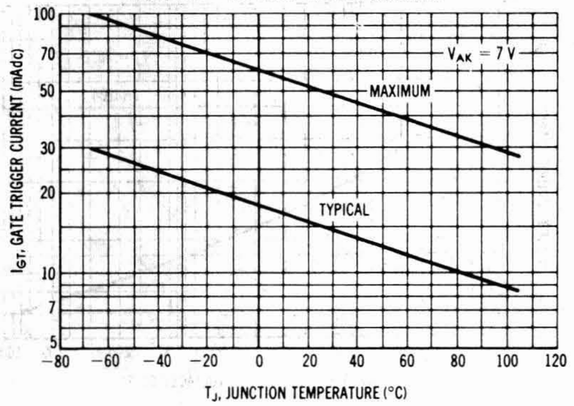


FIGURE 14 — DC GATE TRIGGER CURRENT

FIGURE 15 — TYPICAL BLOCKING VOLTAGE DERATING

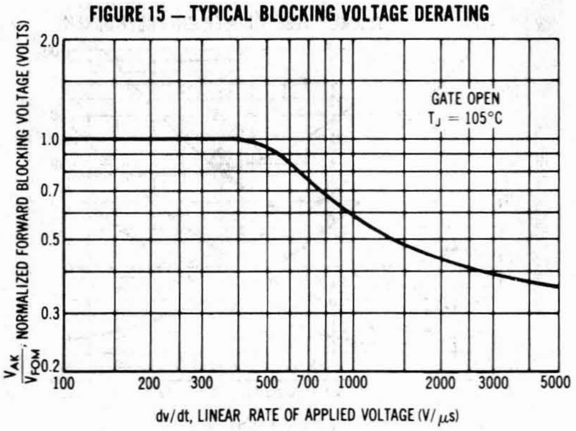


FIGURE 16 — TYPICAL dv/dt CAPABILITY

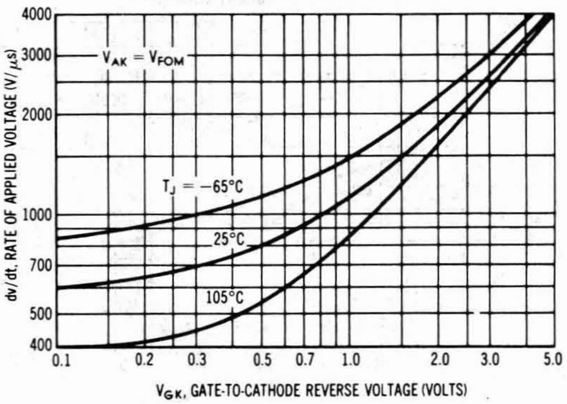


FIGURE 17 — FORWARD BLOCKING CURRENT

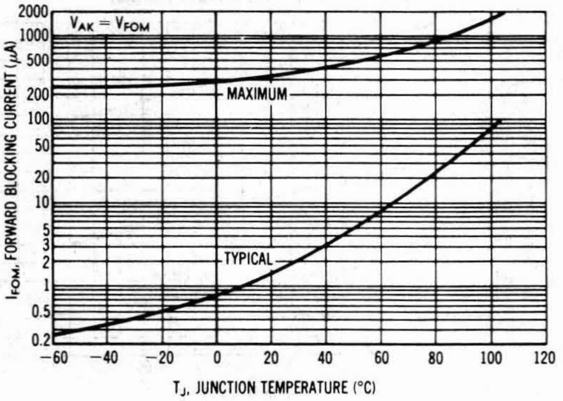


FIGURE 18 — HOLDING CURRENT

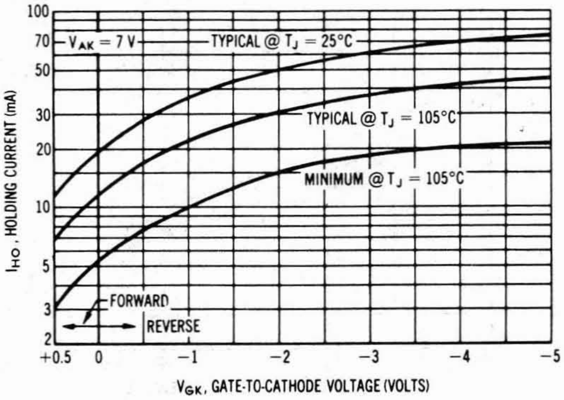


FIGURE 19 — TYPICAL ANODE-TO-CATHODE CAPACITANCE

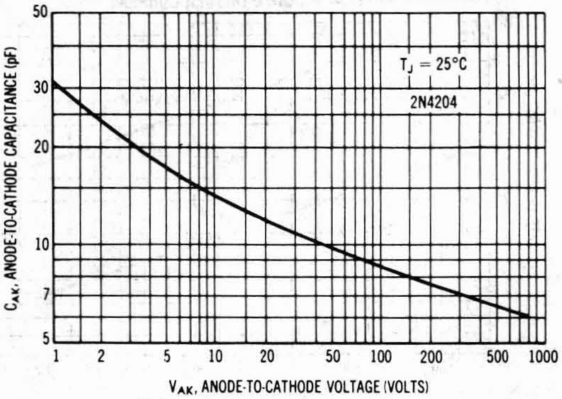
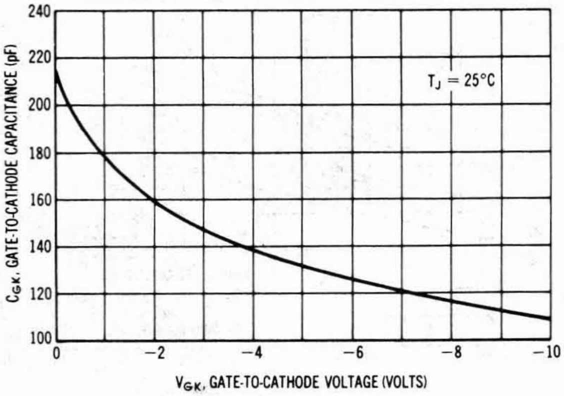


FIGURE 20 — TYPICAL GATE-TO-CATHODE CAPACITANCE



2N4212 thru 2N4216 (SILICON)

CASE 31(2)
(TO-5)

PNPN thyristors (silicon controlled rectifiers) designed for operation in mA/μA signal or detection circuits.

MAXIMUM RATINGS * (T_J = 125°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage (Note 1) 2N4212 2N4213 2N4214 2N4215 2N4216	$V_{RXM(rep)}$	25 50 100 150 200	Volt
Forward Current RMS (All Conduction Angles)	I_f	1.6	Amp
Peak Surge Current (One Cycle, 60 Hz) No Repetition until Thermal Equilibrium is Restored	$I_{FM(surge)}$	15	Amp
Peak Gate Power - Forward	P_{GFM}	0.1	Watt
Average Gate Power - Forward	$P_{GF(AV)}$	0.01	Watt
Peak Gate Current - Forward	I_{GFM}	0.1	Amp
Peak Gate Voltage - Forward	V_{GFM}	6.0	Volt
Reverse	V_{GRM}	6.0	
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C
Lead Solder Temperature (> 1/16" from case, 10 sec. max)	-	+230	°C

* JEDEC Registered Values.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted, R_{GK} = 1000 ohms)

Characteristic	Symbol	Min	Max	Unit
Peak Forward Blocking Voltage (Note 1) 2N4212 2N4213 2N4214 2N4215 2N4216	V_{FXM}	 25* 50* 100* 150* 200*	 - - - - -	Volt
Peak Reverse Blocking Current (Rated V_{RXM}, T_J = 125°C)	I_{RXM}	-	200*	μA
Peak Forward Blocking Current (Rated V_{FXM}, T_J = 125°C)	I_{FXM}	-	200*	μA
Forward "On" Voltage (I_F = 1.0 A Peak) (I_F = 3.14 A Peak)	V_F	 - -	 1.5 2.0*	Volt
Gate Trigger Current (Note 2) (Anode Voltage = 7.0 V, R_L = 100 ohms) (T_C = 25°C) (T_C = -65°C)	I_{GT}	 - -	 100 300*	μAdc
Gate Trigger Voltage (Anode Voltage = 7.0 V, R_L = 100 ohms, T_C = 25°C) (Anode Voltage = 7.0 V, R_L = 100 ohms, T_C = -65°C) (Anode Voltage = Rated V_{FXM}, R_L = 100 ohms, T_J = 125°C)	V_{GT} V_{GT} V_{GNT}	- - 0.1*	0.8 1.0* -	Volt
Holding Current (Anode Voltage = 7.0 V) T_C = 25°C T_C = -65°C	I_{HX}		3.0 7.0*	mA
Turn-On Time	t_{on}	Circuit dependent, consult manufacturer		
Turn-Off Time	t_{off}			

* JEDEC Registered Values

Notes: 1. V_{RXM} and V_{FXM} can be applied for all types on a continuous dc basis without incurring damage.

2. R_{GK} current is not included in measurement.

Thyristor devices shall not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

Thyristor devices shall not have a positive bias applied to the gate concurrently with a negative potential applied to the anode.

FIGURE 1 — CASE TEMPERATURE vs CURRENT

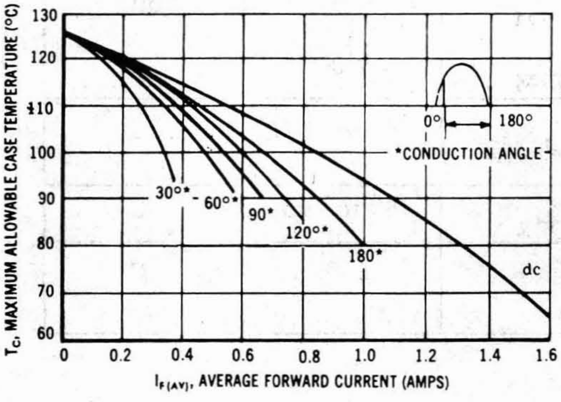
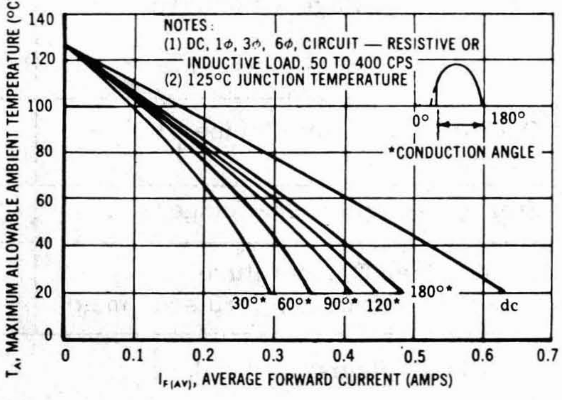


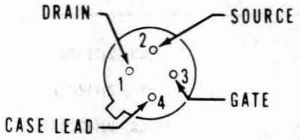
FIGURE 2 — AMBIENT TEMPERATURE vs CURRENT



2N4220 thru 2N4222 (SILICON)
2N4220A thru 2N4222A

CASE 20(3)
(TO-72)

N-channel junction silicon field-effect transistors designed for general purpose amplifier and switching applications. "A" types guarantee low noise figure (2.5 dB maximum @ 100 kHz).



Drain and Source
may be interchanged.

MAXIMUM RATINGS

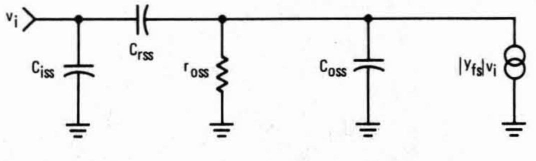
Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	30	Vdc
Drain Current	I_D	15	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate Above 25°C	P_D	300 2.0	mW mW/°C
Operating Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Gate-Source Breakdown Voltage (I_G = -10 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	-30	-	-	Vdc
Gate Reverse Current (V_{GS} = -15 Vdc, V_{DS} = 0)		I_{GSS}	-	-	-0.1	nAdc
(V_{GS} = -15 Vdc, V_{DS} = 0, T_A = 150°C)			-	-	-100	
Gate-Source Voltage (I_D = 50 μAdc, V_{DS} = 15 Vdc)	2N4220, 2N4220A	V_{GS}	-0.5	-	-2.5	Vdc
(I_D = 200 μAdc, V_{DS} = 15 Vdc)	2N4221, 2N4221A		-1.0	-	-5.0	
(I_D = 500 μAdc, V_{DS} = 15 Vdc)	2N4222, 2N4222A		-2.0	-	-6.0	
Gate-Source Cutoff Voltage (I_D = 0.1 nAdc, V_{DS} = 15 Vdc)	2N4220, 2N4220A	$V_{GS(off)}$	-	-	-4.0	Vdc
	2N4221, 2N4221A		-	-	-6.0	
	2N4222, 2N4222A		-	-	-8.0	
ON CHARACTERISTICS						
Zero-Gate-Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0)	2N4220, 2N4220A	I_{DSS}*	0.5	-	3.0	mAdc
	2N4221, 2N4221A		2.0	-	6.0	
	2N4222, 2N4222A		5.0	-	15	
DYNAMIC CHARACTERISTICS						
Forward Transfer Admittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	2N4220, 2N4220A	$\|y_{fs}\|$*	1000	2500	4000	μmhos
	2N4221, 2N4221A		2000	3500	5000	
	2N4222, 2N4222A		2500	4500	6000	
Output Admittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	2N4220, 2N4220A	$\|y_{os}\|$*	-	-	10	μmhos
	2N4221, 2N4221A		-	-	20	
	2N4222, 2N4222A		-	-	40	
Drain-Source Resistance (V_{DS} = 0, V_{GS} = 0)	2N4220, 2N4220A	$r_{ds(on)}$	-	500	-	Ohms
	2N4221, 2N4221A		-	400	-	
	2N4222, 2N4222A		-	300	-	
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{iss}	-	4.5	6.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{rss}	-	1.2	2.0	pF
Common-Source Output Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 30 MHz)		C_{osp}	-	1.5	-	pF
Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_S = 1.0 Megohm, f = 100 Hz)	2N4220A	NF	-	-	2.5	dB
	2N4221A		-	-	2.5	
	2N4222A		-	-	2.5	

*Pulse Test: Pulse Width = 630 ms, Duty Cycle = 10%

FIGURE 1 – EQUIVALENT LOW FREQUENCY CIRCUIT



Common Source
Y Parameters for Frequencies
Below 30 MHz

$y_{is} = j\omega\, C_{iss}$

$y_{os} = j\omega\, C_{osp}^{*} + 1/r_{oss}$

$y_{fs} = |y_{fs}|$

$y_{rs} = -j\omega\, C_{rss}$

*C_{osp} is C_{oss} in parallel with Series Combination of C_{iss} and C_{rss}.

FIGURE 2 – FORWARD TRANSFER ADMITTANCE versus DRAIN CURRENT

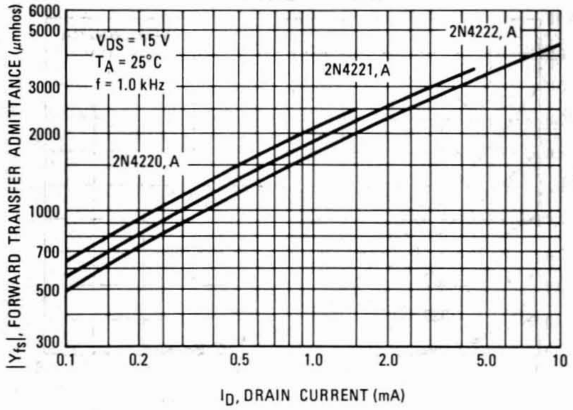


FIGURE 3 – TEMPERATURE COEFFICIENT OF Y_{fs} versus DRAIN CURRENT

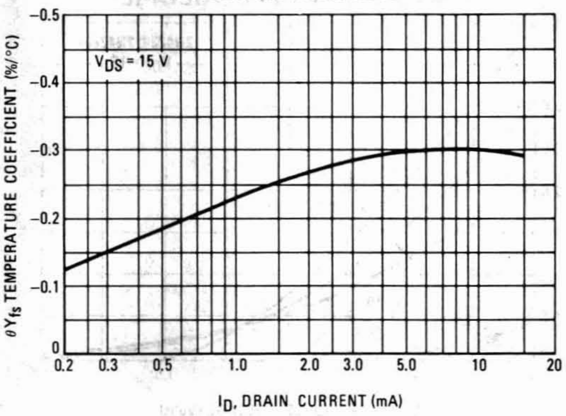


FIGURE 4 – OUTPUT RESISTANCE versus DRAIN CURRENT

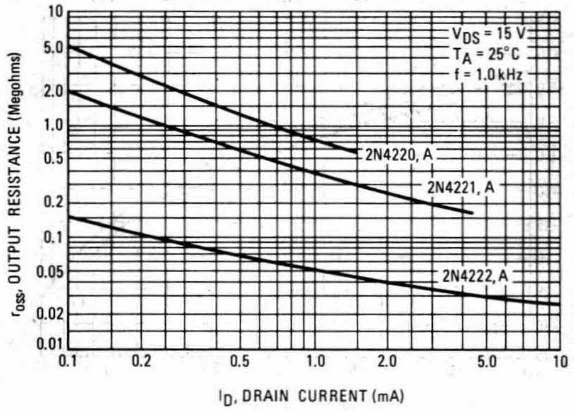


FIGURE 5 – CAPACITANCE versus DRAIN-SOURCE VOLTAGE

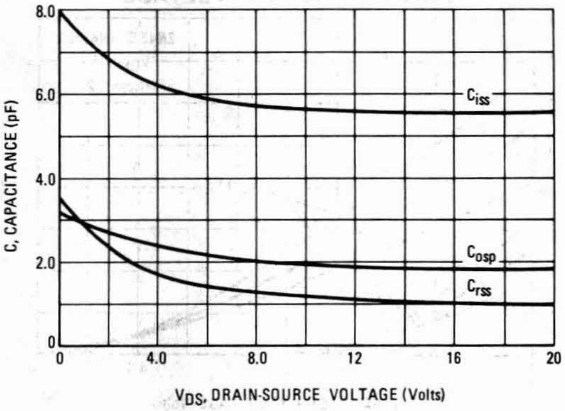


FIGURE 6 – NOISE FIGURE versus FREQUENCY

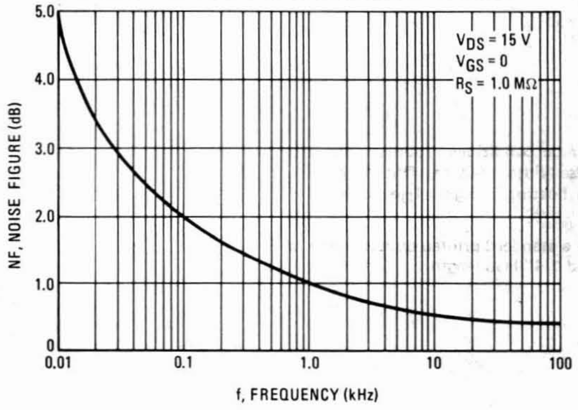


FIGURE 7 – NOISE FIGURE versus SOURCE RESISTANCE

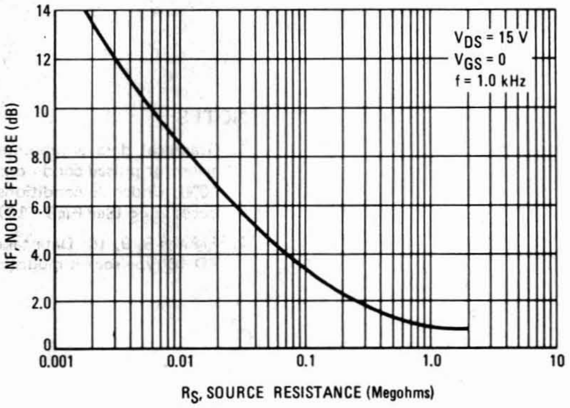


FIGURE 8 – DRAIN CURRENT versus GATE-SOURCE VOLTAGE

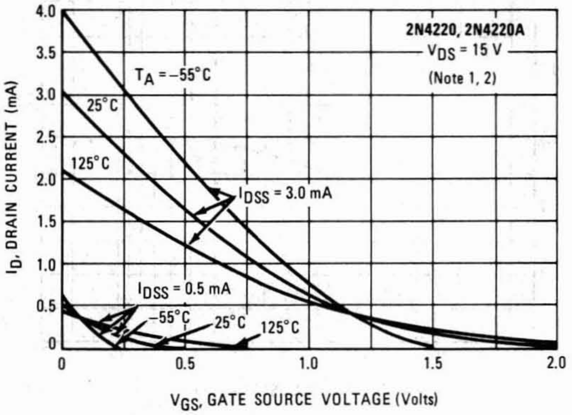


FIGURE 9 – DRAIN CURRENT versus GATE-SOURCE VOLTAGE

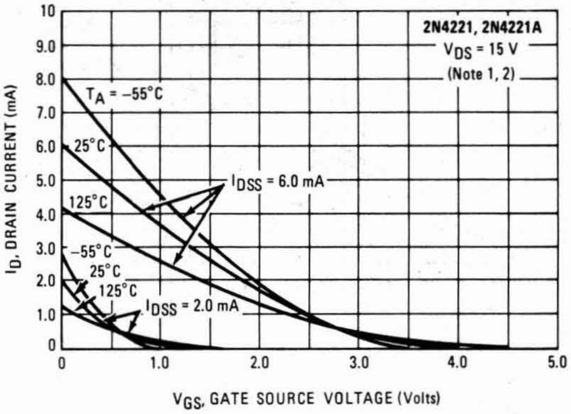


FIGURE 10 – DRAIN CURRENT versus GATE-SOURCE VOLTAGE

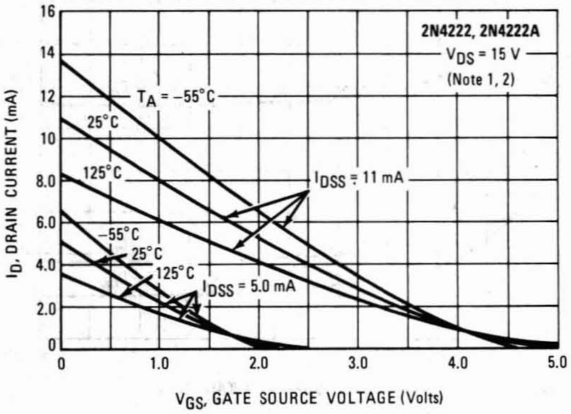
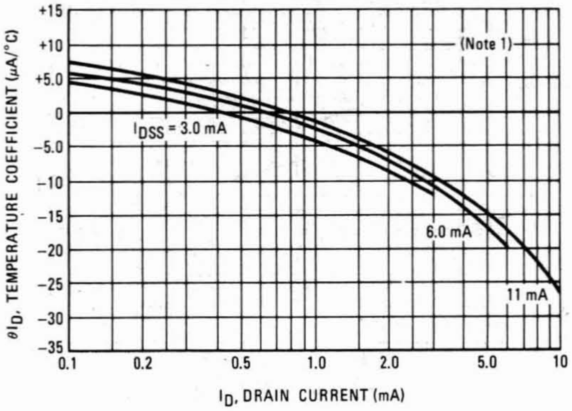


FIGURE 11 – TEMPERATURE COEFFICIENT OF DRAIN CURRENT versus DRAIN CURRENT



NOTES:

1. Graphical data is presented for dc conditions. Tabular data is given for pulsed conditions (Pulse Width = 630 ms, Duty Cycle = 10%). Under dc conditions, self heating in higher I_{DSS} units reduces I_{DSS} (See Figure 10).
2. Figures 8, 9, 10: Data taken in a standard printed circuit with a TO-18 type socket mounting and 1/4" lead length.

2N4223 (SILICON)
2N4224

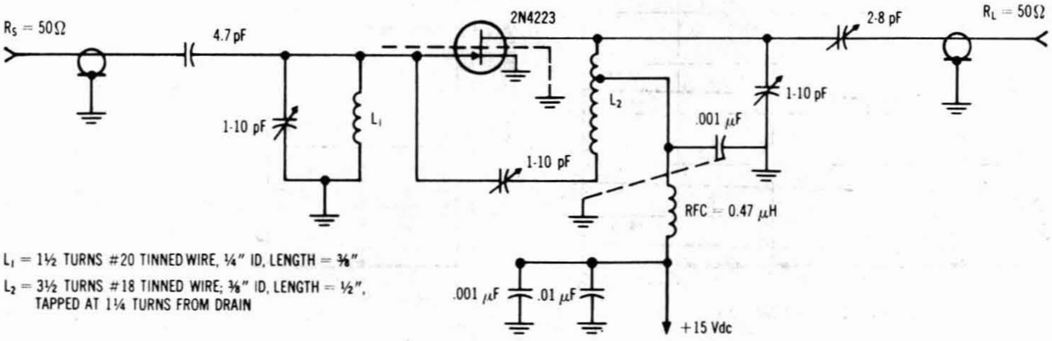
CASE 20(3)
(TO-72)

Silicon N-channel junction field-effect transistors, designed for VHF amplifier and mixer applications. Drain and Source interchangeable.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	30	Vdc
Drain Current	I_D	20	mAdc
Power Dissipation Derate above 25°C	P_D	300 2	mW mW/°C
Operating Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 — NOISE FIGURE AND POWER GAIN TEST CIRCUIT


R$_S$ = 50Ω
4.7 pF
2N4223
2-8 pF
R$_L$ = 50Ω
1-10 pF
L$_1$
L$_2$
1-10 pF
.001 µF
1-10 pF
RFC = 0.47 µH
.001 µF
.01 µF
+15 Vdc

L$_1$ = 1½ TURNS #20 TINNED WIRE, ¼" ID, LENGTH = ⅜"

L$_2$ = 3½ TURNS #18 TINNED WIRE; ⅜" ID, LENGTH = ½", TAPPED AT 1¼ TURNS FROM DRAIN

2N4223, 2N4224 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	30	-	Vdc
Gate Reverse Current (V_{GS} = 20 Vdc, V_{DS} = 0)	2N4223	I_{GSS}	-	0.25	nAdc
	2N4224		-	0.50	
(V_{GS} = 20 Vdc, V_{DS} = 0, T_A = 100°C)	2N4223		-	250	
	2N4224		-	500	
Gate-Source Cutoff Voltage (I_D = 0.25 nAdc, V_{DS} = 15 Vdc)	2N4223	$V_{GS(off)}$	-	8	Vdc
(I_D = 0.50 nAdc, V_{DS} = 15 Vdc)	2N4224		-	8	
Gate-Source Voltage (I_D = 0.3 mAdc, V_{DS} = 15 Vdc)	2N4223	V_{GS}	1.0	7.0	Vdc
(I_D = 0.2 mAdc, V_{DS} = 15 Vdc)	2N4224		1.0	7.5	
ON CHARACTERISTICS					
Zero-Gate-Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0)	2N4223	I_{DSS}*	3	18	mAdc
	2N4224		2	20	
DYNAMIC CHARACTERISTICS					
Forward Transfer Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 kHz)*	2N4223	$\|y_{fs}\|$	3000	7000	μmhos
	2N4224		2000	7500	
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	2N4223		2700	-	
	2N4224		1700	-	
Input Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)		$Re(y_{is})$	-	800	μmhos
Output Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)		$Re(y_{os})$	-	200	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)		C_{iss}	-	6	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)		C_{rss}	-	2	pF
Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_S = 1 k ohm, f = 200 MHz)	2N4223	NF	-	5	dB
Small-Signal Power Gain (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	2N4223	G_{ps}	10	-	dB

*Pulse Test: Pulse Width ≦ 630 ms, Duty Cycle ≦ 10%

FIGURE 2 — TYPICAL DRAIN CHARACTERISTICS

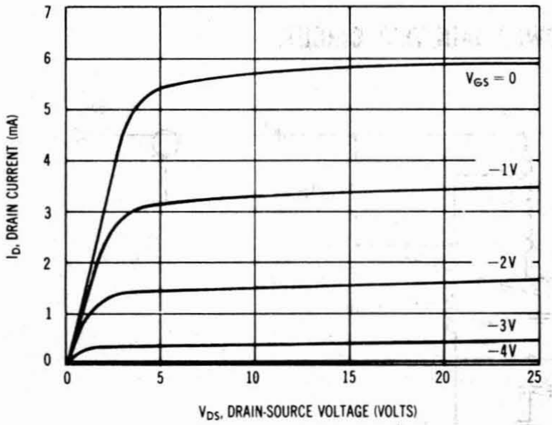


FIGURE 3 — COMMON SOURCE TRANSFER CHARACTERISTICS

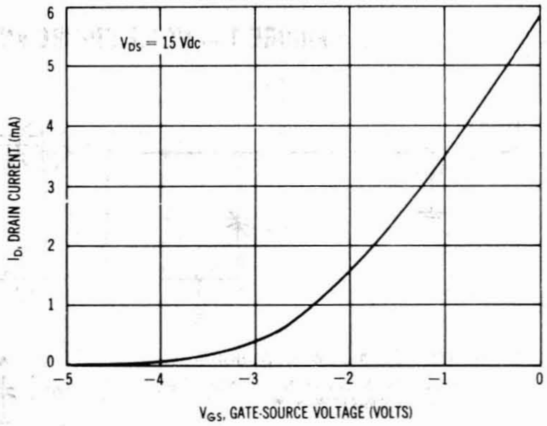


FIGURE 2 – DRAIN CURRENT versus GATE-SOURCE VOLTAGE

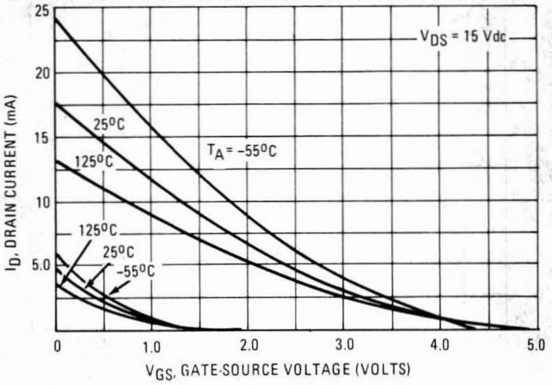


FIGURE 3 – TEMPERATURE COEFFICIENT FOR DRAIN CURRENT

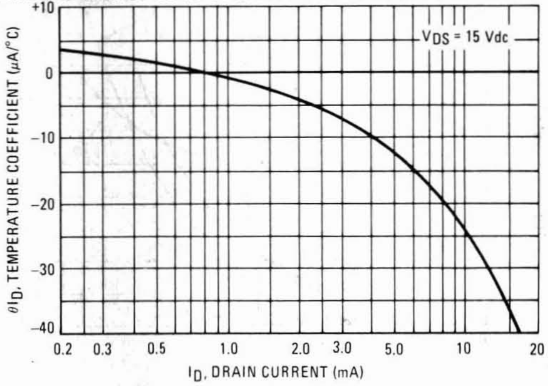


FIGURE 4 – FORWARD TRANSFER ADMITTANCE versus GATE-SOURCE VOLTAGE

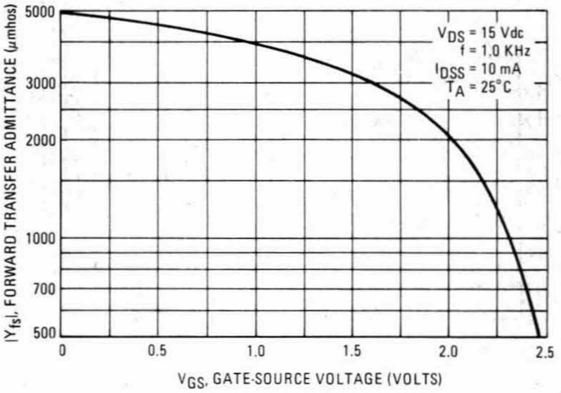


FIGURE 5 – TEMPERATURE COEFFICIENT FOR Y_{fs} versus DRAIN CURRENT

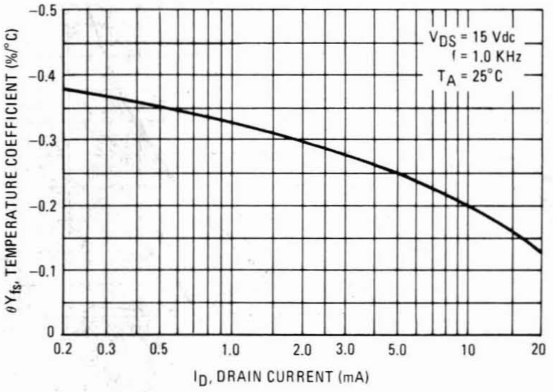


FIGURE 6 – CAPACITANCES

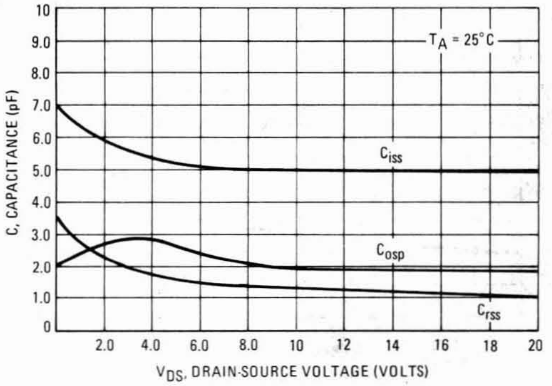


FIGURE 7 – COMMON SOURCE NOISE FIGURE versus SOURCE RESISTANCE

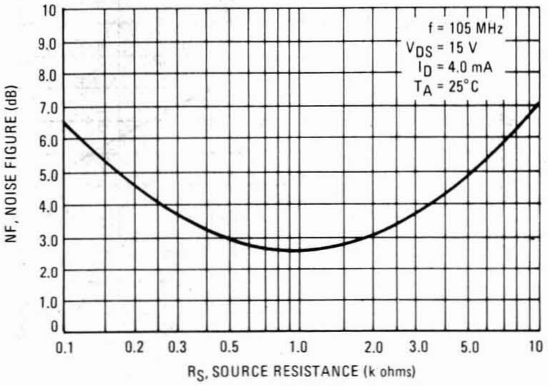


FIGURE 8 – INPUT ADMITTANCE versus FREQUENCY

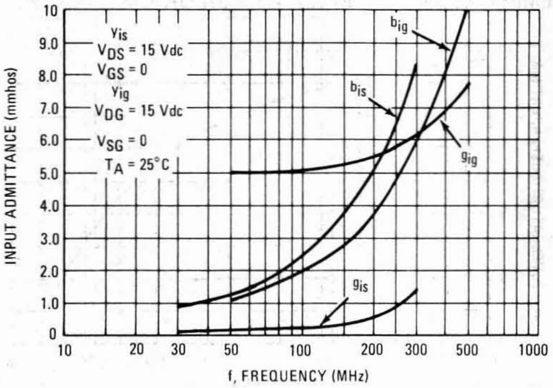


FIGURE 9 – FORWARD TRANSFER ADMITTANCE versus FREQUENCY

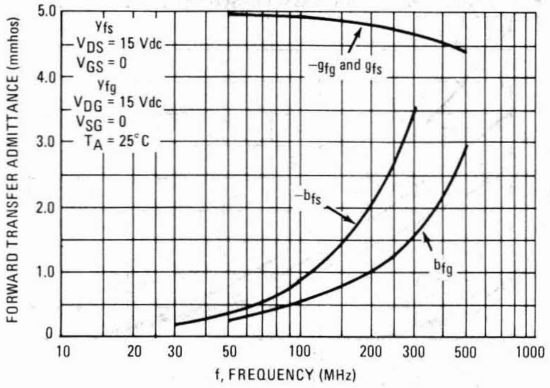


FIGURE 10 – OUTPUT ADMITTANCE versus FREQUENCY

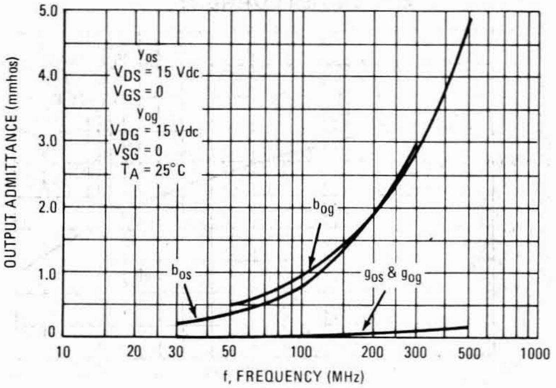


FIGURE 11 – REVERSE TRANSFER ADMITTANCE versus FREQUENCY

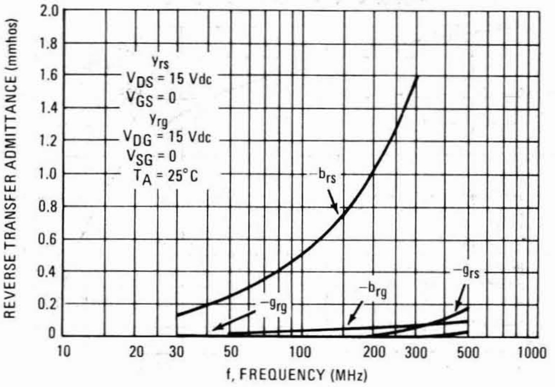


FIGURE 12 – POWER GAIN versus FREQUENCY

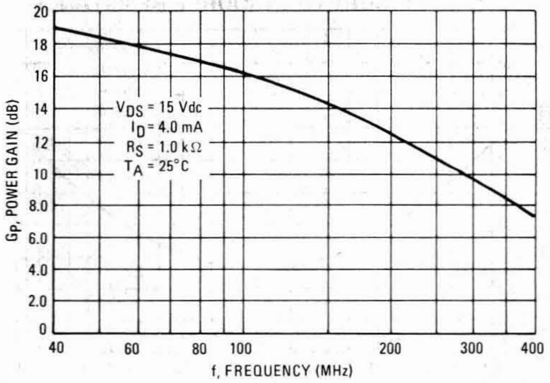
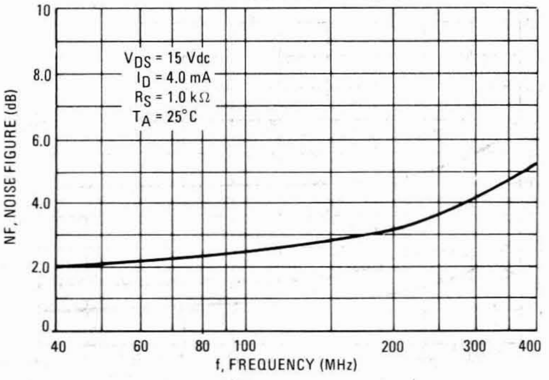


FIGURE 13 – COMMON SOURCE NOISE FIGURE versus FREQUENCY



2N4231 thru 2N4233 (SILICON)

Medium-power NPN silicon transistors designed for driver circuits, switching, and amplifier applications.

CASE 80
(TO-66)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4231	2N4232	2N4233	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	50	70	90	Vdc
Emitter-Base Voltage	V_{EB}	5.0			Vdc
Collector Current - Continuous*	I_C*	3.0 5.0			Adc
Base Current	I_B	1.0			Adc
Total Device Dissipation T_C = 25°C Derate above 25°C	P_D	35 0.2			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +200			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	5.0	°C/W

* The 3.0 Amp maximum I_C value is based upon JEDEC current gain requirements.
The 5.0 Amp maximum value is based upon actual current-handling capability of the device.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, I_B = 0) 2N4231	$BV_{CEO(sus)}$*	40	-	Vdc
2N4232		60	-	
2N4233		80	-	
Collector Cutoff Current (V_{CE} = 30 Vdc, I_B = 0) 2N4231	I_{CEO}	-	1.0	mA
(V_{CE} = 50 Vdc, I_B = 0) 2N4232		-	1.0	
(V_{CE} = 70 Vdc, I_B = 0) 2N4233		-	1.0	
Collector Cutoff Current (V_{CE} @ rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc)	I_{CEX}	-	0.1	mA
(V_{CE} @ rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)		-	1.0	
Collector Cutoff Current (V_{CB} @ rated V_{CB}, I_E = 0)	I_{CBO}	-	0.05	mA
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	500	uA
ON CHARACTERISTICS				
DC Current Gain* (I_C = 0.5 Adc, V_{CE} = 2.0 Vdc)	h_{FE}*	40	-	-
(I_C = 1.5 Adc, V_{CE} = 2.0 Vdc)		25	100	
(I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)		10	-	
Collector-Emitter Saturation Voltage* (I_C = 1.5 Adc, I_B = 0.15 Adc)	$V_{CE(sat)}$*	-	0.7	Vdc
(I_C = 3.0 Adc, I_B = 0.3 Adc)		-	2.0	
Base-Emitter Voltage* (I_C = 1.5 Adc, V_{CE} = 2.0 Vdc)	$V_{BE(on)}$*	-	1.4	Vdc

*** Pulse Test, PW ≈ 300 µs, Duty Cycle ≈ 2.0%**

2N4231 thru 2N4233 (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Max	Unit
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain-Bandwidth Product (I_C = 0.5 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz)	f_T	4.0	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 kHz)	C_{ob}	-	200	pF
Small-Signal Current Gain (I_C = 0.5 Adc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	20	-	-

FIGURE 1 — NORMALIZED DC CURRENT GAIN

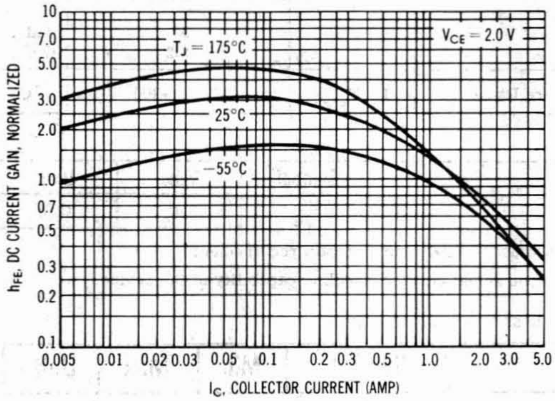


FIGURE 2 — COLLECTOR SATURATION REGION

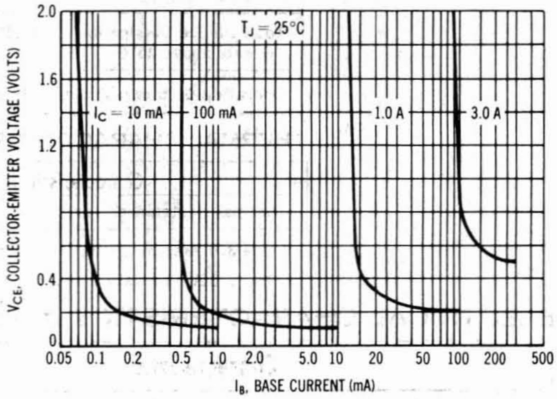


FIGURE 3 — "ON" VOLTAGES

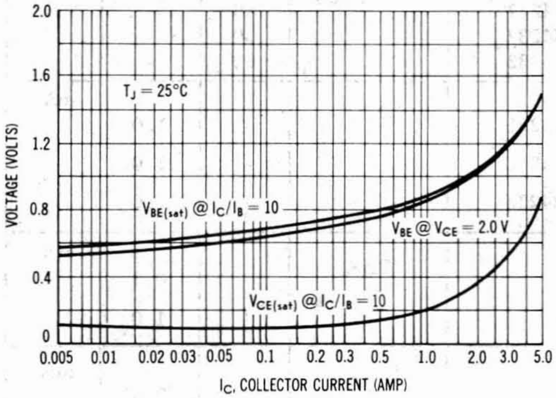


FIGURE 4 — TEMPERATURE COEFFICIENTS

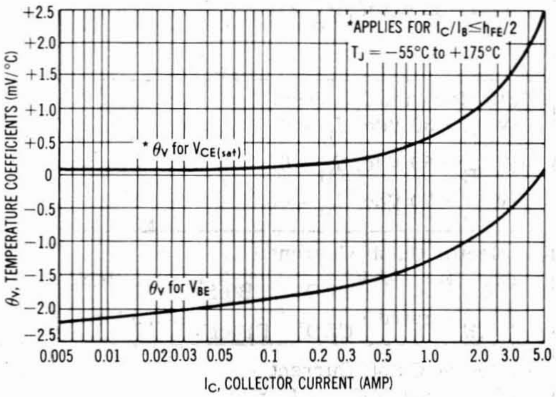
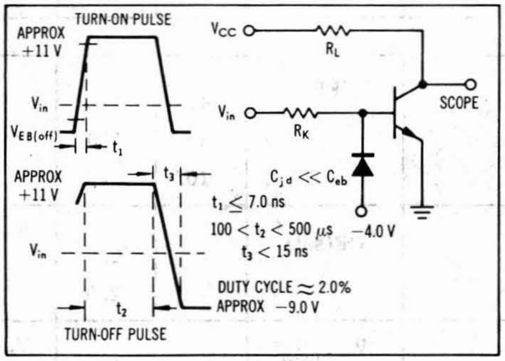


FIGURE 5 — SWITCHING TIME EQUIVALENT CIRCUIT



TURN-ON PULSE
APPROX +11 V
Vin
VEB(off)
t1
VCC
RL
SCOPE
Vin
RK
APPROX +11 V
t3
Cjd << Ceb
t1 ≤ 7.0 ns
100 < t2 < 500 μs
t3 < 15 ns
−4.0 V
Vin
DUTY CYCLE ≈ 2.0%
APPROX −9.0 V
t2
TURN-OFF PULSE

FIGURE 6 — CAPACITANCE

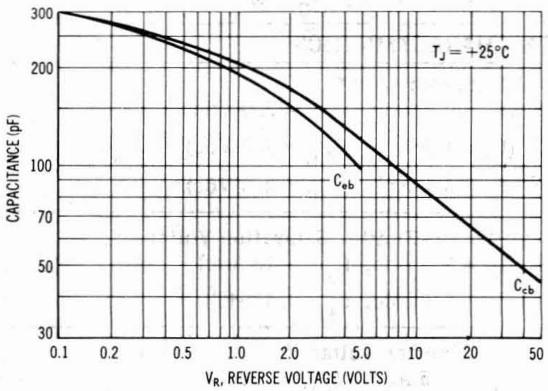


FIGURE 7 — TURN-ON TIME

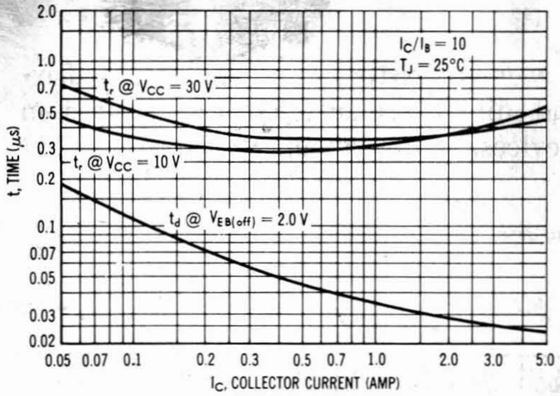
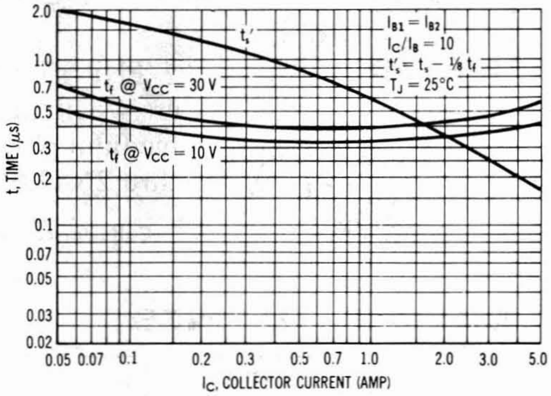


FIGURE 8 — TURN-OFF TIME



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 9 — CUT-OFF REGION

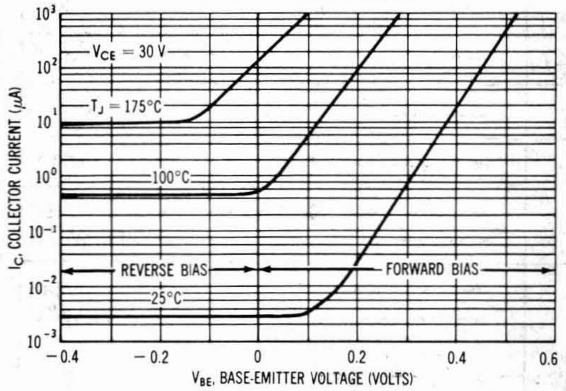


FIGURE 10 — EFFECTS OF BASE-EMITTER RESISTANCE

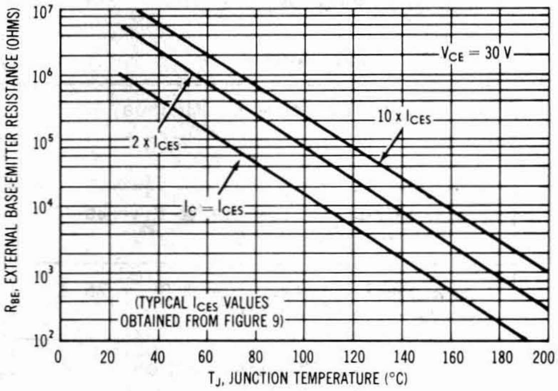
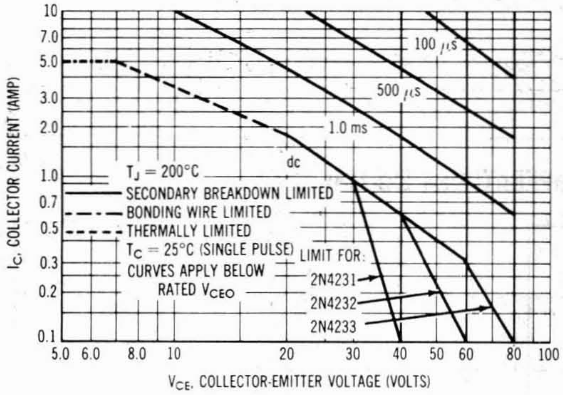


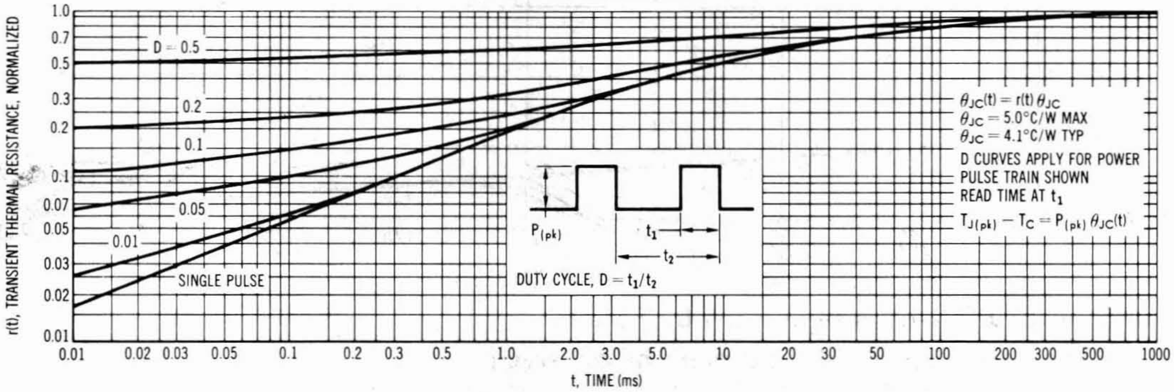
FIGURE 11 — ACTIVE-REGION SAFE-OPERATING AREA



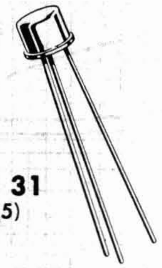
There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 11 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 12. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 12 — THERMAL RESPONSE



2N4234 (SILICON)
2N4235
2N4236


CASE 31
(TO-5)

PNP silicon power transistors ideal for use as drivers, switches, and direct replacement of germanium medium-power devices. Complement to NPN 2N4237 thru 2N4239.

Collector connected to case

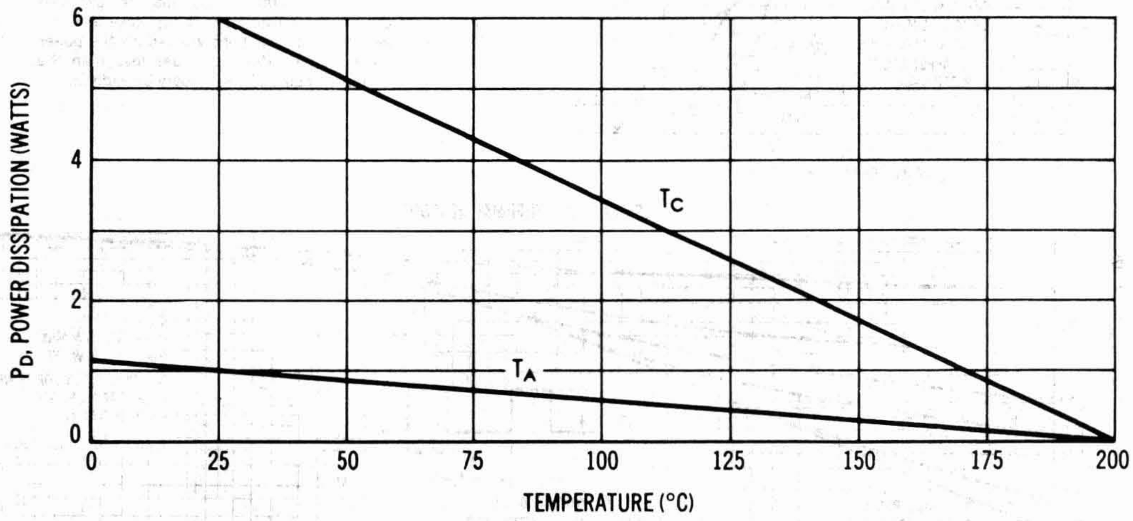
MAXIMUM RATINGS

Rating	Symbol	2N4234	2N4235	2N4236	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 7 →			Vdc
Collector Current — Continuous	I_C	← 3.0 →			Adc
Base Current	I_B	← 0.2 →			Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	← 1.0 → ← 5.7 →			Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	← 6 → ← 34 →			Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θJC	29	°C/W

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 2.

All limits are applicable and must be observed.

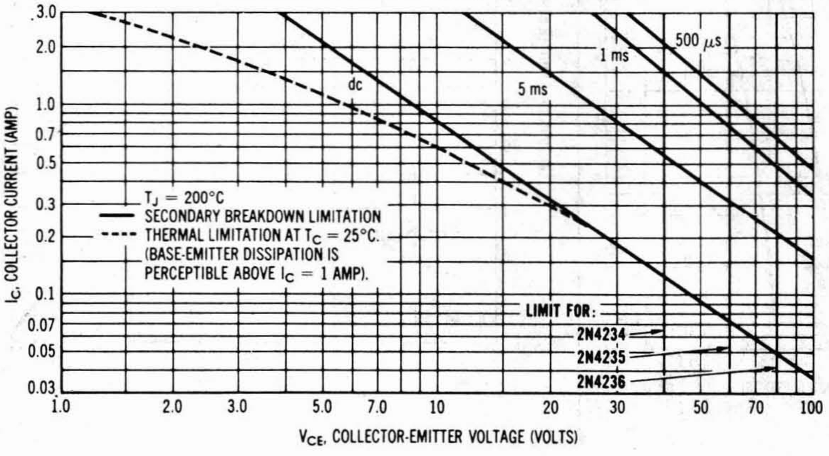
2N4234, 2N4235, 2N4236 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage * (I_C = 100 mAdc, I_B = 0)	2N4234 2N4235 2N4236	$BV_{CEO(sus)}$*	40 60 80	— — —	Vdc
Collector Cutoff Current		I_{CEO}			mAdc
(V_{CE} = 30 Vdc, I_B = 0)	2N4234		—	1.0	
(V_{CE} = 40 Vdc, I_B = 0)	2N4235		—	1.0	
(V_{CE} = 60 Vdc, I_B = 0)	2N4236		—	1.0	
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N4234		—	0.1	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N4235		—	0.1	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 1.5 Vdc)	2N4236		—	0.1	
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	2N4234		—	1.0	
(V_{CE} = 40 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	2N4235		—	1.0	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	2N4236		—	1.0	
Collector Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 40 Vdc, I_E = 0)	2N4234		—	0.1	
(V_{CB} = 60 Vdc, I_E = 0)	2N4235		—	0.1	
(V_{CB} = 80 Vdc, I_E = 0)	2N4236		—	0.1	
Emitter Cutoff Current (V_{BE} = 7 Vdc, I_C = 0)		I_{EBO}	—	0.5	mAdc
ON CHARACTERISTICS					
DC Current Gain *		h_{FE}*			—
(I_C = 100 mAdc, V_{CE} = 1 Vdc)			40	—	
(I_C = 250 mAdc, V_{CE} = 1 Vdc)			30	150	
(I_C = 500 mAdc, V_{CE} = 1 Vdc)			20	—	
(I_C = 1.0 Adc, V_{CE} = 1 Vdc)			10	—	
Collector-Emitter Saturation Voltage * (I_C = 1.0 Adc, I_B = 125 mAdc)		$V_{CE(sat)}$*	—	0.6	Vdc
Base-Emitter Saturation Voltage * (I_C = 1.0 Adc, I_B = 100 mAdc)		$V_{BE(sat)}$*	—	1.5	Vdc
Base-Emitter On Voltage (I_C = 250 mAdc, V_{CE} = 1.0 Vdc)		$V_{BE(on)}$	—	1.0	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)		f_T	3.0	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	100	pF
Small-Signal Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{fe}	25	—	—

*Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2%

FIGURE 2 — ACTIVE-REGION SAFE OPERATING AREAS



The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not enter secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a catastrophic failure. To insure operation below the maximum T_J, power-temperature derating must be observed for both steady state and pulse power conditions.

LARGE SIGNAL CHARACTERISTICS

FIGURE 3 — TRANSCONDUCTANCE

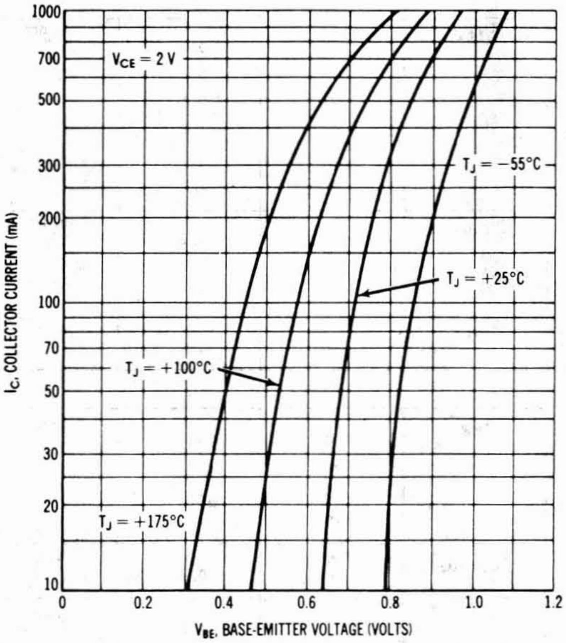
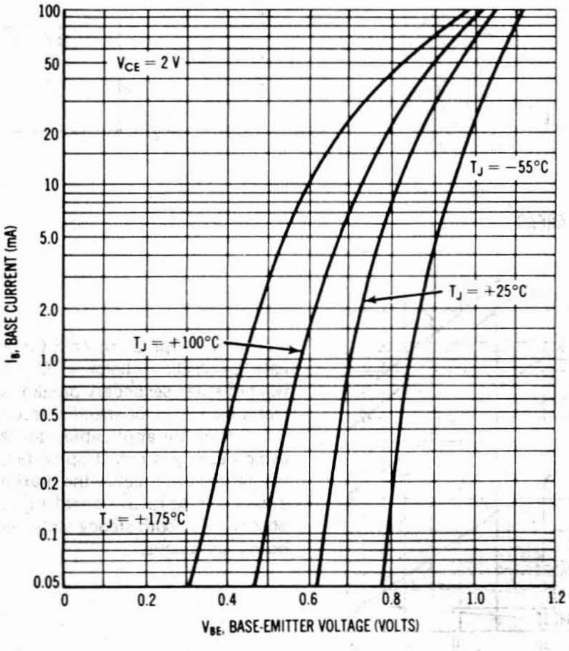


FIGURE 4 — INPUT ADMITTANCE



"OFF" REGION CHARACTERISTICS

FIGURE 5 — TRANSCONDUCTANCE

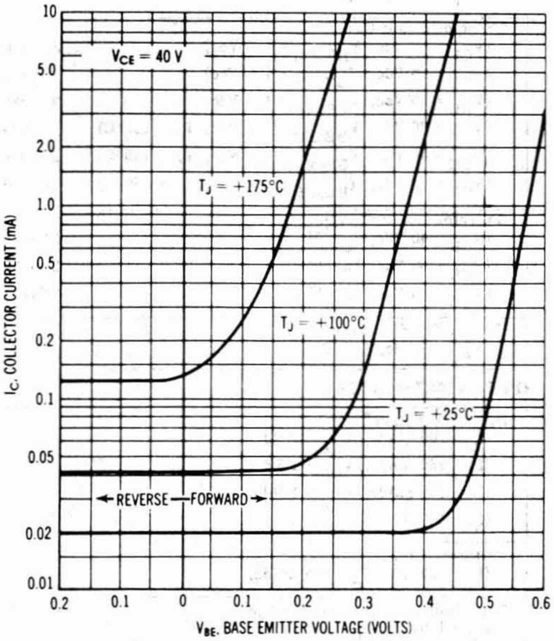


FIGURE 6 — EFFECTS OF BASE-EMITTER RESISTANCE

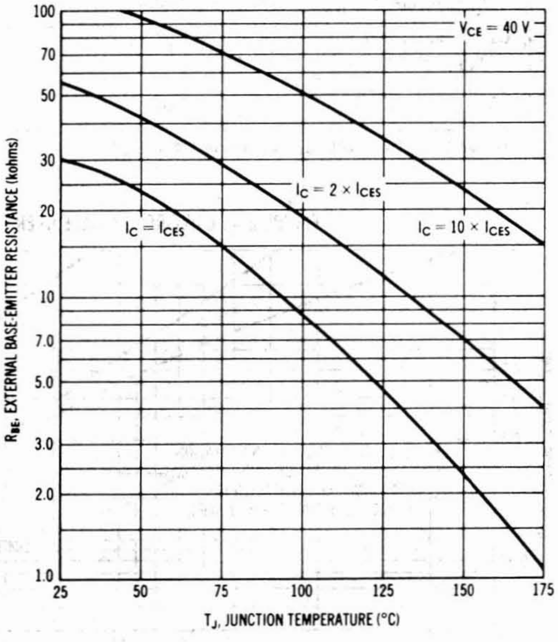
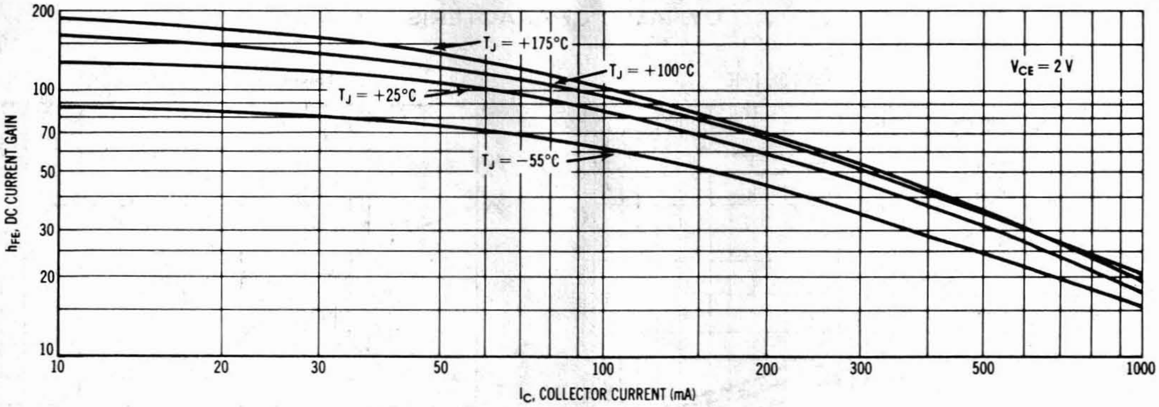


FIGURE 7 — CURRENT GAIN



SATURATION REGION CHARACTERISTICS

FIGURE 8 — COLLECTOR SATURATION REGION

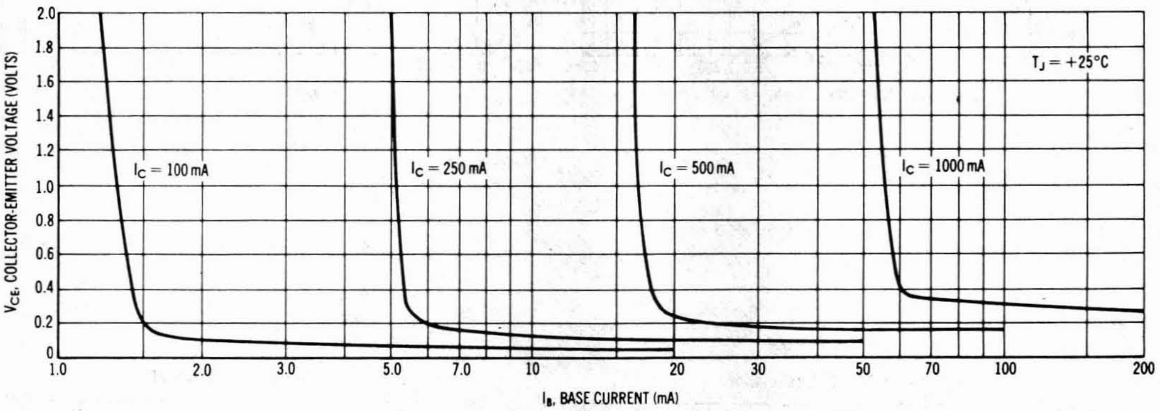


FIGURE 9 — "ON" VOLTAGES

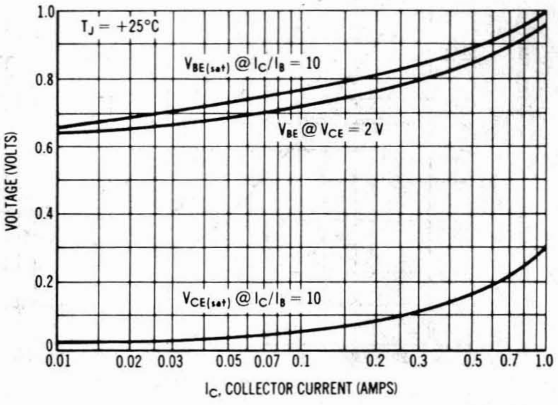
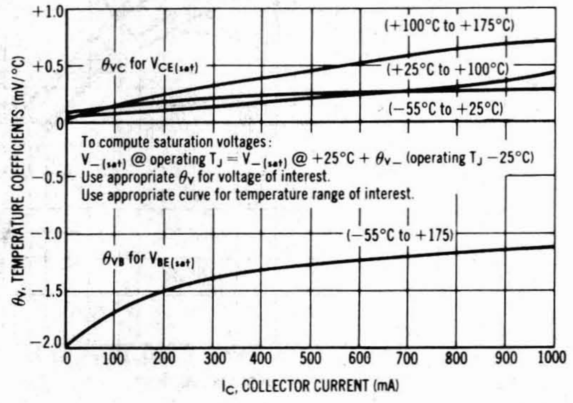


FIGURE 10 — TEMPERATURE COEFFICIENTS



DYNAMIC CHARACTERISTICS

FIGURE 11 — TURN-ON TIME

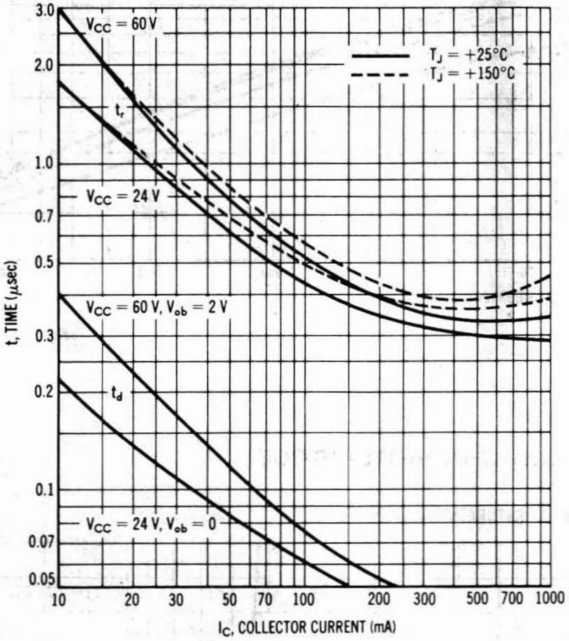


FIGURE 12 — STORAGE TIME

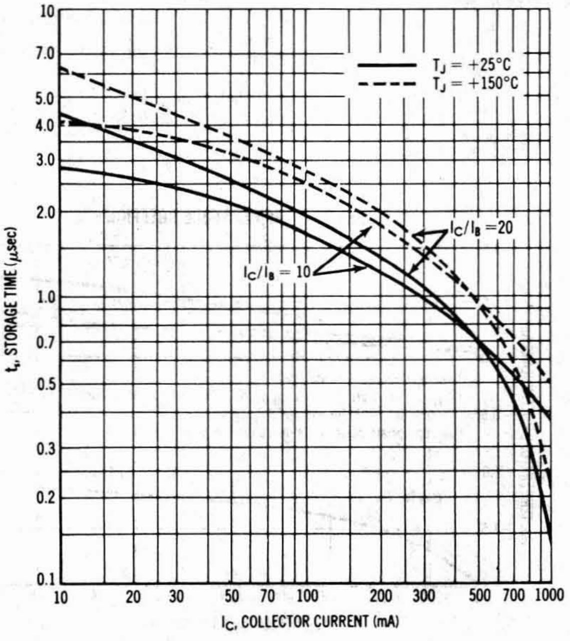


FIGURE 13 — CAPACITANCE

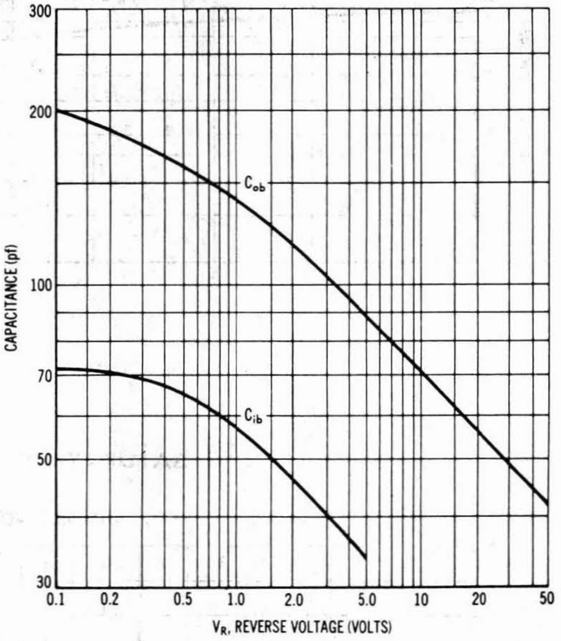
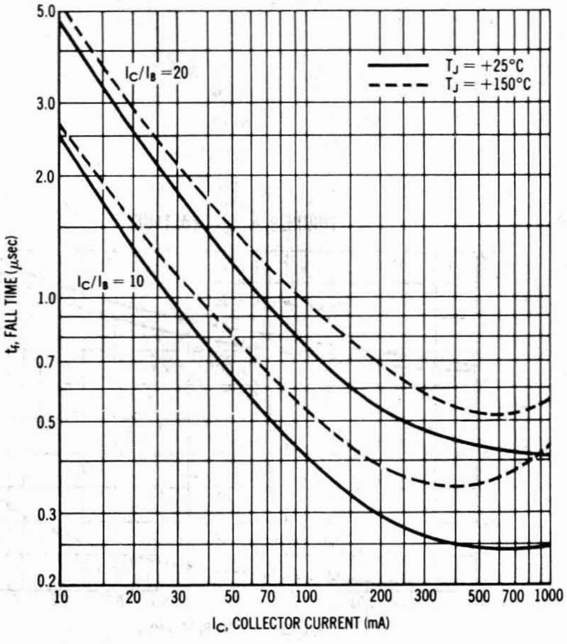


FIGURE 14 — FALL TIME



2N4237 (SILICON)
thru
2N4239

CASE 31
(TO-5)

Medium-power NPN silicon transistors designed for driver circuits, switching, and amplifier applications.

Collector connected to case

MAXIMUM RATINGS

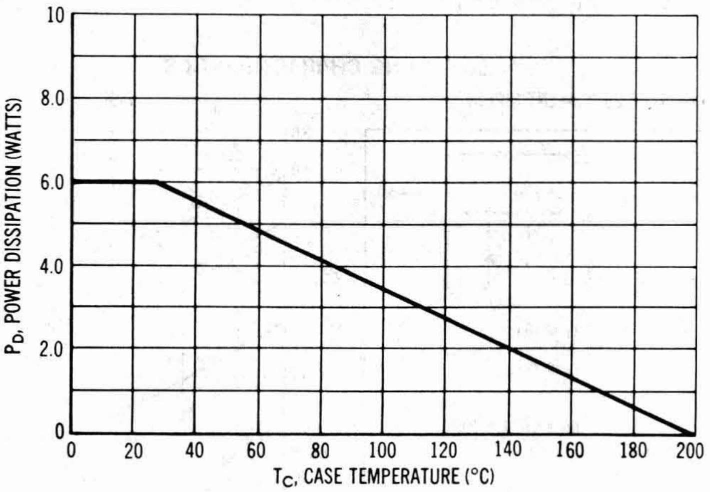
Rating	Symbol	2N4237	2N4238	2N4239	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	50	80	100	Vdc
Emitter-Base Voltage	V_{EB}	← 6.0 →			Vdc
Collector Current — Continuous*	I_C	← 1.0 → ← 3.0 →			Adc
Base Current — Continuous	I_B	← 500 →			mAdc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	← 6.0 → ← 34 →			Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← −65 to +200 →			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	29	°C/W

*The 1.0 Amp maximum I_C value is based upon JEDEC current gain requirements. The 3.0 Amp maximum value is based upon actual current-handling capability of the device (see Figure 5).

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 5. All limits are applicable and must be observed.

2N4237 thru 2N4239 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, I_B = 0) 2N4237 2N4238 2N4239	-	$BV_{CEO(sus)}$*	40 60 80	- - -	Vdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, I_B = 0)	-	I_{CEO}	-	0.7	mAdc
Collector Cutoff Current (V_{CE} = 45 Vdc, $V_{EB(off)}$ = 1.5 Vdc) (V_{CE} = 75 Vdc, $V_{EB(off)}$ = 1.5 Vdc) (V_{CE} = 90 Vdc, $V_{EB(off)}$ = 1.5 Vdc) (V_{CE} = 30 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C) (V_{CE} = 50 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C) (V_{CE} = 70 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	12	I_{CEX}	- - - - - -	0.1 0.1 0.1 1.0 1.0 1.0	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CBO}, I_E = 0)	-	I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current (V_{EB} = 6.0 Vdc, I_C = 0)	-	I_{EBO}	-	0.5	mAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 50 mAdc, V_{CE} = 1.0 Vdc) (I_C = 250 mAdc, V_{CE} = 1.0 Vdc) (I_C = 500 mAdc, V_{CE} = 1.0 Vdc) (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	8	h_{FE}*	30 30 30 15	- 150 - -	-
Collector-Emitter Saturation Voltage* (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1.0 Adc, I_B = 0.1 Adc)	9, 11, 13	$V_{CE(sat)}$*	- -	0.3 0.6	Vdc
Base-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)		$V_{BE(sat)}$*	-	1.5	Vdc
Base-Emitter On Voltage* (I_C = 250 mAdc, V_{CE} = 1.0 Vdc)	11, 13	$V_{BE(on)}$*	-	1.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)	-	f_T	2.0	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 0.1 MHz)	-	C_{ob}	-	100	pF
Small-Signal Current Gain (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	-	h_{fe}	30	-	-

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

SWITCHING CHARACTERISTICS

FIGURE 2 — SWITCHING TIME EQUIVALENT CIRCUIT

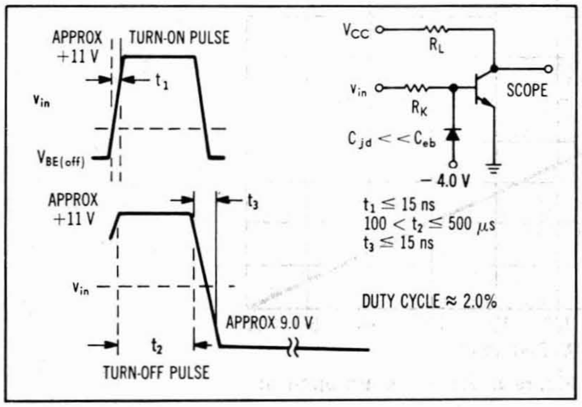

APPROX +11 V
TURN-ON PULSE
t_1
V_{in}
$V_{BE(off)}$
APPROX +11 V
t_3
V_{in}
APPROX 9.0 V
t_2
TURN-OFF PULSE
V_{CC}
R_L
V_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
− 4.0 V
$t_1 \leq 15$ ns
$100 < t_2 \leq 500$ μs
$t_3 \leq 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 3 — TURN-ON TIME

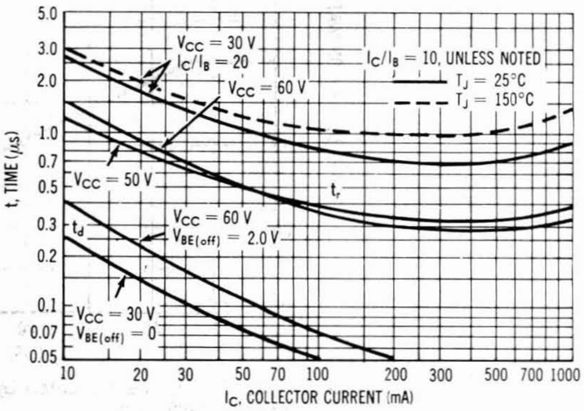


FIGURE 4 — THERMAL RESPONSE

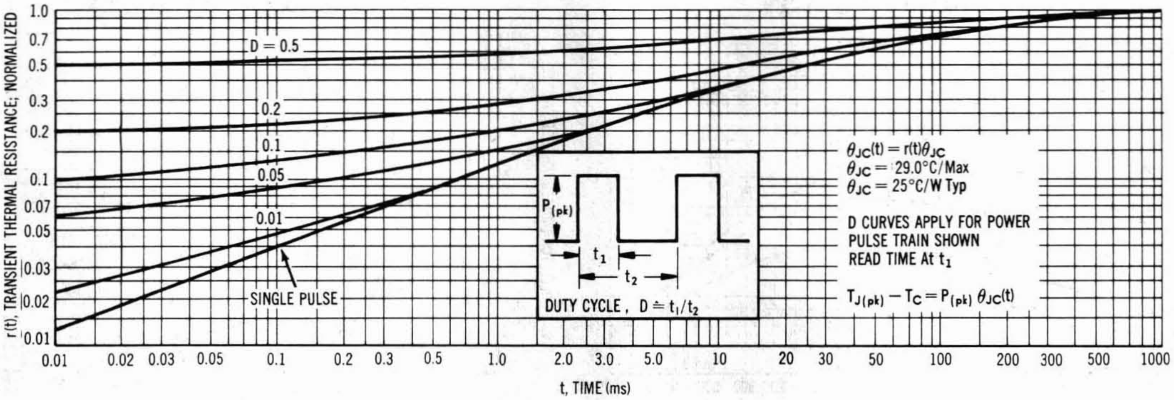
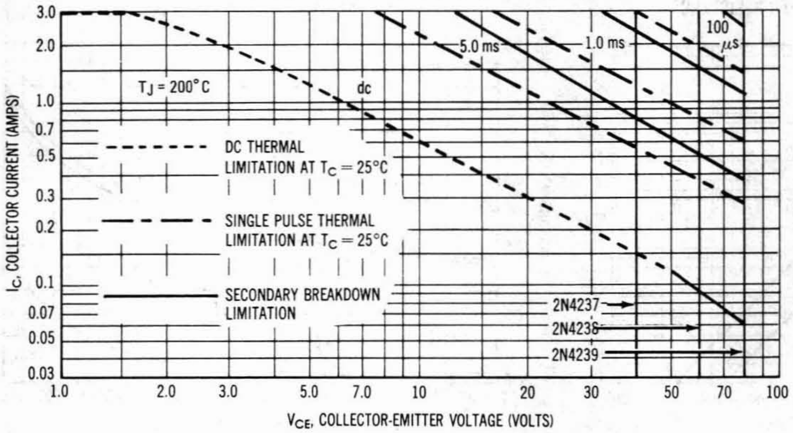


FIGURE 5 — ACTIVE-REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

For this particular transistor family, the thermal curves are the limiting design values, except for a small portion of the dc curve. The pulse secondary breakdown curves are shown for information only.

FIGURE 6 — STORAGE TIME

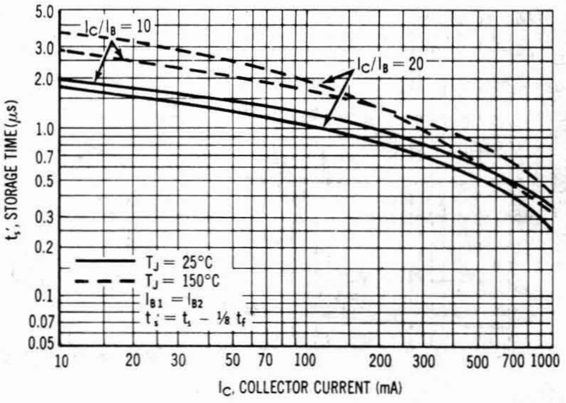
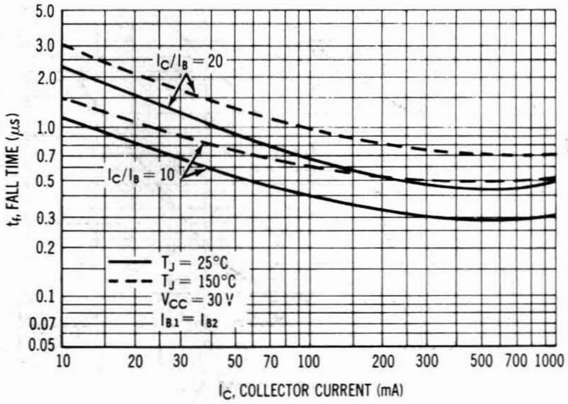


FIGURE 7 — FALL TIME



TYPICAL DC CHARACTERISTICS

FIGURE 8 — CURRENT GAIN

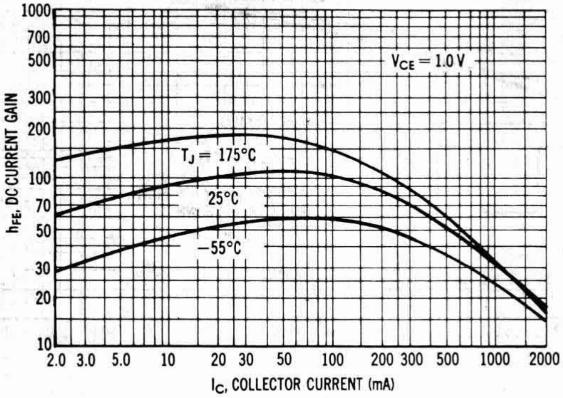


FIGURE 9 — COLLECTOR SATURATION REGION

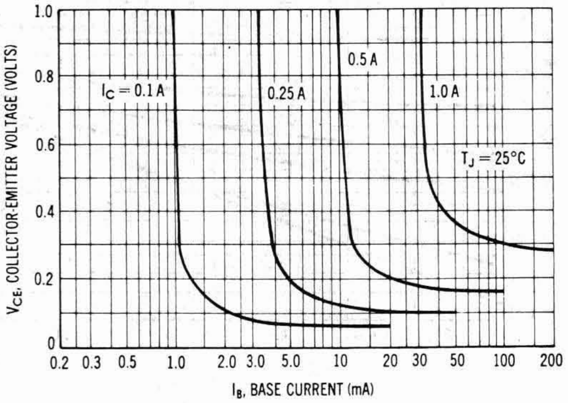


FIGURE 10 — EFFECTS OF BASE-EMITTER RESISTANCE

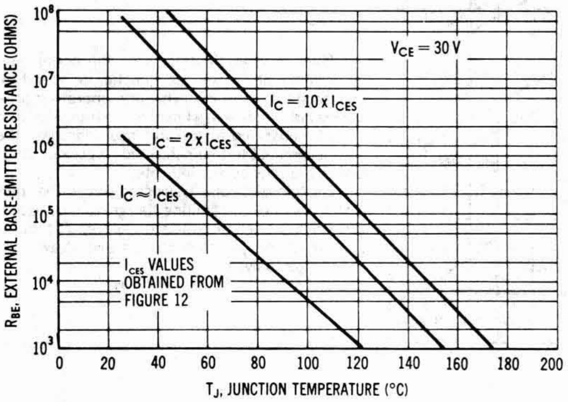


FIGURE 11 — "ON" VOLTAGE

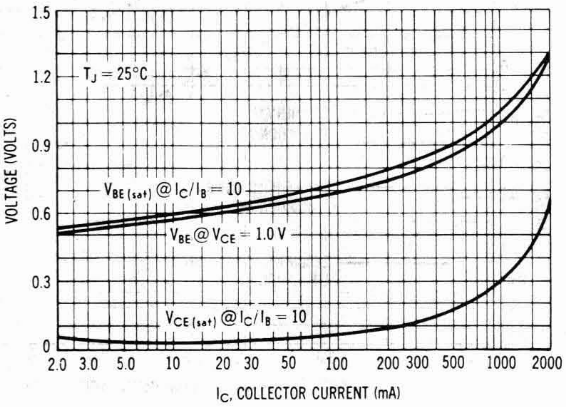


FIGURE 12 — COLLECTOR CUTOFF REGION

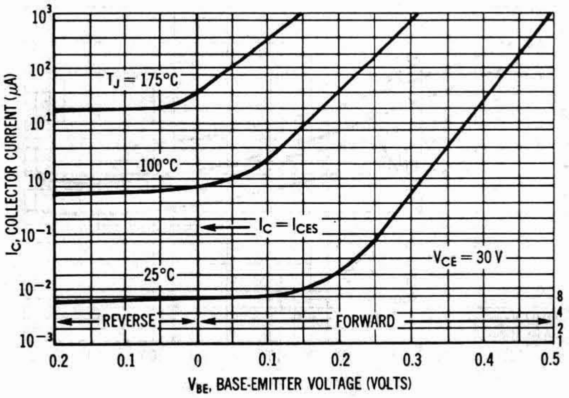
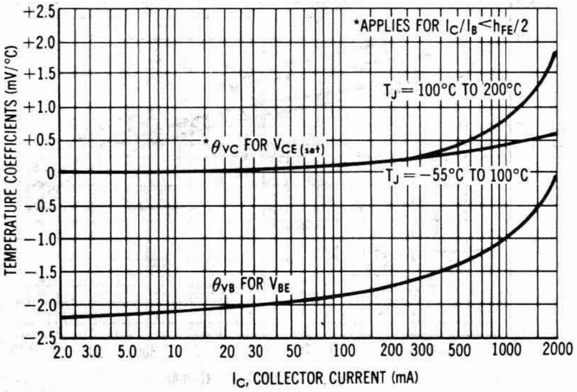


FIGURE 13 — TEMPERATURE COEFFICIENTS



2N4260 (SILICON)

2N4261

CASE 20
(TO-72)

PNP silicon annular transistors, designed for high-speed current-mode logic switching applications and for complementary circuitry with NPN types 2N3959 and 2N3960.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Collector Current - Continuous	I_C	30	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	200 1.14	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_E = 0)		BV_{CEO}	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	15	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	4.5	-	Vdc
Collector Cutoff Current (V_{CE} = 10 Vdc, $V_{BE(off)}$ = 2 Vdc)		I_{CEX}	-	0.005	μAdc
(V_{CE} = 10 Vdc, $V_{BE(off)}$ = 2 Vdc, T_A = 150°C)			-	5.0	
(V_{CE} = 10 Vdc, $V_{EB(on)}$ = 0.4 Vdc)			-	0.05	
Base Cutoff Current (V_{CE} = 10 Vdc, $V_{BE(off)}$ = 2 Vdc)		I_{BL}	-	0.005	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 1 mAdc, V_{CE} = 1 Vdc)	1	h_{FE}	25	-	-
(I_C = 10 mAdc, V_{CE} = 1 Vdc)			30	150	
(I_C = 30 mAdc, V_{CE} = 2 Vdc)			20	-	
Collector-Emitter Saturation Voltage (I_C = 1 mAdc, I_B = 0.1 Adc)	2, 3, 4	$V_{CE(sat)}$	-	0.15	Vdc
(I_C = 10 mAdc, I_B = 1 mAdc)			-	0.35	
Base-Emitter On Voltage (I_C = 1 mAdc, V_{CE} = 1 Vdc)	3, 4	$V_{BE(on)}$	-	0.8	Vdc
(I_C = 10 mAdc, V_{CE} = 1 Vdc)			-	1.0	
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 5 mAdc, V_{CE} = 4 Vdc, f = 100 MHz) 2N4260	5	f_T	1200	-	MHz
2N4261			1500	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N4260			1600	-	
2N4261			2000	-	
High-Frequency Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N4260		$\|h_{fe}\|$	16	-	-
2N4261			20	-	
Output Capacitance (V_{CB} = 4 Vdc, I_E = 0, f = 100 kHz)	8	C_{ob}	-	2.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	8	C_{ib}	-	2.5	pF
Collector-Base Time Constant (I_C = 5 mAdc, V_{CE} = 4 Vdc, f = 31.8 MHz) 2N4260	6	$r_b'C_c$	-	35	ps
2N4261			-	60	
(I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 31.8 MHz) 2N4260			-	30	
2N4261			-	50	

TYPICAL SWITCHING TIMES

			Typical Performance (v_{out} = 1 V)		
			@ 10 mA	@ 30 mA	
Turn-On Delay Time	Test Circuit Figure 7	$t_{on(delay)}$	1.0	1.2	ns
Rise Time		t_r	0.5	0.9	ns
Turn-Off Delay Time	Test Circuit Figure 7	$t_{off(delay)}$	1.0	1.2	ns
Fall-Time		t_f	1.0	1.2	ns

FIGURE 1 — DC CURRENT GAIN

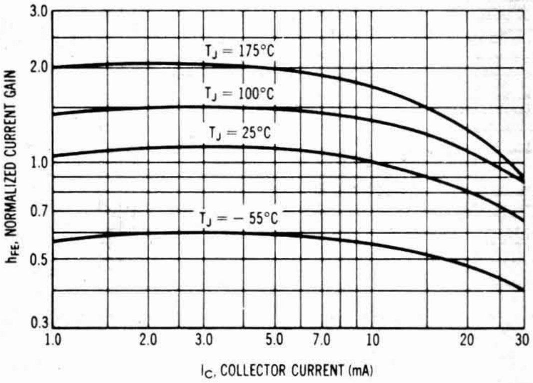
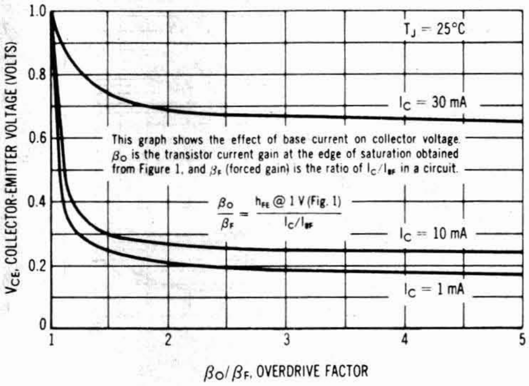


FIGURE 2 — COLLECTOR SATURATION REGION



This graph shows the effect of base current on collector voltage. β_O is the transistor current gain at the edge of saturation obtained from Figure 1, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit.

$$\frac{\beta_O}{\beta_F} = \frac{h_{FE} @ 1\text{ V (Fig. 1)}}{I_C/I_{BF}}$$

FIGURE 3 — "ON" VOLTAGES

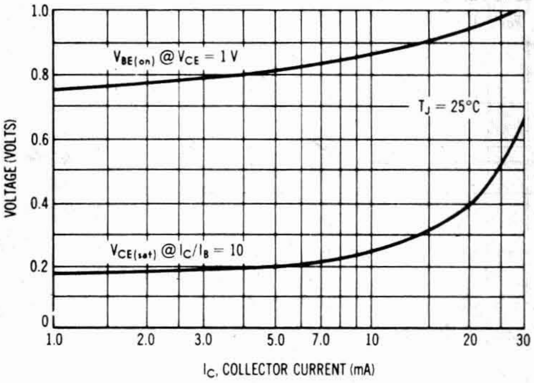


FIGURE 4 — TEMPERATURE COEFFICIENTS

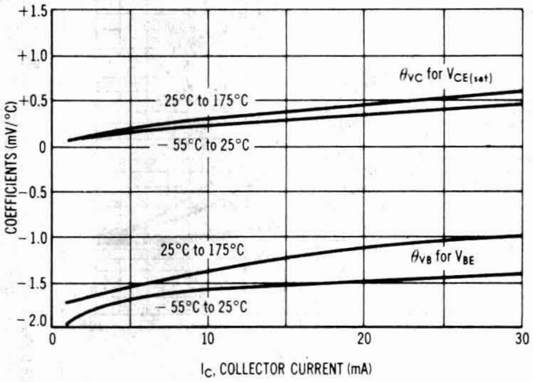


FIGURE 5 —
CURRENT-GAIN — BANDWIDTH PRODUCT

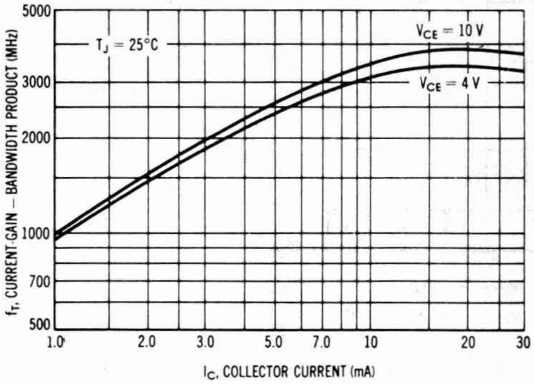


FIGURE 6 —
COLLECTOR-BASE TIME CONSTANT

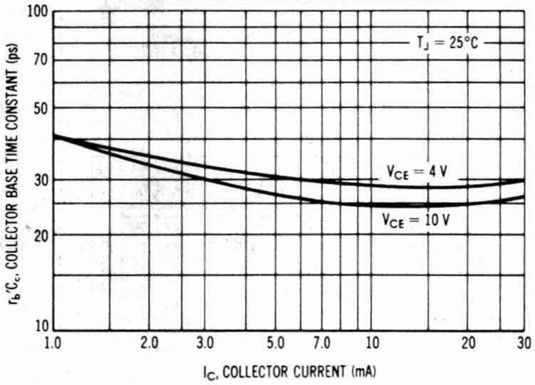
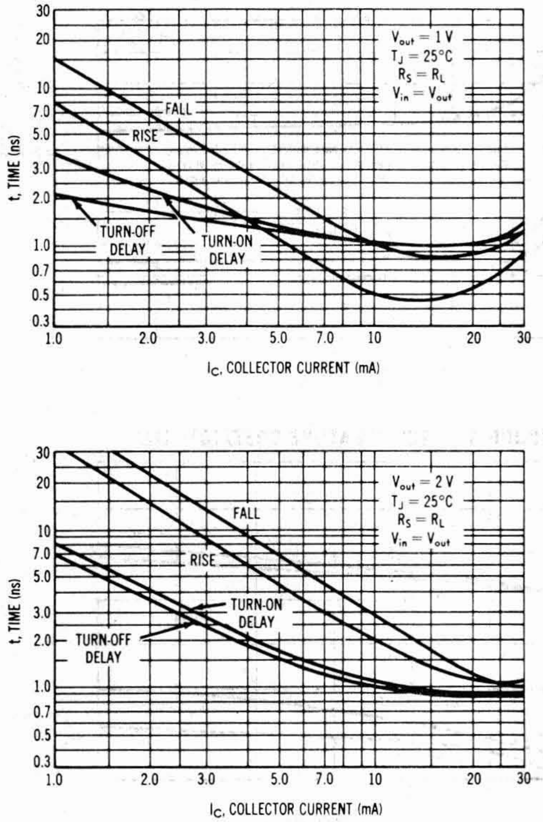
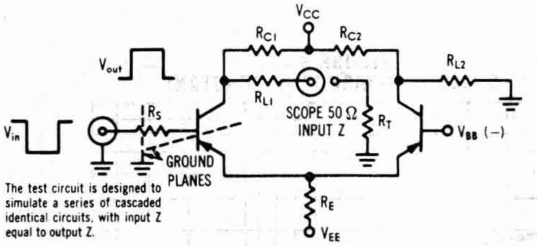


FIGURE 7 — SWITCHING TIMES




VCC
RC1
RC2
Vout
RL2
RL1
SCOPE 50 Ω INPUT Z
RT
Vin
RS
VBB (−)
GROUND PLANES
RE
VEE

The test circuit is designed to simulate a series of cascaded identical circuits, with input Z equal to output Z.

$V_{in} = V_{out} = 2\ V$ $V_{BB} = 1\ V$ $R_{C1} = R_{C2}$								$V_{in} = V_{out} = 1\ V$ $V_{BB} = 0.5\ V$ $R_{C1} = R_{C2}$						
I_C mA	R_S ohms	R_C ohms	R_{L1} ohms	R_{L2} ohms	R_E ohms	V_{EE} volts	V_{CC} volts	R_S ohms	R_C ohms	R_{L1} ohms	R_{L2} ohms	R_E ohms	V_{EE} volts	V_{CC} volts
1	2 k	6 k	3 k	3 k	10 k	10	16	1 k	6 k	1.2 k	1.2 k	24 k	24	32
5	360	3.56 k	400	450	2 k	10	47	175	1 k	200	250	3 k	15	27
10	160	1 k	200	250	3 k	30	26.3	75	300	100	150	3 k	30	17
20	62	300	100	150	1 k	20	16	25	150	25	75	1 k	20	11
30	28	157	66	116	1 k	30	13	8	77	0	50	1 k	30	9

FIGURE 8 — CAPACITANCE

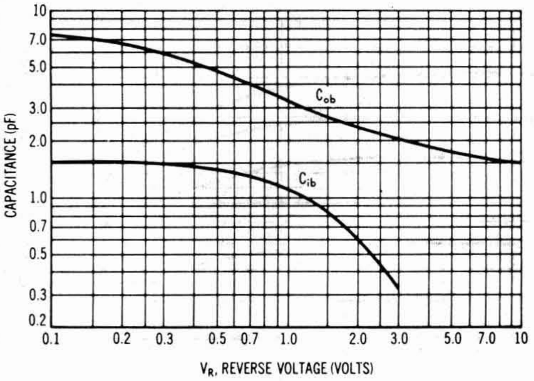
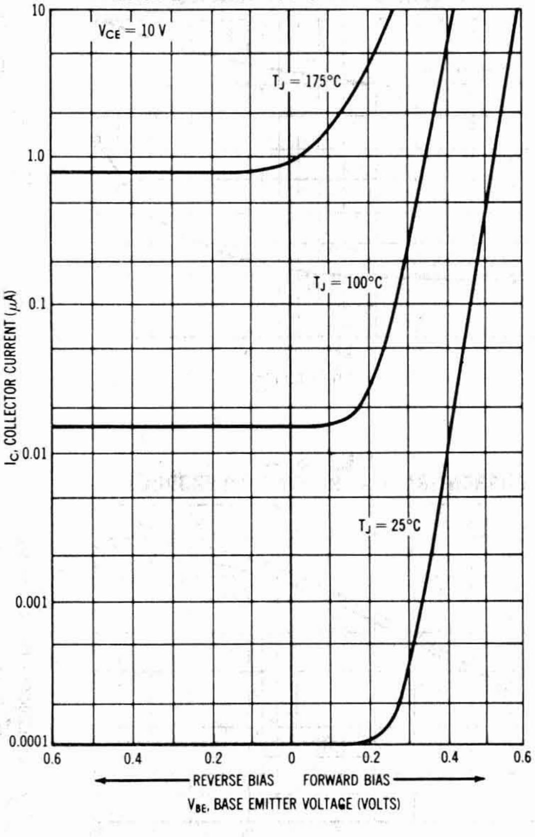


FIGURE 9 — CUT-OFF CHARACTERISTICS



2N4264 (SILICON)
2N4265

CASE 29(1)
(TO-92)

NPN silicon annular transistors, designed for low-level, saturated logic applications featuring one-piece, injection-molded plastic package for high reliability.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

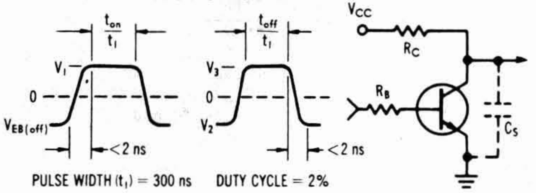
Rating	Symbol	2N4264	2N4265	Unit
Collector-Emitter Voltage	V_{CEO}	15	12	Vdc
Collector-Base Voltage	V_{CB}	30		Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current	I_C	200		mAdc
Total Device Dissipation @ $T_A = 60°C$	P_D	210		mW
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

FIGURE 1 — SWITCHING TIME EQUIVALENT TEST CIRCUIT

TEST CONDITION	I_C	V_{CC}	R_B	R_C	$C_{S(max)}$	$V_{EB(off)}$	V_1	V_2	V_3
	mA	V	Ω	Ω	pF	V	V	V	V
A	10	3	3300	270	4	−1.5	10.55	−4.15	10.70
B	10	10	560	960	4	—	—	−4.65	6.55
C	100	10	560	96	12	−2.0	6.35	−4.65	6.55



PULSE WIDTH (t_1) = 300 ns DUTY CYCLE = 2%

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_E = 0) 2N4264 2N4265		BV_{CEO}	15 12	— —	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	30	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	6.0	—	Vdc
Collector Cutoff Current (V_{CE} = 12 Vdc, $V_{EB(off)}$ = 0.25 Vdc)		I_{CEX}	—	100	nAdc
Base Cutoff Current (V_{CE} = 12 Vdc, $V_{EB(off)}$ = 0.25 Vdc) (V_{CE} = 12 Vdc, $V_{EB(off)}$ = 0.25 Vdc, T_A = 100°C)		I_{BL}	— —	0.1 10	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 1 mAdc, V_{CE} = 1 Vdc) 2N4264 2N4265 (I_C = 10 mAdc, V_{CE} = 1 Vdc) 2N4264 2N4265 (I_C = 10 mAdc, V_{CE} = 1 Vdc, T_A = -55°C) 2N4264 2N4265 (I_C = 30 mAdc, V_{CE} = 1 Vdc) 2N4264 2N4265 (I_C = 100 mAdc, V_{CE} = 1 Vdc) 2N4264 2N4265 (I_C = 200 mAdc, V_{CE} = 1 Vdc) 2N4264 2N4265	2	h_{FE}	25 50 40 100 20 45 40 90 30 55 20 35	— — 160 400 — — — — — — — —	—
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	5, 6, 7	$V_{CE(sat)}$	— —	0.22 0.35	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	6, 7	$V_{BE(sat)}$	0.65 0.75	0.80 0.95	Vdc
SMALL SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	300	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz)	12	C_{ob}	—	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	12	C_{ib}	—	8.0	pF

SWITCHING CHARACTERISTICS

Turn-On Time	Figure 1, Test Condition A V_{CC} = 3 Vdc, $V_{EB(off)}$ = 1.5 Vdc, I_C = 10 mAdc, I_{B1} = 3 mAdc	1	t_{on}	—	25	ns
Turn-Off Time	Figure 1, Test Condition A V_{CC} = 3 Vdc, I_C = 10 mAdc, I_{B1} = 3 mAdc, I_{B2} = 1.5 mAdc	1	t_{off}	—	35	ns
Storage Time	Figure 1, Test Condition B V_{CC} = 10 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc	1	t_s	—	20	ns
Delay Time	Figure 1, Test Condition C V_{CC} = 10 Vdc, $V_{EB(off)}$ = 2 Vdc, I_C = 100 mAdc, I_{B1} = 10 mAdc	1, 8	t_d	—	8.0	ns
Rise Time		1, 9	t_r	—	15	ns
Storage Time	Figure 1, Test Condition C V_{CC} = 10 Vdc, I_C = 100 mAdc, I_{B1} = I_{B2} = 10 mAdc	1, 10	t_s	—	20	ns
Fall Time		1, 11	t_f	—	15	ns
Total Control Charge	V_{CC} = 3 Vdc, I_C = 10 mAdc, I_B = mAdc	3, 13	Q_T	—	80	pC

CURRENT GAIN CHARACTERISTICS

FIGURE 2 — MINIMUM CURRENT GAIN

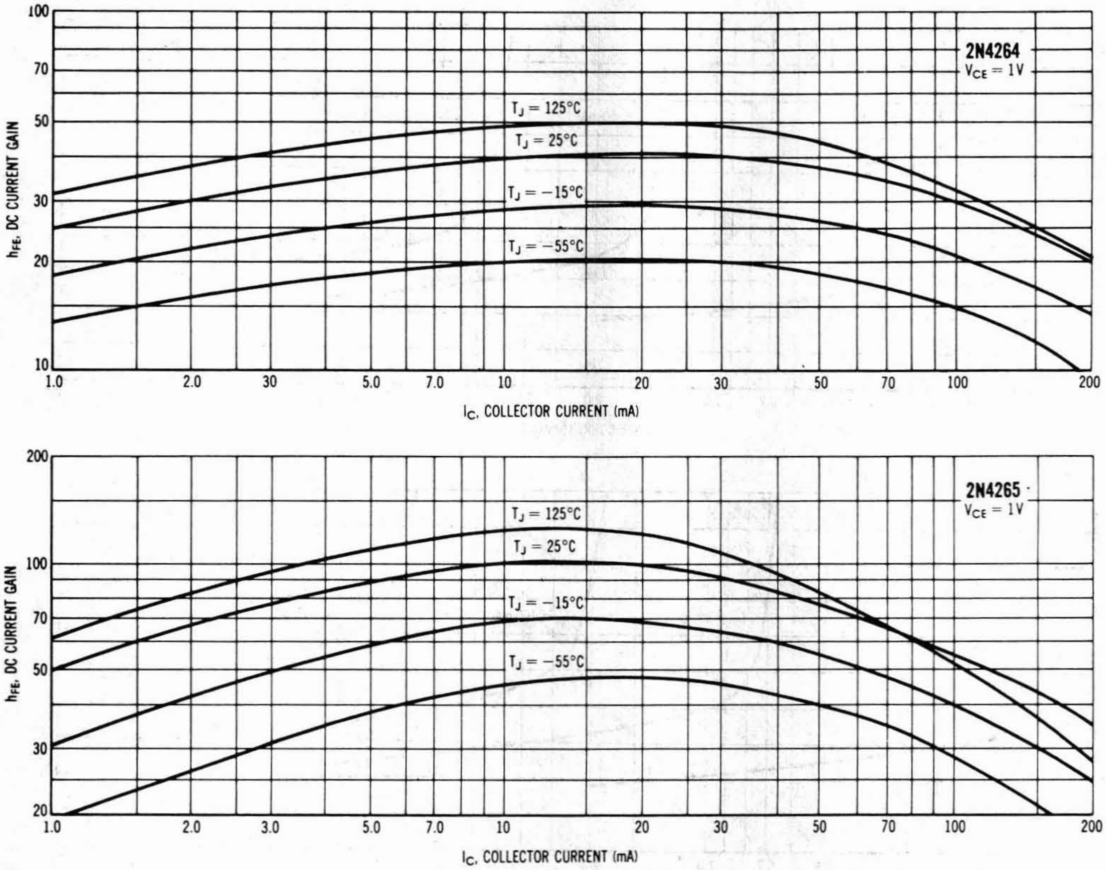
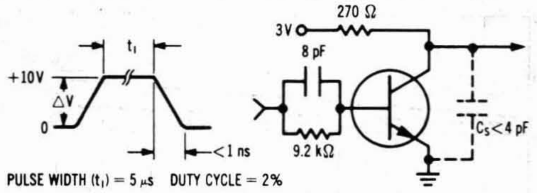
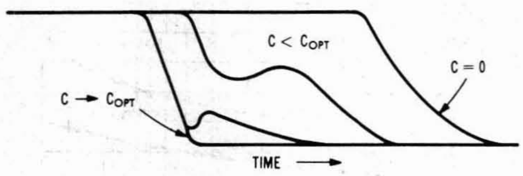


FIGURE 3 — Q_T TEST CIRCUIT



PULSE WIDTH $(t_1) = 5\ \mu s$ DUTY CYCLE = 2%

FIGURE 4 — TURN-OFF WAVEFORM



NOTE 1

When a transistor is held in a conductive state by a base current, I_B, a charge, Q_S, is developed or "stored" in the transistor. Q_S may be written: $Q_S = Q_I + Q_V + Q_X$.

Q_I is the charge required to develop the required collector current. This charge is primarily a function of alpha cutoff frequency. Q_V is the charge required to charge the collector-base feedback capacity. Q_X is excess charge resuiting from overdrive, i.e., operation in saturation.

The charge required to turn a transistor "on" to the edge of saturation is the sum of Q_I and Q_V which is defined as the active region charge, Q_A. $Q_A = I_{B1}t_r$ when the transistor is driven by a constant current step (I_{B1}) and $I_{B1} << \frac{I_C}{h_{FE}}$.

If I_B were suddenly removed, the transistor would continue to conduct until Q_S is removed from the active regions through an external path or through internal recombination. Since the internal recombination time is long compared to the ultimate capability of a transistor, a charge, Q_T, of opposite polarity, equal in magnitude, can be stored on an external capacitor, C, to neutralize the internal charge and considerably reduce the turn-off time of the transistor. Figure 3 shows the test circuit and Figure 4 the turn-off waveform. Given Q_T from Figure 13, the external C for worst-case turn-off in any circuit is: $C = Q_T/\triangle V$, where $\triangle V$ is defined in Figure 3.

"ON" CONDITION CHARACTERISTICS

FIGURE 5 — COLLECTOR SATURATION REGION

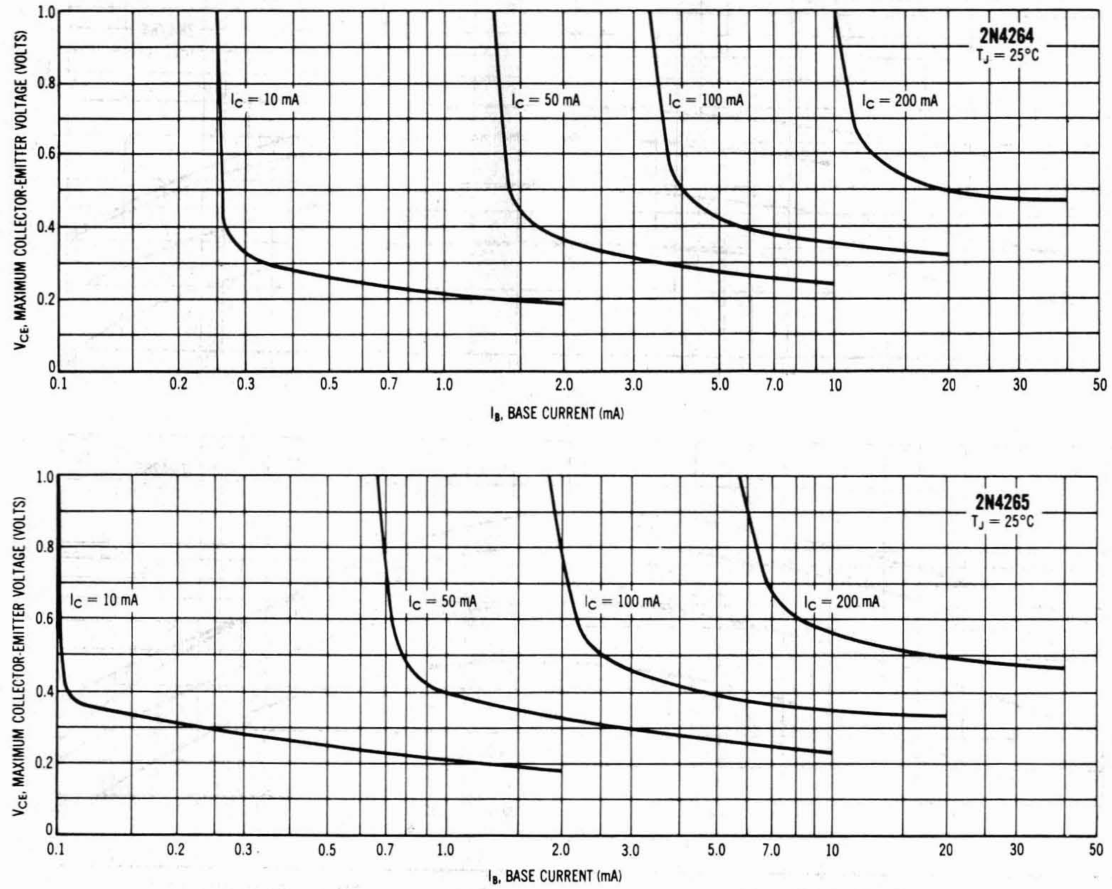


FIGURE 6 — SATURATION VOLTAGE LIMITS

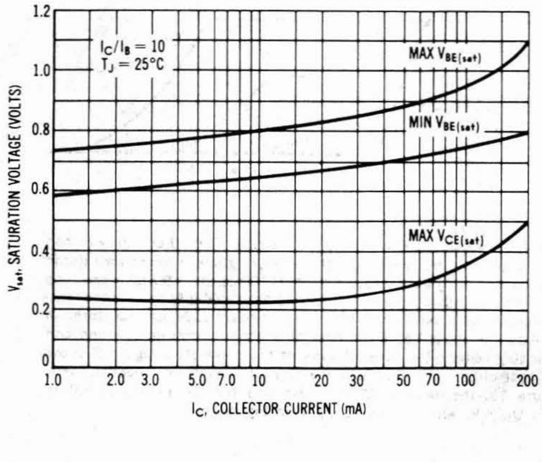
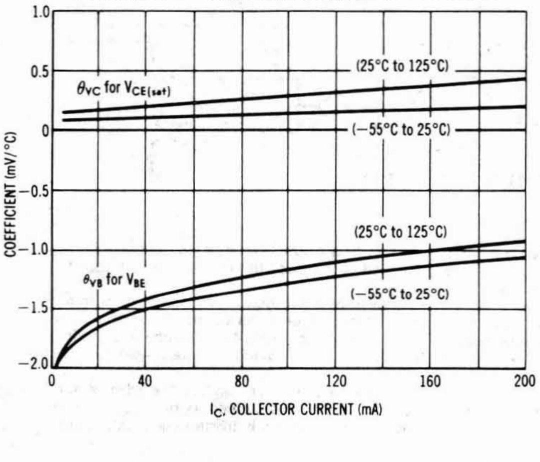


FIGURE 7 — TEMPERATURE COEFFICIENTS



DYNAMIC CHARACTERISTICS

FIGURE 8 — DELAY TIME

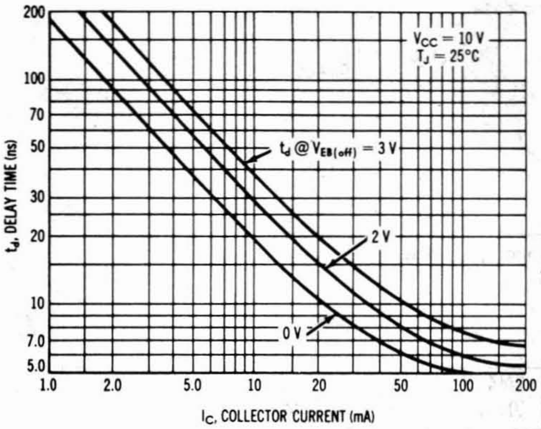


FIGURE 9 — RISE TIME

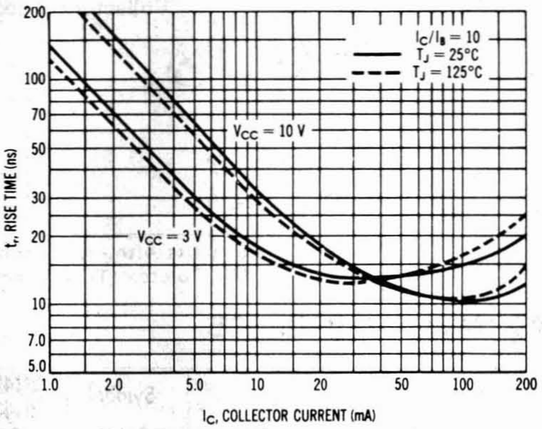


FIGURE 10 — STORAGE TIME

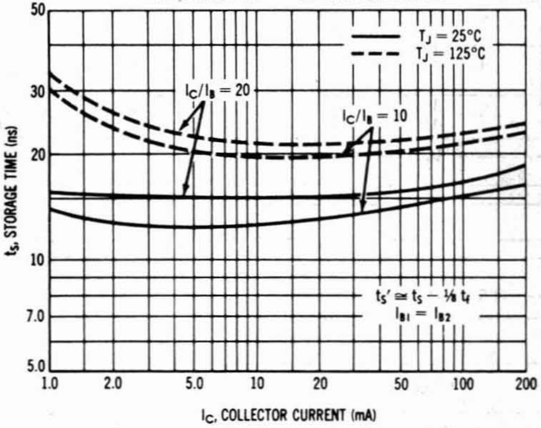


FIGURE 11 — FALL TIME

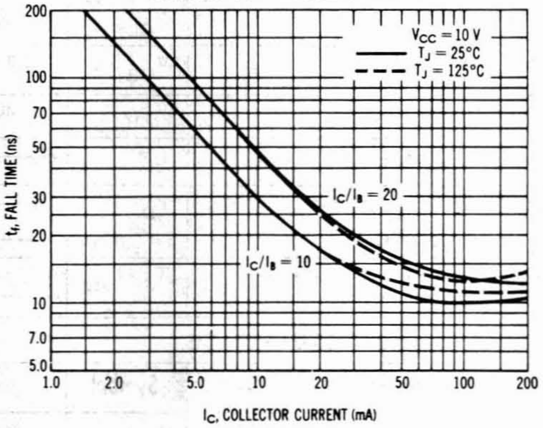


FIGURE 12 — JUNCTION CAPACITANCE

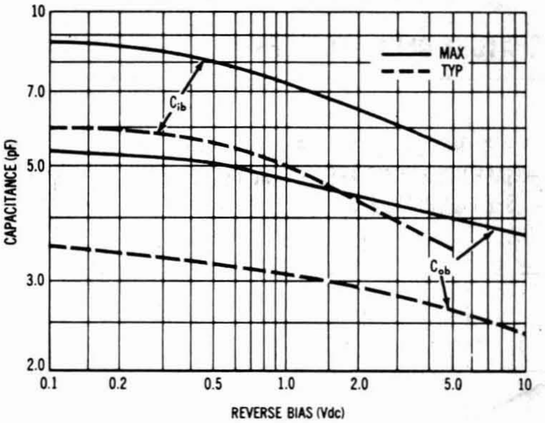
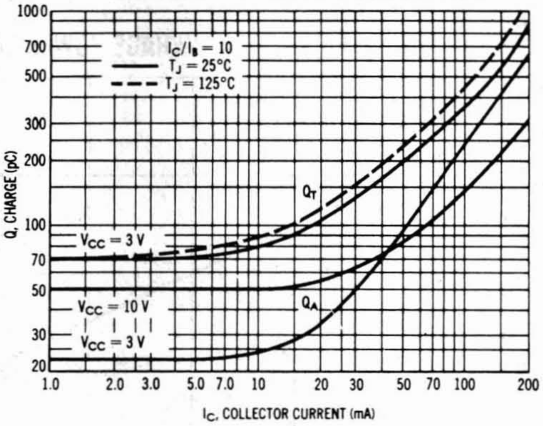


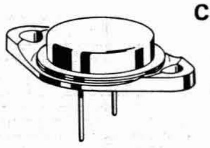
FIGURE 13 — MAXIMUM CHARGE DATA



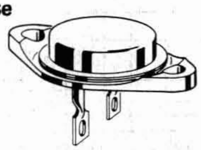
2N4276 (GERMANIUM)
thru
2N4283

PNP germanium power transistors designed for high current applications requiring high-gain and low saturation voltages.

Collector connected to case



CASE 3A
(TO-3 modified)



CASE 161
(TO-41)

For units with lugs attached, specify devices MP4276 etc. (TO-41 package)

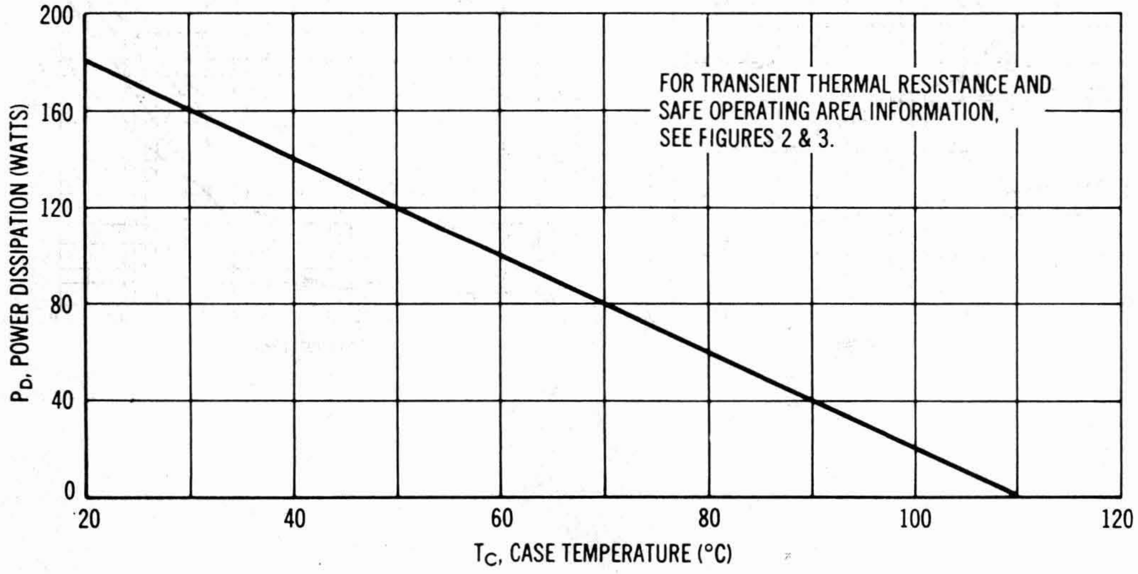
MAXIMUM RATINGS

Rating	Symbol	2N4276 2N4277	2N4278 2N4279	2N4280 2N4281	2N4282 2N4283	Unit
Collector-Emitter Voltage	V_{CEO}	20	30	45	60	Vdc
Collector-Emitter Voltage	V_{CES}	30	45	60	75	Vdc
Collector-Base Voltage	V_{CB}	30	45	60	75	Vdc
Emitter-Base Voltage	V_{EB}	20	25	30	40	Vdc
Collector Current – Continuous *	I_C*	← 60 →				Adc
Total Device Dissipation @ T_C = 25°C	P_D	← 170 →				Watts
Derate above 25°C		← 2.0 →				W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +110 →				°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.5	°C/W

FIGURE 1 — AVERAGE POWER-TEMPERATURE DERATING CURVE



FOR TRANSIENT THERMAL RESISTANCE AND SAFE OPERATING AREA INFORMATION, SEE FIGURES 2 & 3.

*JEDEC Registered Values, For True Capability See Figure 3.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage† (I_C = 1.0 Adc, I_B = 0) 2N4276, 2N4277	BV_{CEO}†	20	-	Vdc
2N4278, 2N4279		30	-	
2N4280, 2N4281		45	-	
2N4282, 2N4283		60	-	
Collector-Emitter Breakdown Voltage (I_C = 300 mAdc, V_{BE} = 0) 2N4276, 2N4277	BV_{CES}	30	-	Vdc
2N4278, 2N4279		45	-	
2N4280, 2N4281		60	-	
2N4282, 2N4283		75	-	
Floating Potential (V_{CB} = 30 Vdc, I_E = 0) 2N4276, 2N4277	V_{EBF}	-	0.5	Vdc
(V_{CB} = 45 Vdc, I_E = 0) 2N4278, 2N4279		-	0.5	
(V_{CB} = 60 Vdc, I_E = 0) 2N4280, 2N4281		-	0.5	
(V_{CB} = 75 Vdc, I_E = 0) 2N4282, 2N4283		-	0.5	
Collector Cutoff Current (V_{CE} = 20 Vdc, $V_{BE(off)}$ = 2.0 Vdc, T_C = +71°C) 2N4276, 2N4277	I_{CEX}	-	15	mAdc
(V_{CE} = 30 Vdc, $V_{BE(off)}$ = 2.0 Vdc, T_C = +71°C) 2N4278, 2N4279		-	15	
(V_{CE} = 45 Vdc, $V_{BE(off)}$ = 2.0 Vdc, T_C = +71°C) 2N4280, 2N4281		-	15	
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 2.0 Vdc, T_C = +71°C) 2N4282, 2N4283		-	15	
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)	I_{CBO}	-	0.2	mAdc
(V_{CB} = 30 Vdc, I_E = 0) 2N4276, 2N4277		-	4.0	
(V_{CB} = 45 Vdc, I_E = 0) 2N4278, 2N4279		-	4.0	
(V_{CB} = 60 Vdc, I_E = 0) 2N4280, 2N4281		-	4.0	
(V_{CB} = 75 Vdc, I_E = 0) 2N4282, 2N4283		-	4.0	
Emitter Cutoff Current (V_{BE} = 20 Vdc, I_C = 0) 2N4276, 2N4277	I_{EBO}	-	4.0	mAdc
(V_{BE} = 20 Vdc, I_C = 0, T_C = +71°C)		-	15	
(V_{BE} = 25 Vdc, I_C = 0) 2N4278, 2N4279		-	4.0	
(V_{BE} = 25 Vdc, I_C = 0, T_C = +71°C)		-	15	
(V_{BE} = 30 Vdc, I_C = 0) 2N4280, 2N4281		-	4.0	
(V_{BE} = 30 Vdc, I_C = 0, T_C = +71°C)		-	15	
(V_{BE} = 40 Vdc, I_C = 0) 2N4282, 2N4283		-	4.0	
(V_{BE} = 40 Vdc, I_C = 0, T_C = +71°C)		-	15	
ON CHARACTERISTICS				
DC Current Gain† (I_C = 15 Adc, V_{CE} = 2.0 Vdc) 2N4276, 2N4278, 2N4280, 2N4282	h_{FE}†	60	120	-
2N4277, 2N4279, 2N4281, 2N4283		80	180	
(I_C = 60 Adc, V_{CE} = 2.0 Vdc)		15	-	
Collector-Emitter Saturation Voltage† (I_C = 15 Adc, I_B = 1.0 Adc)	$V_{CE(sat)}$†	-	0.15	Vdc
(I_C = 60 Adc, I_B = 6.0 Adc)		-	0.3	
Base-Emitter Saturation Voltage† (I_C = 15 Adc, I_B = 1.0 Adc)	$V_{BE(sat)}$†	-	0.6	Vdc
(I_C = 60 Adc, I_B = 6.0 Adc)		-	1.0	
SMALL SIGNAL CHARACTERISTICS				
Common-Emitter Cutoff Frequency (I_C = 15 Adc, V_{CE} = 2.0 Vdc)	$f_{\alpha e}$	2.0	-	kHz

† To avoid excessive heating of the collector junction, perform test with pulse method.

FIGURE 2 — TRANSIENT THERMAL RESISTANCE

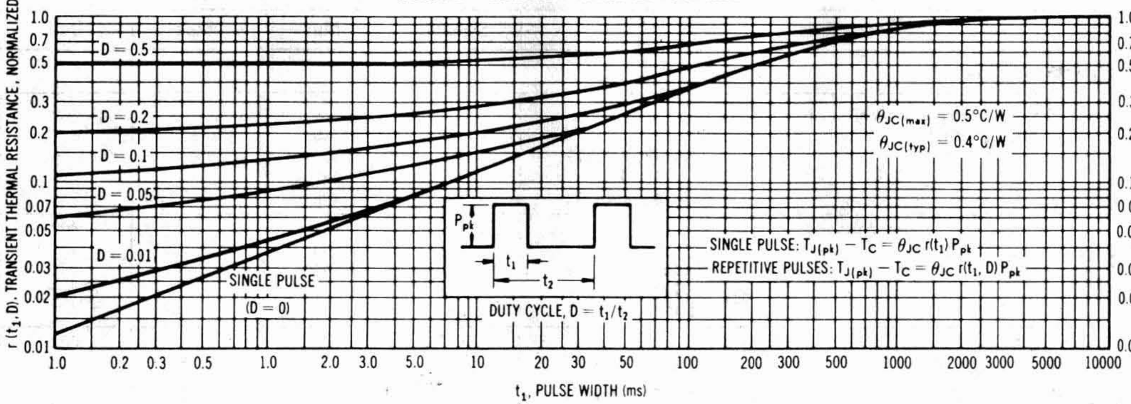
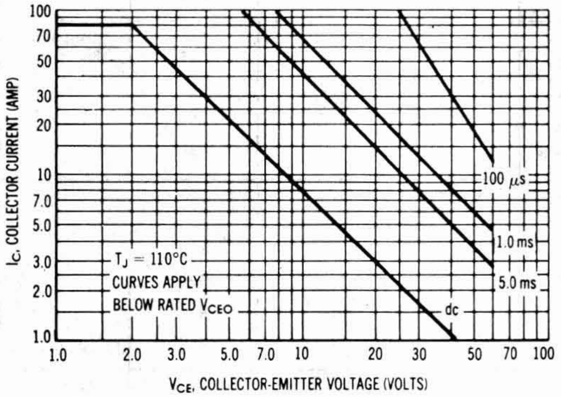


FIGURE 3 — ACTIVE REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e. the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 3 is based on $T_{J(pk)} = 110°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 110°C$. $T_{J(pk)}$ may be calculated from the data in Figure 2. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 4 — SWITCHING TEST CIRCUIT

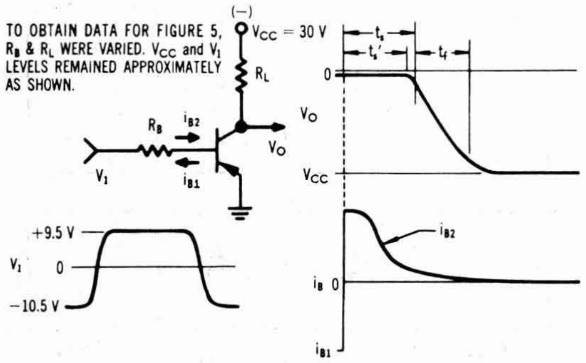
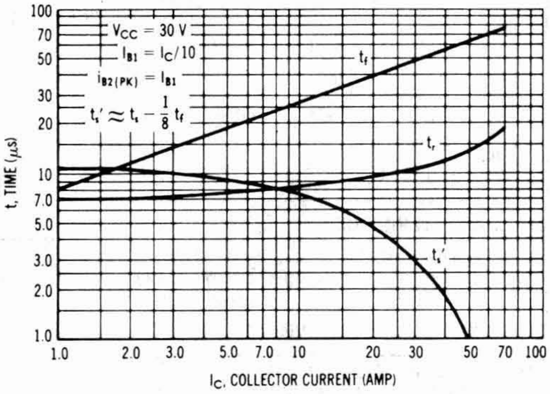

TO OBTAIN DATA FOR FIGURE 5, R_B & R_L WERE VARIED. V_{CC} and V_1 LEVELS REMAINED APPROXIMATELY AS SHOWN.

FIGURE 5 — SWITCHING TIMES



The switching performance of this transistor is determined primarily by the gain-bandwidth product, f_T*, and the behavior of the base-spreading resistance, r_B'.

In the case of rise time, the base-spreading resistance plays a small part, and the test circuit delivers a constant current step of turn-on current to the transistor (I_{B1}). Therefore, the curve of t_r on Figure 5 follows theory closely, i.e.:

$$t_r \approx 0.8 \frac{I_C}{I_{B1}} \cdot \frac{1}{2\pi f_T}$$

From the curve, it can be seen that f_T is roughly constant with current; using the equation, its large signal value can be calculated to be approximately 120 kHz at the 20-Amp level. A lower supply voltage will increase rise time slightly.

Turn-off time is slow because of conductivity modulation which occurs in the base region. When the transistor is held "on" in saturation, the base region becomes filled with excess charge; i.e., charge in excess of that necessary to sustain the circuit limited value of I_C. As a result, the base resistivity and consequently r_B' become very low. During turn off, as the excess charge is reduced, the accompanying increase in resistivity causes a marked reduction in the turn-off current, i_{B2}, as can be seen from the waveforms of Figure 4. During fall time, the i_{B2} current is very low causing an extended fall time.

Only a slight improvement in turn-off performance is achieved with a "speed-up" capacitor placed across R_B. This unusual behavior occurs because r_B' limits the amount of reverse current which can be achieved. Also, it seems evident that r_B' increases with applied reverse current, so that efforts to speed up the turn-off behavior are somewhat futile.

In most applications, switching time will be close to the values shown on Figure 5. Delay time is not shown as it is negligible in comparison to the other times.

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* $f_T \approx f_{\alpha e} \times h_{fe}$

TYPICAL DC CHARACTERISTICS

FIGURE 6 — DC CURRENT GAIN

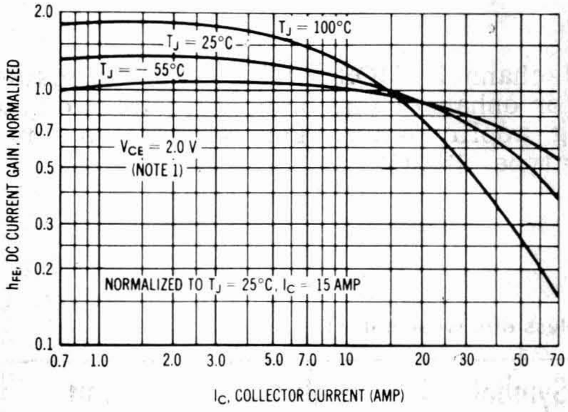


FIGURE 7 — COLLECTOR SATURATION REGION

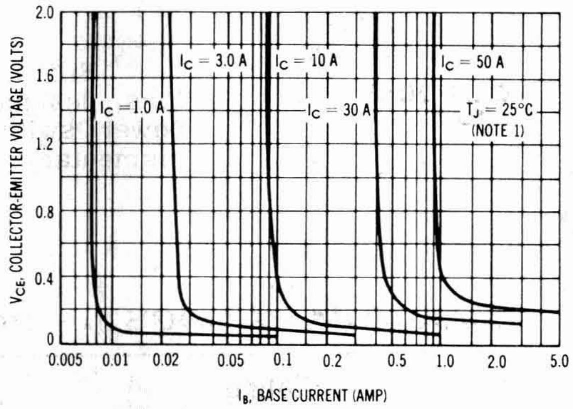


FIGURE 8 — EFFECTS OF BASE-EMITTER RESISTANCE

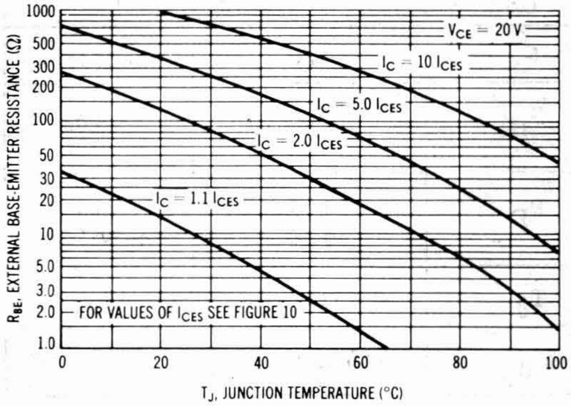


FIGURE 9 — "ON" VOLTAGES

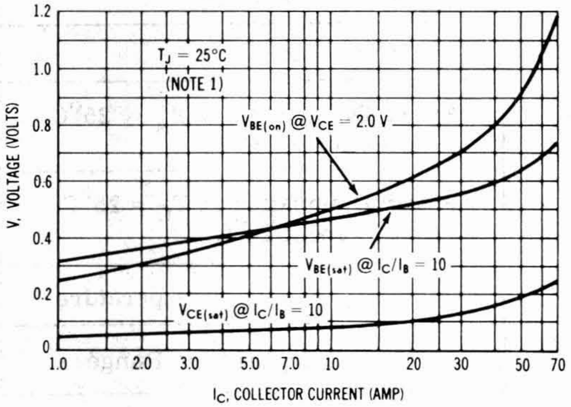
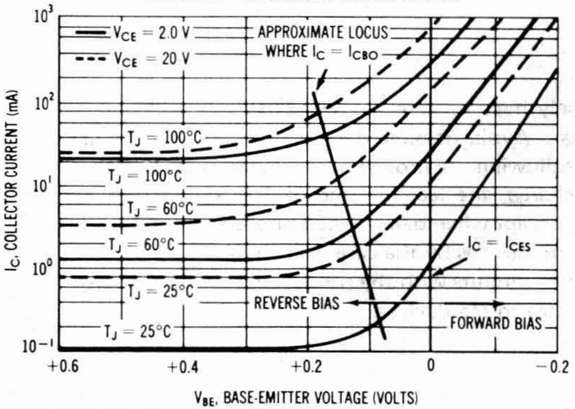
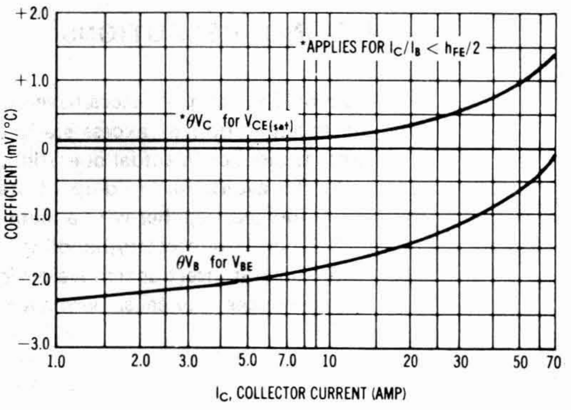


FIGURE 10 — COLLECTOR CUTOFF REGION



NOTE 1: Data is obtained from pulse tests and adjusted to nullify the effect of I$_{CBO}$.

FIGURE 11 — TEMPERATURE COEFFICIENTS



2N4351 (SILICON)

CASE 20(2)
(TO-72)

Silicon N-channel MOS field effect transistors, designed for enhancement-mode operation in low power switching applications. The 2N4351 is complementary with type 2N4352 .

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	25	Vdc
Gate-Source Voltage	V_{GS}	± 30	Vdc
Drain Current	I_D	30	mAdc
Power Dissipation at T_A = 25°C Derate above 25°C	P_D	300 1.7	mW mW/°C
Power Dissipation at T_C = 25°C Derate about 25°C	P_D	800 4.56	mW mW/°C
Operating Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Substrate connected to source.

Characteristic	Figure No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Drain-Source Breakdown Voltage (I_D = 10 μA, V_{GS} = 0)	—	$V_{(BR)DSS}$	25	—	Vdc
Gate Leakage Current (V_{GS} = ±15 Vdc, V_{DS} = 0)	—	I_{GSS}	—	10	pAdc
Zero-Gate-Voltage Drain Current (V_{DS} = 10 V, V_{GS} = 0)	—	I_{DSS}	—	10	nAdc
ON CHARACTERISTICS					
Gate-Source Threshold Voltage (V_{DS} = 10 V, I_D = 10 μA)	—	$V_{GS(TH)}$	1.0	5	Vdc
"ON" Drain Current (V_{GS} = 10 V, V_{DS} = 10 V)	3	$I_{D(on)}$	3	—	mAdc
Drain-Source "ON" Voltage (I_D = 2 mA, V_{GS} = 10 V)	—	$V_{DS(on)}$	—	1.0	Vdc
SMALL SIGNAL CHARACTERISTICS					
Drain-Source Resistance (V_{GS} = 10 V, I_D = 0, f = 1 kHz)	4	$r_{ds(on)}$	—	300	ohms
Forward Transfer Admittance (V_{DS} = 10 V, I_D = 2 mA, f = 1 kHz)	1	$\|y_{fs}\|$	1000	—	μmho
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 0, f = 140 kHz)	2	C_{rss}	—	1.3	pF
Input Capacitance (V_{DS} = 10 V, V_{GS} = 0, f = 140 kHz)	2	C_{iss}	—	5.0	pF
Drain-Substrate Capacitance ($V_{D(SUB)}$ = 10 V, f = 140 kHz)	—	$C_{d(sub)}$	—	5.0	pF

SWITCHING CHARACTERISTICS

Turn-On Delay	I_D = 2.0 mAdc, V_{DS} = 10 Vdc, V_{GS} = 10 Vdc (See Figure 10; Times Circuit Determined)	6, 10	t_{d1}	—	45	ns
Rise Time		7, 10	t_r	—	65	ns
Turn-Off Delay		8, 10	t_{d2}	—	60	ns
Fall Time		9, 10	t_f	—	100	ns

FIGURE 1 — FORWARD TRANSFER ADMITTANCE

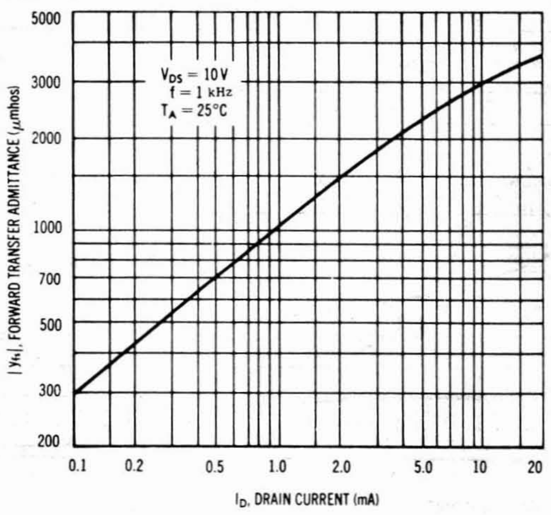


FIGURE 2 — CAPACITANCE

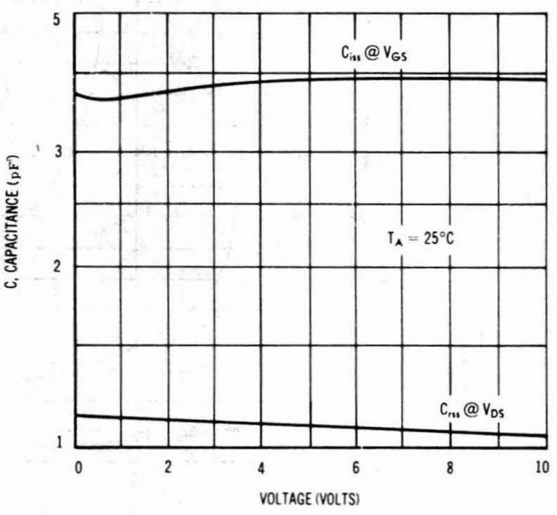


FIGURE 3 — TRANSFER CHARACTERISTICS

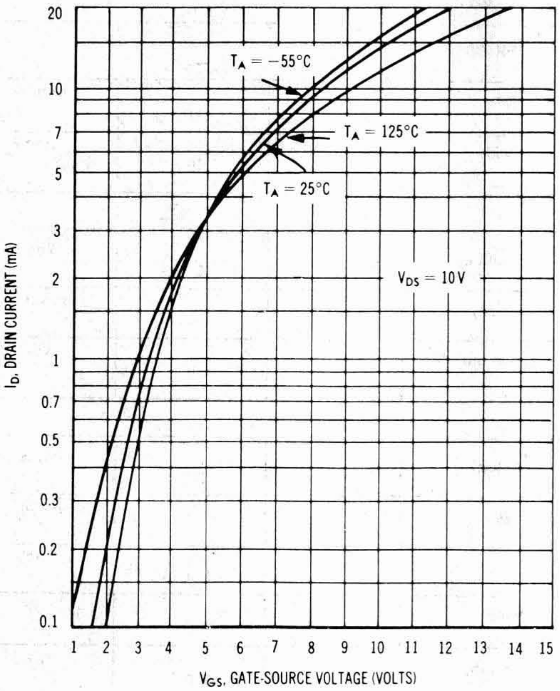


FIGURE 4 — DRAIN SOURCE "ON" RESISTANCE

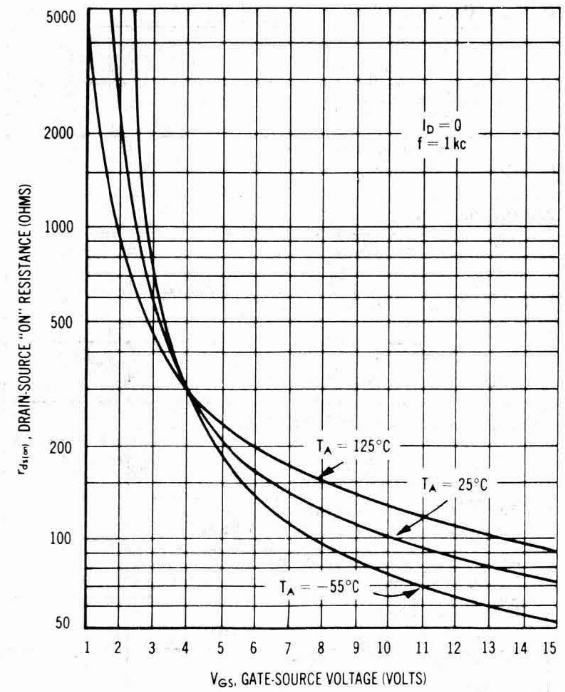
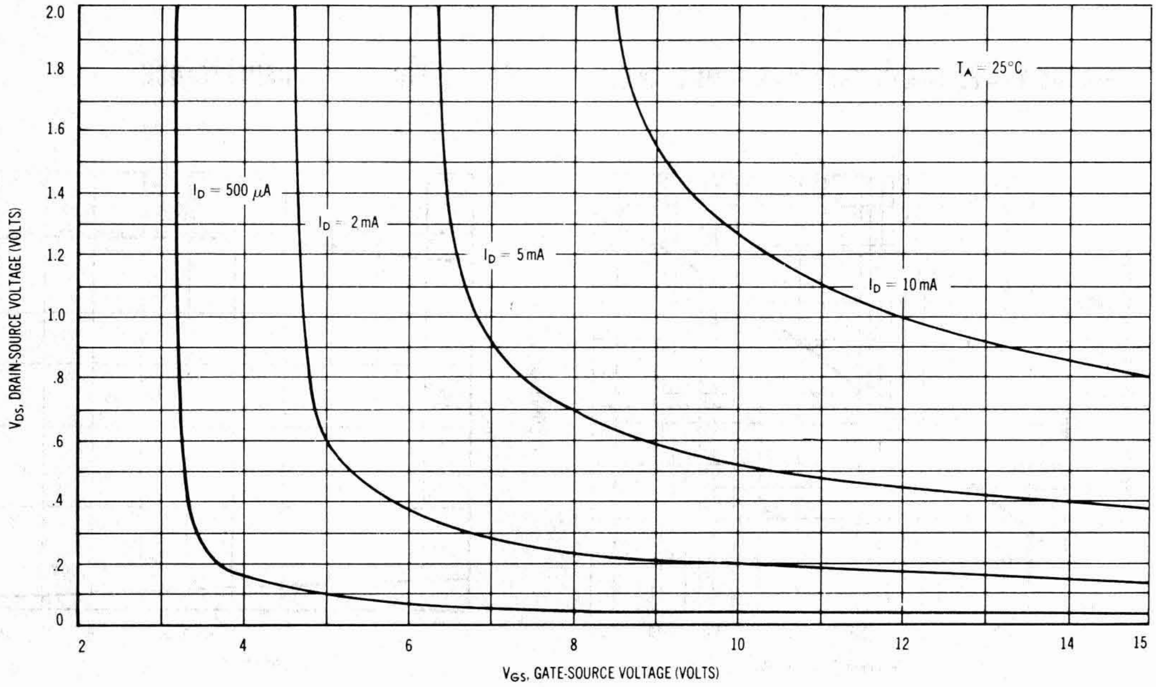


FIGURE 5 — "ON" DRAIN-SOURCE VOLTAGE



SWITCHING CHARACTERISTICS

($T_A = 25°C$)

FIGURE 6 — TURN-ON DELAY TIME

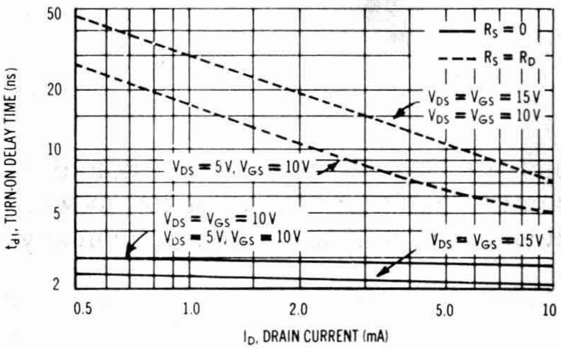


FIGURE 7 — RISE TIME

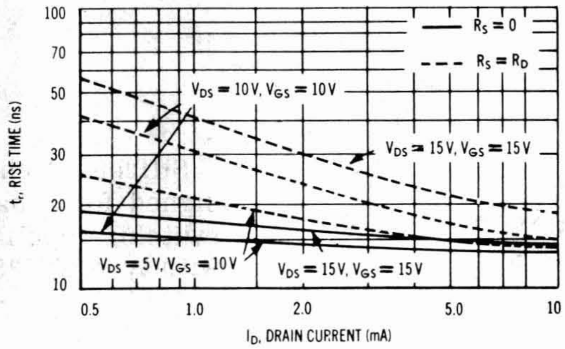


FIGURE 8 — TURN-OFF DELAY TIME

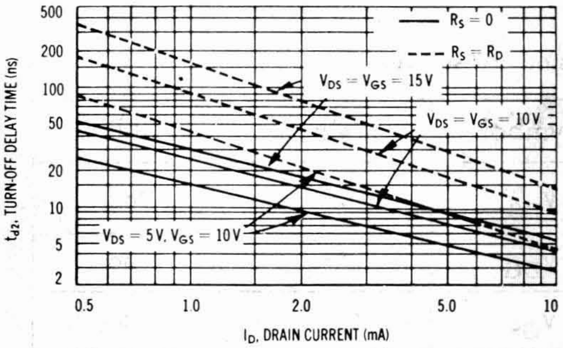


FIGURE 9 — FALL TIME

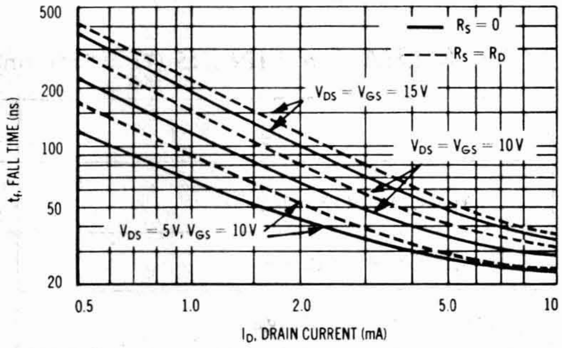
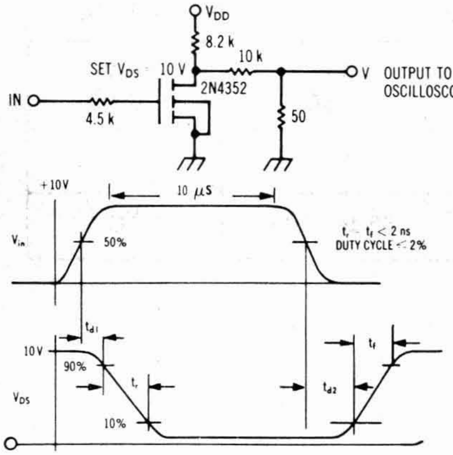


FIGURE 10 — SWITCHING CIRCUIT and WAVEFORMS



The switching characteristics shown above were measured in a test circuit similar to Figure 10. At the beginning of the switching interval, the gate voltage is at ground and the gate-source capacitance ($C_{gs} = C_{iss} - C_{rss}$) has no charge. The drain voltage is at V_{DD}, and thus the feedback capacitance (C_{rss}) is charged to V_{DD}. Similarly, the drain-substrate capacitance ($C_{d(sub)}$) is charged to V_{DD} since the substrate and source are connected to ground.

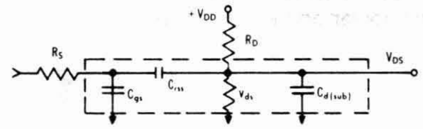
During the turn-on interval, C_{gs} is charged to V_{GS} (the input voltage) through R_S (generator impedance) (Figure 11). C_{rss} must be discharged to $V_{GS} - V_{D(on)}$ through R_S and the parallel combination of the load resistor (R_D) and the channel resistance (r_{ds}). In addition, $C_{d(sub)}$ is discharged to a low value ($V_{D(on)}$) through R_D in parallel with r_{ds}. During turn-off this charge flow is reversed.

Predicting turn-on time proves to be somewhat difficult since the channel resistance (r_{ds}) is a function of the gate-source voltage (V_{GS}). As C_{gs} becomes charged V_{GS} is approaching V_{in} and r_{ds} decreases (see Figure 4) and since C_{rss} and $C_{d(sub)}$ are charged through r_{ds}, turn-on time is quite non-linear.

If the charging time of C_{gs} is short compared to that of C_{rss} and $C_{d(sub)}$, then r_{ds} (which is in parallel with R_D) will be low compared to R_D during the switching interval and will largely determine the turn-on time. On the other hand, during turn-off r_{ds} will be almost an open circuit requiring C_{rss} and $C_{d(sub)}$ to be charged through R_D and resulting in a turn-off time that is long compared to the turn-on time. This is especially noticeable for the curves where $R_S = 0$ and C_{gs} is charged through the pulse generator impedance only.

The switching curves shown with $R_S = R_D$ simulate the switching behavior of cascaded stages where the driving source impedance is normally the same as the load impedance. The set of curves with $R_S = 0$ simulates a low source impedance drive such as might occur in complementary logic circuits.

FIGURE 11 — SWITCHING CIRCUIT with MOSFET EQUIVALENT MODEL



2N4352 (SILICON)

CASE 20 (2)
(TO-72)

Silicon P-channel MOS field-effect transistor designed for enhancement-mode operation in low-power switching applications. The 2N4352 is complementary with type 2N4351.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	25	Vdc
Gate-Source Voltage	V_{GS}	± 30	Vdc
Drain Current	I_D	30	mAdc
Power Dissipation at $T_A = 25^oC$ Derate above 25^oC	P_D	300 1.7	mW mW/^oC
Power Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	800 4.56	mW mW/^oC
Operating Junction Temperature	T_J	175	^oC
Storage Temperature Range	T_{stg}	-65 to + 175	^oC

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Substrate connected to source.

OFF CHARACTERISTICS

Characteristic	Figure No.	Symbol	Min	Max	Unit
Drain-Source Breakdown Voltage (I_D = -10 μA, V_{GS} = 0)	—	$V_{(BR)DSS}$	25	—	Vdc
Gate Leakage Current (V_{GS} = ±15 V, V_{DS} = 0)	—	I_{GSS}	—	10	pAdc
Zero-Gate Voltage Drain Current (V_{DS} = -10 V, V_{GS} = 0)	—	I_{DSS}	—	10	nAdc

ON CHARACTERISTICS

Characteristic	Figure No.	Symbol	Min	Max	Unit
Gate-Source Threshold Voltage (V_{DS} = -10 V, I_D = -10 μA)	—	$V_{GS(TH)}$	1.0	5.0	Vdc
"ON" Drain Current (V_{GS} = -10 V_{DS} = -10 V)	3	$I_{D(on)}$	3.0	—	mA
Drain-Source "ON" Voltage (I_D = -2.0 mA, V_{GS} = -10 V)	5	$V_{DS(on)}$	—	1.0	V

SMALL SIGNAL CHARACTERISTICS

Characteristic	Figure No.	Symbol	Min	Max	Unit
Drain-Source Resistance (V_{GS} = -10 V, I_D = 0, f = 1 kHz)	4	$r_{ds(on)}$	—	600	ohms
Forward Transfer Admittance (V_{DS} = -10 V, I_D = 2 mA, f = 1 kHz)	1	$\|y_{fs}\|$	1000	—	μmho
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 0, f = 140 kHz)	2	C_{rss}	—	1.3	pF
Input Capacitance (V_{DS} = -10 V, V_{GS} = 0, f=140 kHz)	2	C_{iss}	—	5.0	pF
Drain-Substrate Capacitance ($V_{D(SUB)}$= -10 V, f=140 kHz)	—	$C_{d(sub)}$	—	4.0	pF

SWITCHING CHARACTERISTICS

Characteristic		Figure No.	Symbol	Min	Max	Unit
Turn-On Delay	I_D = -2.0 mAdc, V_{DS} = -10 Vdc, V_{GS} = -10 V (See Figure 10, Times Circuit Determined)	6, 10	t_{d1}	—	45	ns
Rise Time		7, 10	t_r	—	65	ns
Turn-Off Delay		8, 10	t_{d2}	—	60	ns
Fall Time		9, 10	t_f	—	100	ns

FIGURE 1 — FORWARD TRANSFER ADMITTANCE

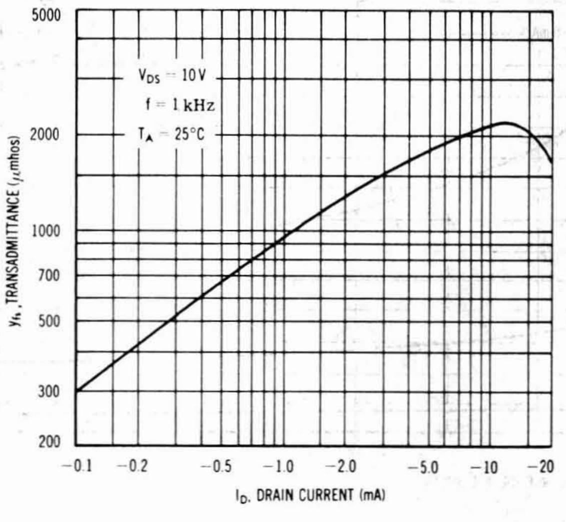


FIGURE 2 — CAPACITANCE

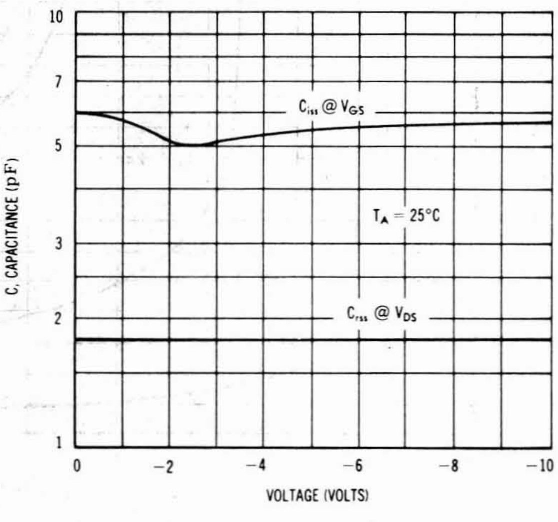


FIGURE 3 — TRANSFER CHARACTERISTICS

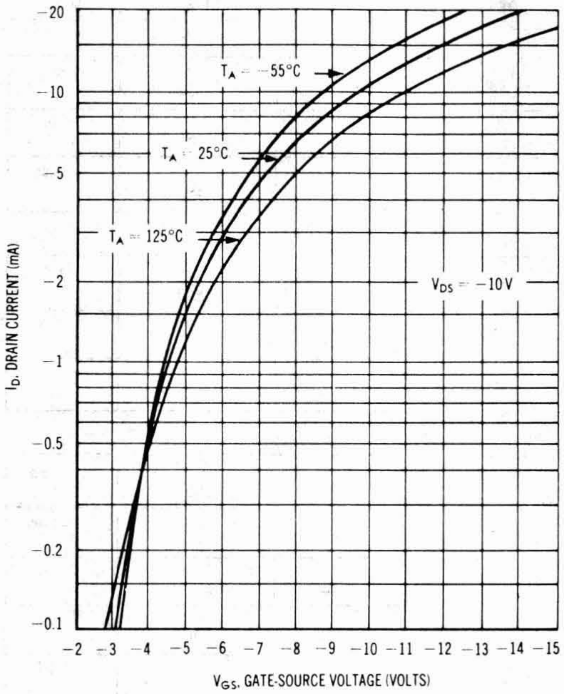


FIGURE 4 — DRAIN SOURCE "ON" RESISTANCE

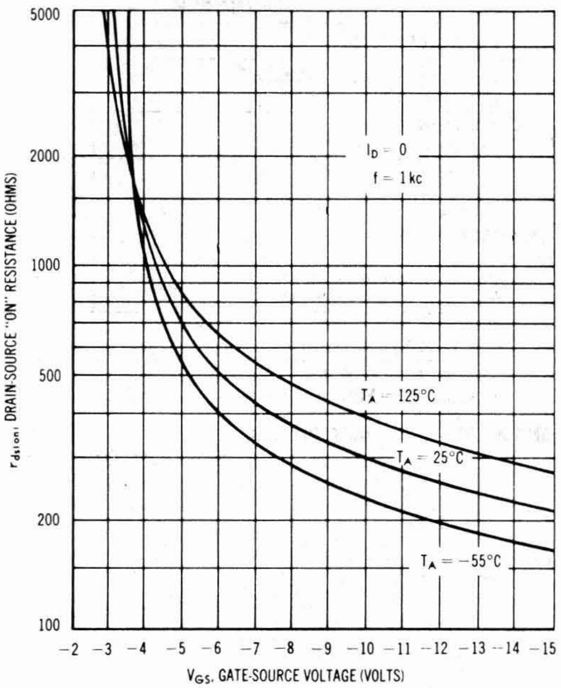
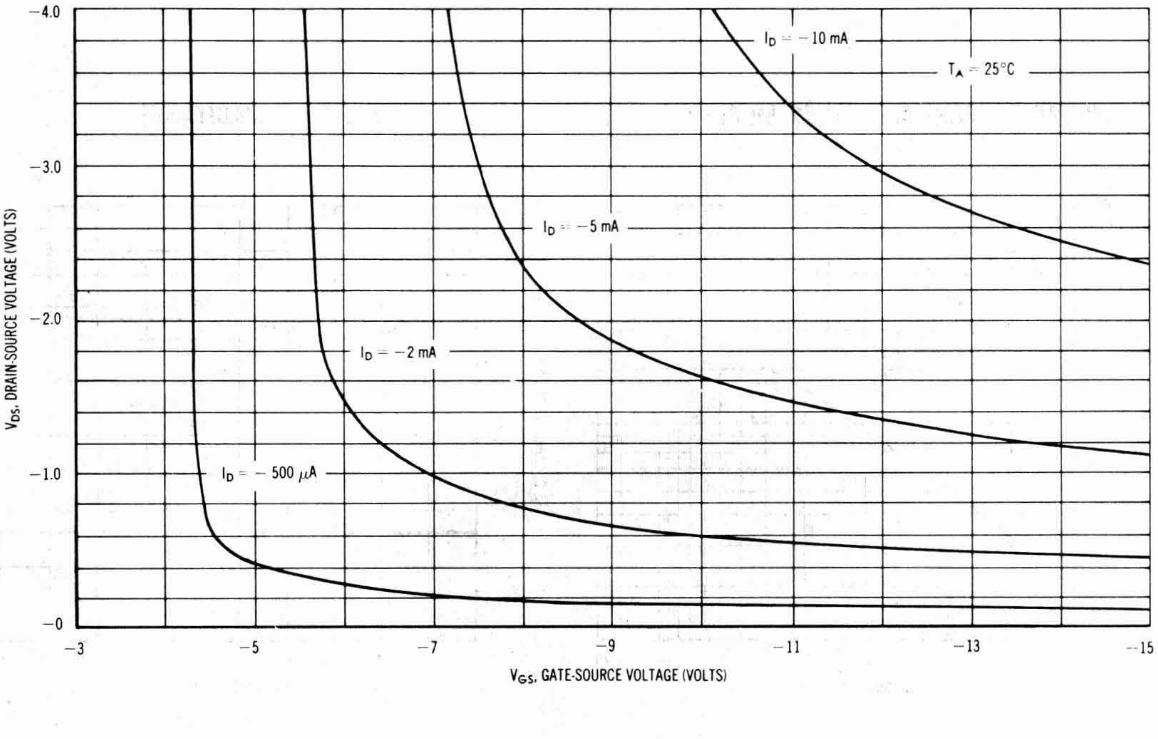


FIGURE 5 — "ON" DRAIN-SOURCE VOLTAGE



SWITCHING CHARACTERISTICS

($T_A = 25°C$)

FIGURE 6 — TURN-ON DELAY TIME

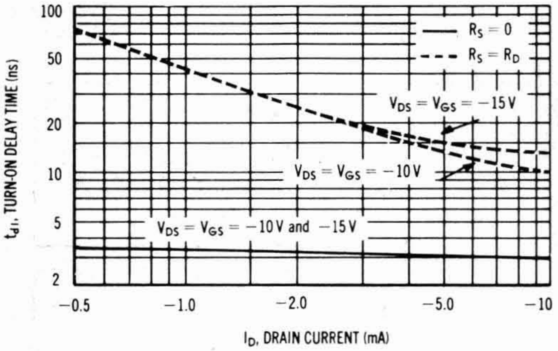


FIGURE 7 — RISE TIME

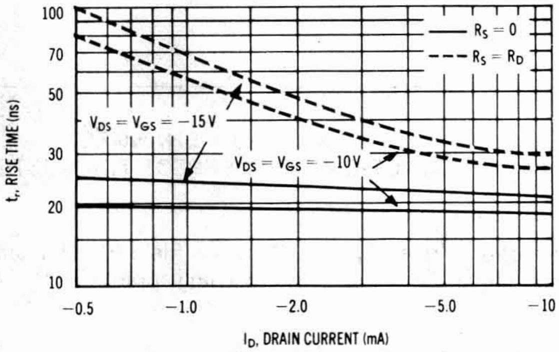


FIGURE 8 — TURN-OFF DELAY TIME

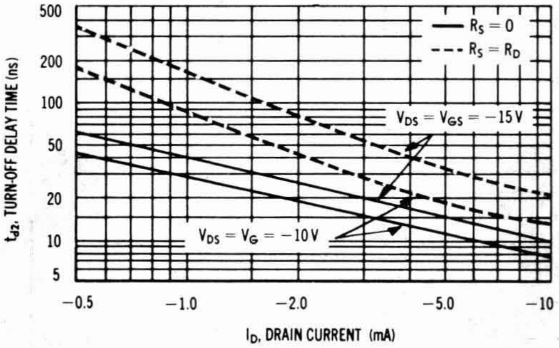


FIGURE 9 — FALL TIME

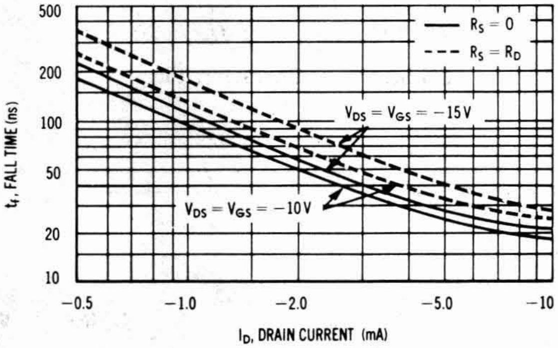
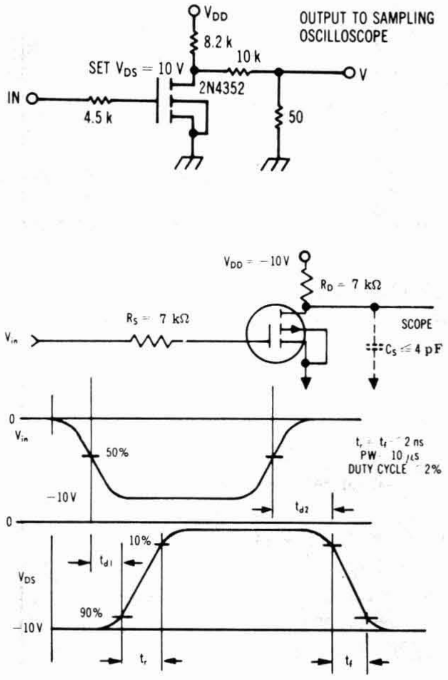


FIGURE 10 — SWITCHING CIRCUIT and WAVEFORMS



The switching characteristics shown above were measured in a test circuit similar to Figure 10. At the beginning of the switching interval, the gate voltage is at ground and the gate-source capacitance ($C_{gs} = C_{iss} - C_{rss}$) has no charge. The drain voltage is at V_{DD}, and thus the feedback capacitance (C_{rss}) is charged to V_{DD}. Similarly, the drain-substrate capacitance ($C_{d(sub)}$) is charged to V_{DD} since the substrate and source are connected to ground.

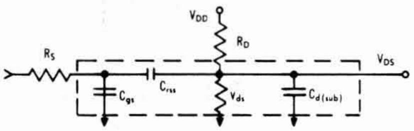
During the turn-on interval, C_{gs} is charged to V_{GS} (the input voltage) through R_S (generator impedance) (Figure 11). C_{rss} must be discharged to $V_{GS} - V_{D(on)}$ through R_S and the parallel combination of the load resistor (R_D) and the channel resistance (r_{ds}). In addition, $C_{d(sub)}$ is discharged to a low value ($V_{D(on)}$) through R_D in parallel with r_{ds}. During turn-off this charge flow is reversed.

Predicting turn-on time proves to be somewhat difficult since the channel resistance (r_{ds}) is a function of the gate-source voltage (V_{GS}). As C_{gs} becomes charged V_{GS} is approaching V_{in} and r_{ds} decreases (see Figure 4) and since C_{rss} and $C_{d(sub)}$ are charged through r_{ds}, turn-on time is quite non-linear.

If the charging time of C_{gs} is short compared to that of C_{rss} and $C_{d(sub)}$, then r_{ds} (which is in parallel with R_D) will be low compared to R_D during the switching interval and will largely determine the turn-on time. On the other hand, during turn-off r_{ds} will be almost an open circuit requiring C_{rss} and $C_{d(sub)}$ to be charged through R_D and resulting in a turn-off time that is long compared to the turn-on time. This is especially noticeable for the curves where $R_S = 0$ and C_{gs} is charged through the pulse generator impedance only.

The switching curves shown with $R_S = R_D$ simulate the switching behavior of cascaded stages where the driving source impedance is normally the same as the load impedance. The set of curves with $R_S = 0$ simulates a low source impedance drive such as might occur in complementary logic circuits.

FIGURE 11 — SWITCHING CIRCUIT with MOSFET EQUIVALENT MODEL



2N4391 (SILICON)
2N4392
2N4393

SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

Depletion Mode (Type A) Junction Field-Effect Transistors designed for chopper and high-speed switching applications.

- Low Drain-Source "On" Resistance — $r_{ds(on)}$ = 30 Ohms (Max) @ f = 1.0 kHz (2N4391)
- Low Gate Reverse Current — I_{GSS} = 0.1 nAdc (Max) @ V_{GS} = 20 Vdc
- Guaranteed Switching Characteristics

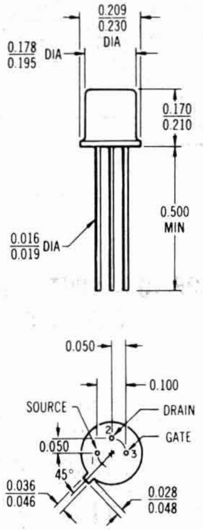
N-CHANNEL

JUNCTION FIELD-EFFECT TRANSISTORS

(Type A)

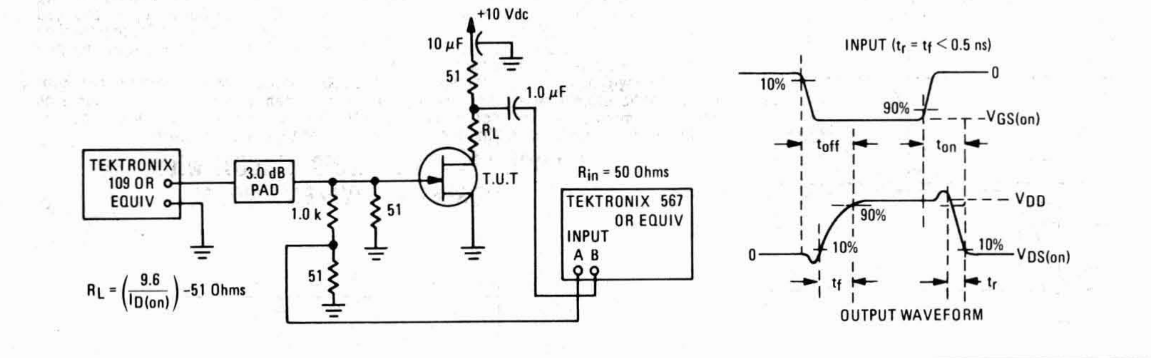
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	40	Vdc
Drain-Gate Voltage	V_{DG}	40	Vdc
Gate-Source Voltage	V_{GS}	40	Vdc
Forward Gate Current	$I_{G(f)}$	50	mAdc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.8 10	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
SOURCE
DRAIN
GATE
0.050
45°
0.036
0.046
0.028
0.048
1
2
3

CASE 22 (3)
(TO-18)

FIGURE 1 SWITCHING TIMES TEST CIRCUIT


+10 Vdc
10 μF
51
1.0 μF
R_L
TEKTRONIX 109 OR EQUIV
3.0 dB PAD
1.0 k
51
T.U.T
51
R_{in} = 50 Ohms
TEKTRONIX 567 OR EQUIV INPUT A B
$R_L = \left(\frac{9.6}{I_{D(on)}}\right) - 51$ Ohms
INPUT ($t_r = t_f < 0.5$ ns)
10%
0
90%
$-V_{GS(on)}$
t_{off}
t_{on}
V_{DD}
90%
0
10%
10%
$V_{DS(on)}$
t_f
t_r
OUTPUT WAVEFORM

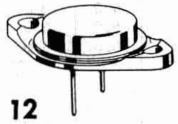
2N4391, 2N4392, 2N4393 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 1.0 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	40	-	Vdc
Gate-Source Forward Voltage (I_G = 1.0 mAdc, V_{DS} = 0)		$V_{GS(f)}$	-	1.0	Vdc
Gate-Source Voltage (V_{DS} = 20 Vdc, I_D = 1.0 nAdc)	2N4391	V_{GS}	4.0	10	Vdc
	2N4392		2.0	5.0	
	2N4393		0.5	3.0	
Gate Reverse Current		I_{GSS}			nAdc
(V_{GS} = 20 Vdc, V_{DS} = 0)			-	0.1	
(V_{GS} = 20 Vdc, V_{DS} = 0, T_A = 150°C)			-	0.2	μAdc
Drain-Cutoff Current		$I_{D(off)}$			nAdc
(V_{DS} = 20 Vdc, V_{GS} = 12 Vdc)	2N4391		-	0.1	
(V_{DS} = 20 Vdc, V_{GS} = 7.0 Vdc)	2N4392		-	0.1	
(V_{DS} = 20 Vdc, V_{GS} = 5.0 Vdc)	2N4393		-	0.1	
(V_{DS} = 20 Vdc, V_{GS} = 12 Vdc, T_A = 150°C)	2N4391		-	0.2	μAdc
(V_{DS} = 20 Vdc, V_{GS} = 7.0 Vdc, T_A = 150°C)	2N4392		-	0.2	
(V_{DS} = 20 Vdc, V_{GS} = 5.0 Vdc, T_A = 150°C)	2N4393		-	0.2	
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current* (V_{DS} = 20 Vdc, V_{GS} = 0)	2N4391	I_{DSS}*	50	150	mAdc
	2N4392		25	75	
	2N4393		5.0	30	
Drain-Source "ON" Voltage		$V_{DS(on)}$			Vdc
(I_D = 12 mAdc, V_{GS} = 0)	2N4391		-	0.4	
(I_D = 6.0 mAdc, V_{GS} = 0)	2N4392		-	0.4	
(I_D = 3.0 mAdc, V_{GS} = 0)	2N4393		-	0.4	
Static Drain-Source "ON" Resistance (I_D = 1.0 mAdc, V_{GS} = 0)	2N4391	$r_{DS(on)}$	-	30	Ohms
	2N4392		-	60	
	2N4393		-	100	
SMALL-SIGNAL CHARACTERISTICS					
Drain-Source "ON" Resistance (V_{GS} = 0, I_D = 0, f = 1.0 kHz)	2N4391	$r_{ds(on)}$	-	30	Ohms
	2N4392		-	60	
	2N4393		-	100	
Input Capacitance (V_{DS} = 20 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{iss}	-	14	pF
Reverse Transfer Capacitance		C_{rss}			pF
(V_{DS} = 0, V_{GS} = 12 Vdc, f = 1.0 MHz)	2N4391		-	3.5	
(V_{DS} = 0, V_{GS} = 7.0 Vdc, f = 1.0 MHz)	2N4392		-	3.5	
(V_{DS} = 0, V_{GS} = 5.0 Vdc, f = 1.0 MHz)	2N4393		-	3.5	
SWITCHING CHARACTERISTICS					
Turn-On Time (See Figure 1)		t_{on}			ns
($I_{D(on)}$ = 12 mAdc)	2N4391		-	15	
($I_{D(on)}$ = 6.0 mAdc)	2N4392		-	15	
($I_{D(on)}$ = 3.0 mAdc)	2N4393		-	15	
Rise Time (See Figure 1)		t_r			ns
($I_{D(on)}$ = 12 mAdc)	2N4391		-	5.0	
($I_{D(on)}$ = 6.0 mAdc)	2N4392		-	5.0	
($I_{D(on)}$ = 3.0 mAdc)	2N4393		-	5.0	
Turn-Off Time (See Figure 1)		t_{off}			ns
($V_{GS(off)}$ = 12 Vdc)	2N4391		-	20	
($V_{GS(off)}$ = 7.0 Vdc)	2N4392		-	35	
($V_{GS(off)}$ = 5.0 Vdc)	2N4393		-	50	
Fall Time (See Figure 1)		t_f			ns
($V_{GS(off)}$ = 12 Vdc)	2N4391		-	15	
($V_{GS(off)}$ = 7.0 Vdc)	2N4392		-	20	
($V_{GS(off)}$ = 5.0 Vdc)	2N4393		-	30	

*Pulse Test: Pulse Width ≤ 100 μs, Duty Cycle ≤ 1.0%.

2N4398 (SILICON)
2N4399



CASE 12
(TO-3 modified)

High-power PNP silicon transistors for use in power amplifier and switching circuits; serves as direct replacements for germanium high-power devices.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4398	2N4399	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	Vdc
Collector-Base Voltage	V_{CB}	40	60	Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current-Continuous	I_C	30		Adc
Peak		50		
Base Current	I_B	7.5		Adc
Total Device Dissipation @ T_A = 25°C	P_D	5.0		Watts
Total Device Dissipation @ T_C = 25°C	P_D	200		Watts
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.875	°C/W
Thermal Resistance, Case to Ambient	θ_{CA}	34	°C/W

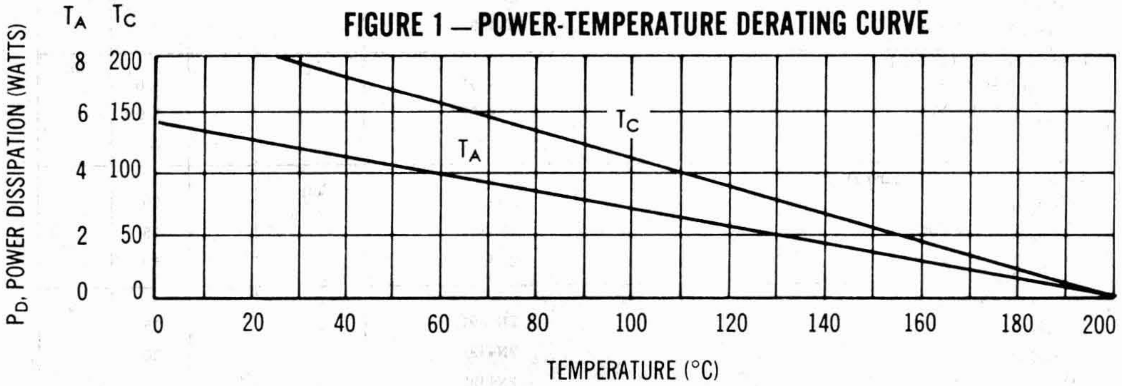


FIGURE 1 — POWER-TEMPERATURE DERATING CURVE

Safe Area Curves are indicated by Figure 13. All limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 200 mAdc, I_B = 0) 2N4398 2N4399	13	$BV_{CEO(sus)}$*	40 60	— —	Vdc
Collector Cutoff Current (V_{CE} = 40 Vdc, I_B = 0) 2N4398 (V_{CE} = 60 Vdc, I_B = 0) 2N4399		I_{CEO}	— —	5.0 5.0	mAdc
Collector Cutoff Current (V_{CE} = 30 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C) (V_{CE} = 40 Vdc, $V_{BE(off)}$ = 1.5 Vdc) 2N4398 (V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1.5 Vdc) 2N4399	7, 8	I_{CEX}	— — —	10 5.0 5.0	mAdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0) 2N4398 (V_{CB} = 60 Vdc, I_E = 0) 2N4399	7, 8	I_{CBO}	— —	1.0 1.0	mAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		I_{EBO}	—	5.0	mAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc) (I_C = 15 Adc, V_{CE} = 2.0 Vdc) (I_C = 30 Adc, V_{CE} = 4.0 Vdc)	9	h_{FE}*	40 15 5.0	— 60 —	—
Collector-Emitter Saturation Voltage* (I_C = 10 Adc, I_B = 1.0 Adc) (I_C = 15 Adc, I_B = 1.5 Adc) (I_C = 20 Adc, I_B = 2.0 Adc)	10, 11, 12	$V_{CE(sat)}$*	— — —	0.75 1.0 2.0	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 Adc, I_B = 1.0 Adc) (I_C = 15 Adc, I_B = 1.5 Adc) (I_C = 20 Adc, I_B = 2.0 Adc)	11, 12	$V_{BE(sat)}$*	— — —	1.6 1.85 2.5	Vdc
Base-Emitter "On" Voltage* (I_C = 15 Adc, V_{CE} = 2.0 Vdc) (I_C = 30 Adc, V_{CE} = 4.0 Vdc)	11, 12	$V_{BE(on)}$*	— —	1.7 3.0	Vdc
DYNAMIC CHARACTERISTICS					
Current Gain — Bandwidth Product (I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz)		f_T	4.0	—	MHz
Small Signal Current Gain (I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{fe}	40	—	—
Rise Time (V_{CC} = 30 Vdc, I_C = 10 Adc, I_{B1} = I_{B2} = 1.0 Adc)	2, 5	t_r	—	0.4	μs
Storage Time	2, 3, 6	t_s	—	1.5	μs
Fall Time	2, 3, 6	t_f	—	0.6	μs

* Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2.0%

SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 2 — TURN-ON TIME

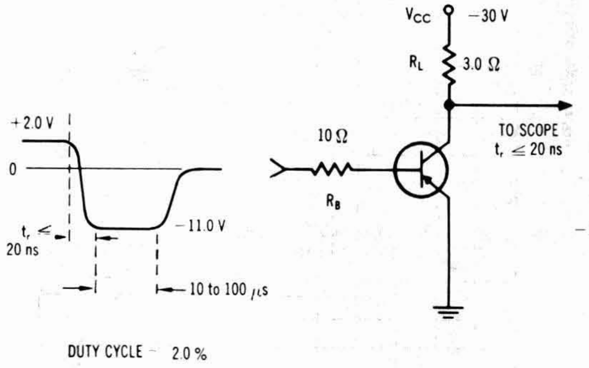
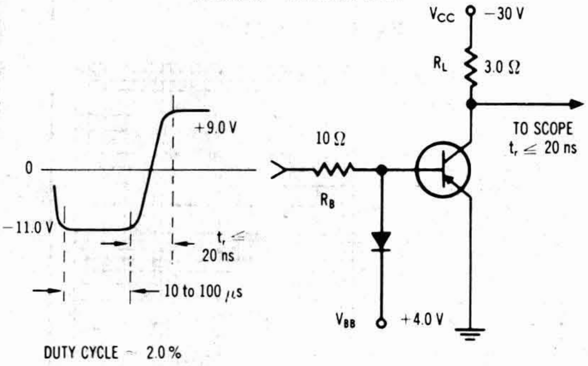

+2.0 V
0
$t_r \leq$ 20 ns
−11.0 V
10 to 100 μs
DUTY CYCLE ≈ 2.0%
V_{CC}
−30 V
R_L
3.0 Ω
10 Ω
R_B
TO SCOPE
$t_r \leq$ 20 ns

FIGURE 3 — TURN-OFF TIME


+9.0 V
0
−11.0 V
$t_f \leq$ 20 ns
10 to 100 μs
DUTY CYCLE ≈ 2.0%
V_{CC}
−30 V
R_L
3.0 Ω
10 Ω
R_B
TO SCOPE
$t_r \leq$ 20 ns
V_{BB}
+4.0 V

FOR CURVES OF FIGURES 5 & 6, R_B, R_L, & V_{CC} ARE VARIED.
INPUT LEVELS ARE APPROXIMATELY AS SHOWN.

TYPICAL TRANSIENT CHARACTERISTICS

FIGURE 4 — CAPACITANCES

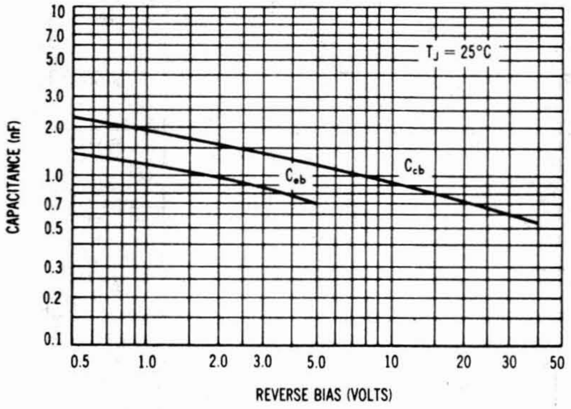


FIGURE 5 — TURN-ON TIME

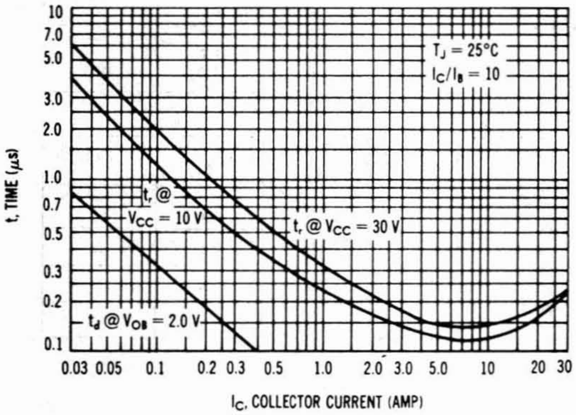
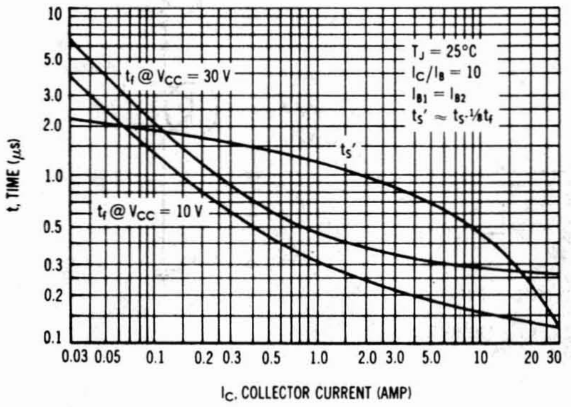


FIGURE 6 — TURN-OFF TIME



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 7 — TRANSCONDUCTANCE

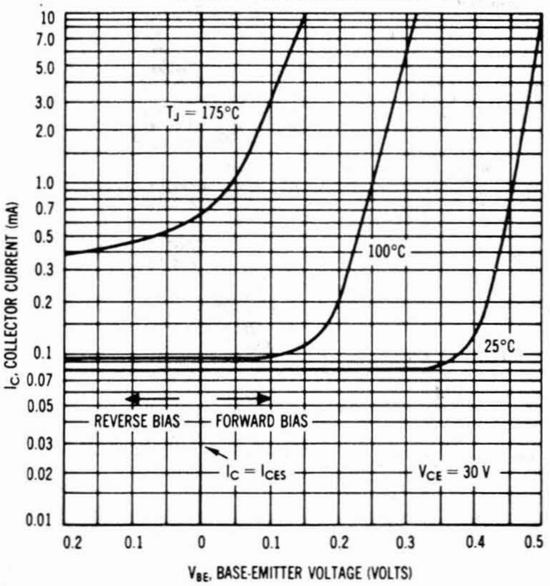
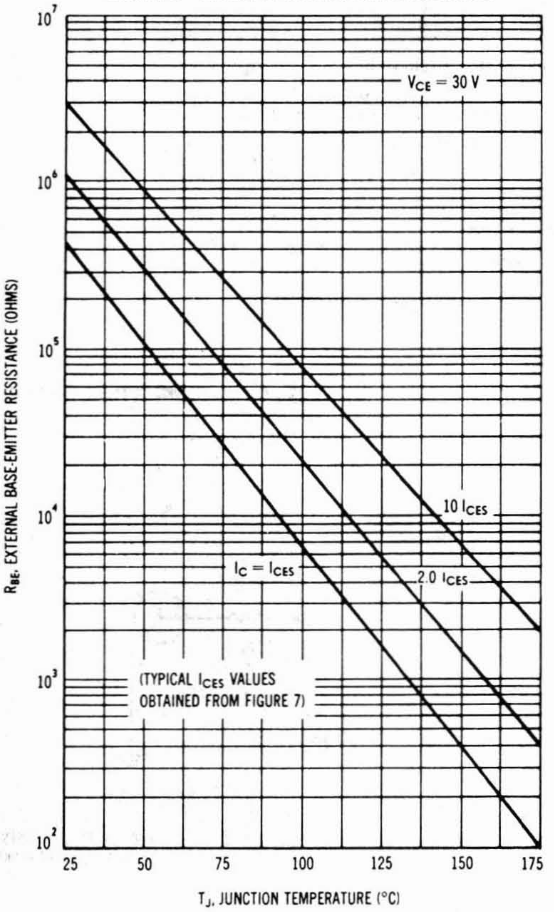


FIGURE 8 — EFFECT OF BASE-EMITTER RESISTANCE



TYPICAL "ON" REGION CHARACTERISTICS

FIGURE 9 — NORMALIZED DC CURRENT GAIN

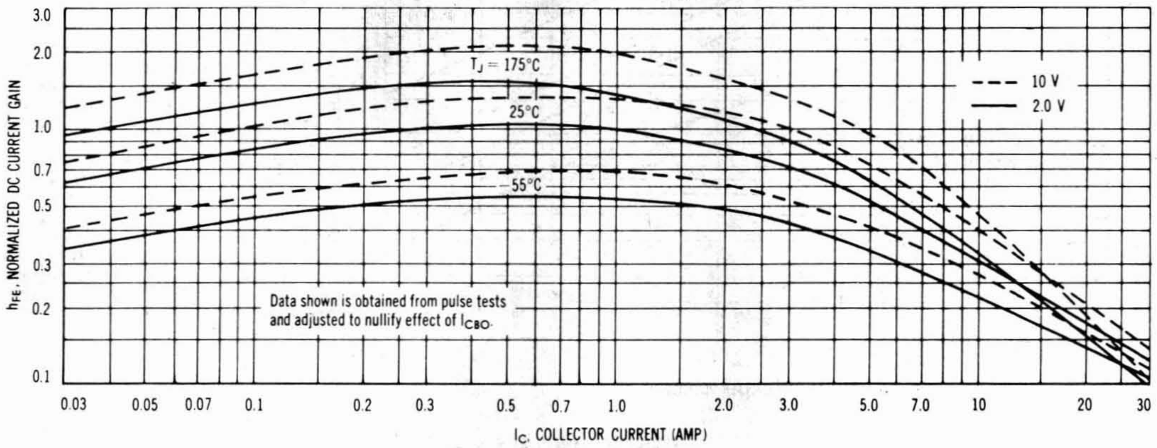


FIGURE 10 — COLLECTOR SATURATION REGION

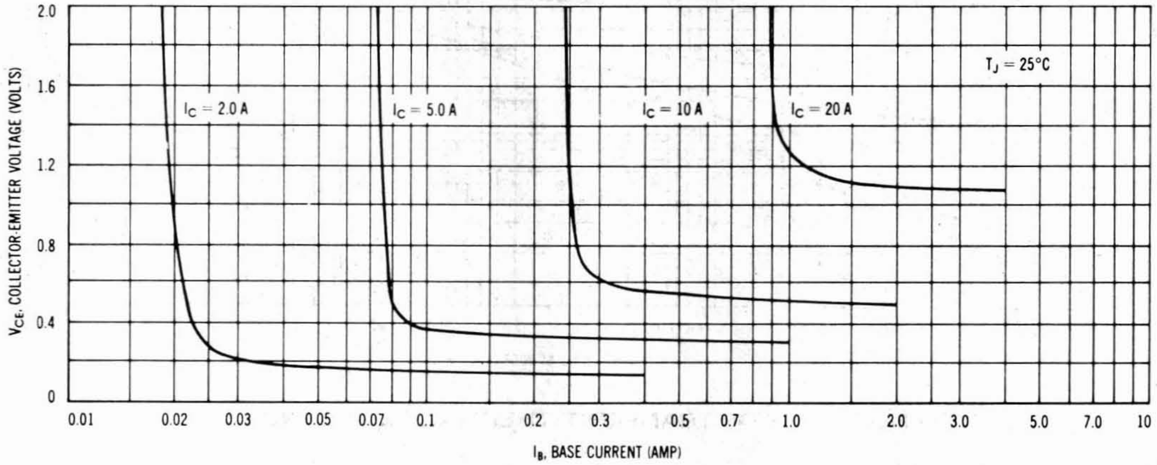


FIGURE 11 — "ON" VOLTAGES

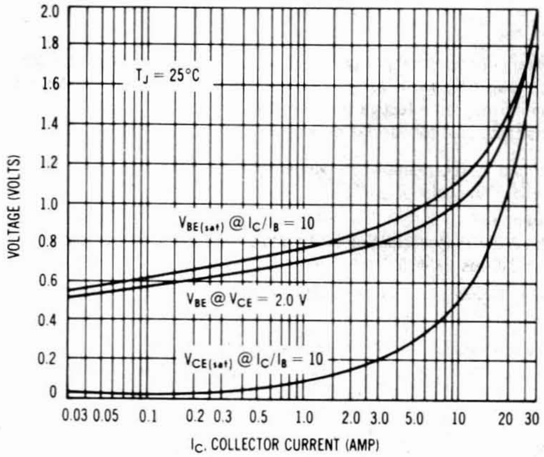
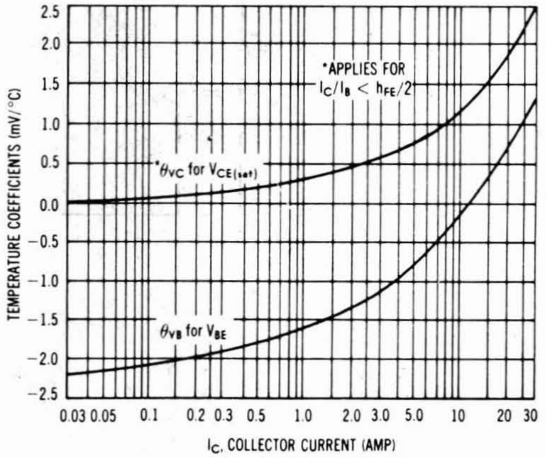
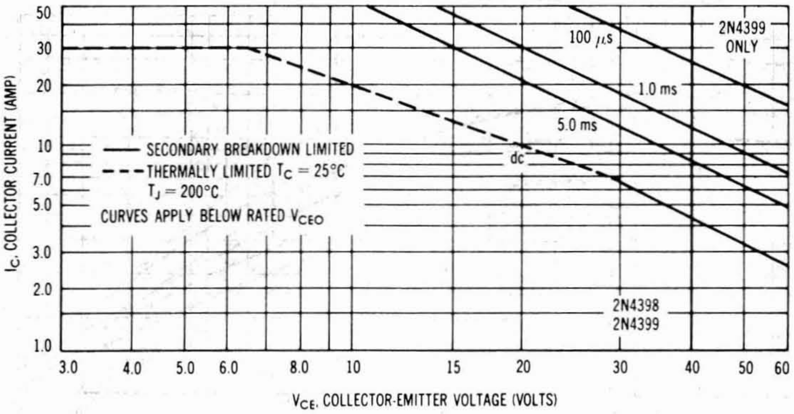


FIGURE 12 — TEMPERATURE COEFFICIENTS



RATINGS AND THERMAL DATA

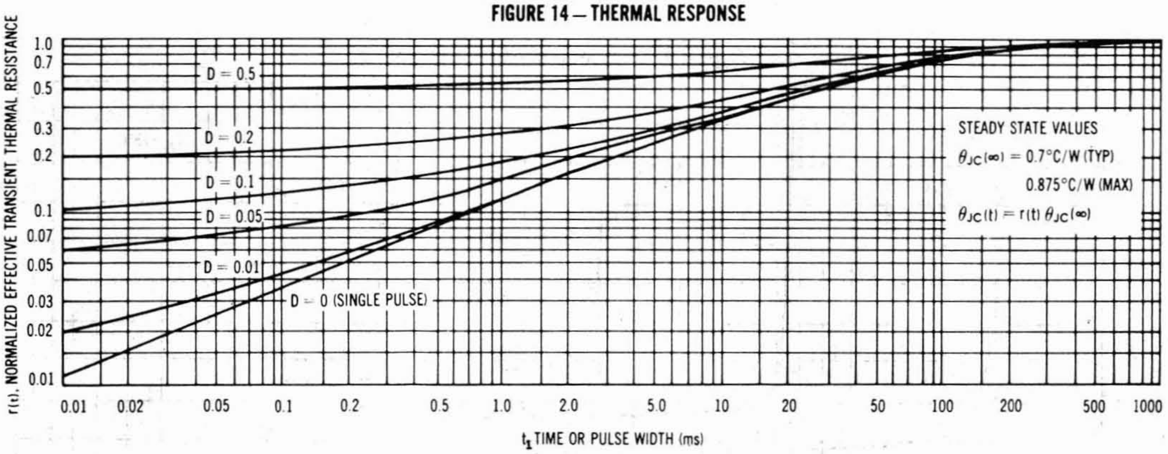
FIGURE 13 — ACTIVE-REGION SAFE OPERATING AREA



The safe operating area curves indicate I_C-V_{CE} limits of the transistor that must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

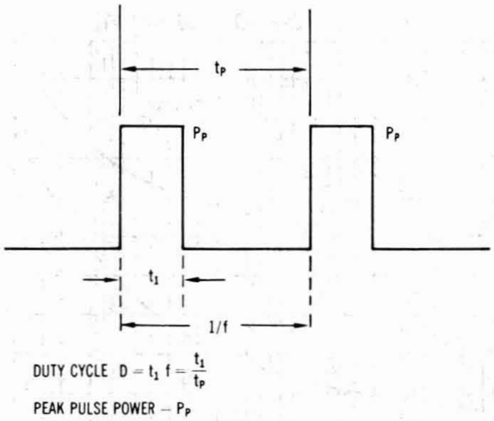
The data of Figure 13 is based upon $T_{J(pk)} = 200°C$; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} \leq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 14. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by the secondary breakdown.

FIGURE 14 — THERMAL RESPONSE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



A train of periodical power pulses can be represented by the model as shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 14 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 14 by the steady state value $\theta_{JC}(\infty)$.

Example:

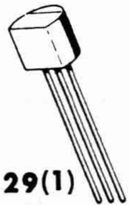
The 2N4398 is dissipating 100 watts under the following conditions: $t_1 = 1.0$ ms, $t_P = 5.0$ ms. $(D = 0.2)$

Using Figure 14, at a pulse width of 1.0 ms and D = 0.2, the reading of r (t) is 0.28.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P_P \times \theta_{JC}(\infty) = 0.28 \times 100 \times 0.875 = 24.5°C$$

2N4400 (SILICON)
2N4401



CASE 29(1)
(TO-92)

NPN silicon annular transistors designed for general purpose switching and amplifier applications and for complementary circuitry with PNP types 2N4402 and 2N4403. Features one-piece, injection-molded plastic package for high reliability.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current - Continuous	I_C	600	mAdc
Total Device Dissipation $T_A = 25^oC$	P_D	310	mW
Derate above 25°C		2.81	mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.137	°C/mW
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

2N4400, 2N4401 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 1 mAdc, I_B = 0)		BV_{CEO}*	40	—	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)		BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)		BV_{EBO}	6.0	—	Vdc
Collector Cutoff Current (V_{CE} = 35 Vdc, $V_{EB(off)}$ = 0.4 Vdc)		I_{CEX}	—	0.1	μAdc
Base Cutoff Current (V_{CE} = 35 Vdc, $V_{EB(off)}$ = 0.4 Vdc)		I_{BL}	—	0.1	μAdc
ON CHARACTERISTICS					
DC Current Gain	15	h_{FE}			—
(I_C = 0.1 mAdc, V_{CE} = 1 Vdc) 2N4401			20	—	
(I_C = 1 mAdc, V_{CE} = 1 Vdc) 2N4400 2N4401			20 40	— —	
(I_C = 10 mAdc, V_{CE} = 1 Vdc) 2N4400 2N4401			40 80	— —	
(I_C = 150 mAdc, V_{CE} = 1 Vdc)* 2N4400 2N4401			50 100	150 300	
(I_C = 500 mAdc, V_{CE} = 2 Vdc)* 2N4400 2N4401			20 40	— —	
Collector-Emitter Saturation Voltage*	16, 17, 18	$V_{CE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			—	0.4	
(I_C = 500 mAdc, I_B = 50 mAdc)			—	0.75	
Base-Emitter Saturation Voltage*	17, 18	$V_{BE(sat)}$			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)			0.75	0.95	
(I_C = 500 mAdc, I_B = 50 mAdc)			—	1.2	
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N4400 2N4401		f_T	200 250	— —	MHz
Collector-Base Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz, emitter guarded)	3	C_{cb}	—	6.5	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz, collector guarded)	3	C_{eb}	—	30	pF
Input Impedance (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz) 2N4400 2N4401	12	h_{ie}	0.5 1.0	7.5 15	k ohms
Voltage Feedback Ratio (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	13	h_{re}	0.1	8.0	$X 10^{-4}$
Small-Signal Current Gain (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz) 2N4400 2N4401	11	h_{fe}	20 40	250 500	—
Output Admittance (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	14	h_{oe}	1.0	30	μmhos
SWITCHING CHARACTERISTICS					
Delay Time — V_{CC} = 30 Vdc, $V_{EB(off)}$ = 2 Vdc,	1, 5	t_d	—	15	ns
Rise Time — I_C = 150 mAdc, I_{B1} = 15 mAdc	1, 5, 6	t_r	—	20	ns
Storage Time — V_{CC} = 30 Vdc, I_C = 150 mAdc,	2, 7	t_s	—	225	ns
Fall Time — I_{B1} = I_{B2} = 15 mAdc	2, 8	t_f	—	30	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2%

SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 — TURN-ON TIME

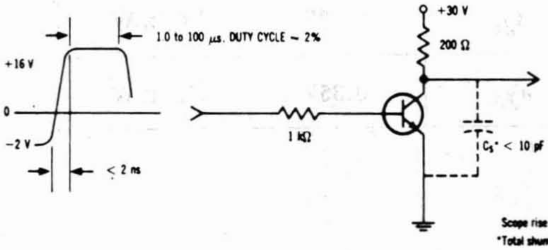
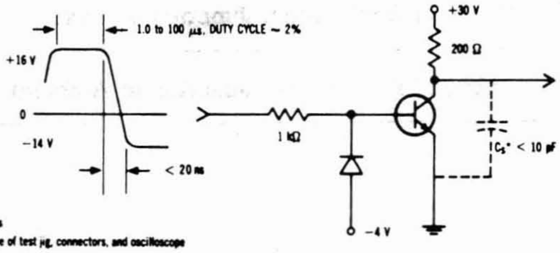


FIGURE 2 — TURN-OFF TIME



Scope rise time < 4 ns

*Total shunt capacitance of test jig, connectors, and oscilloscope

TRANSIENT CHARACTERISTICS

—— 25°C – – – 100°C

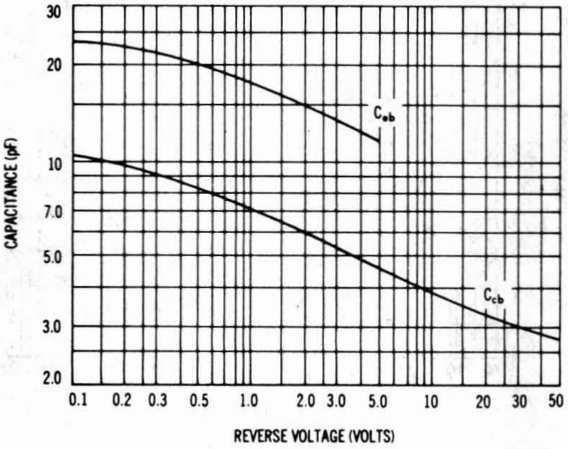


FIGURE 3 — CAPACITANCES

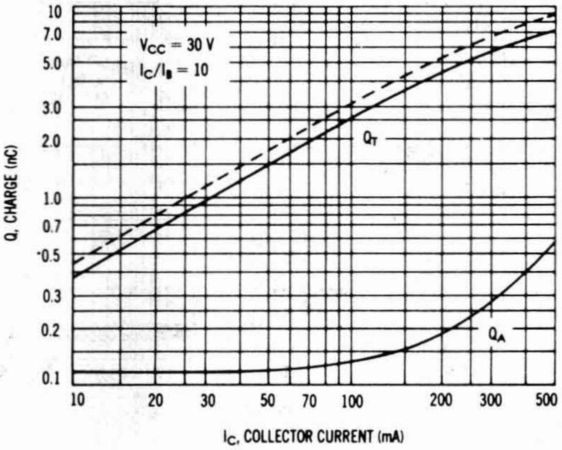


FIGURE 4 — CHARGE DATA

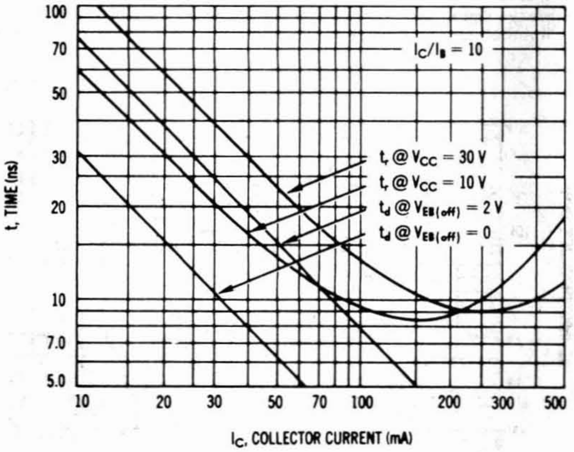


FIGURE 5 — TURN-ON TIME

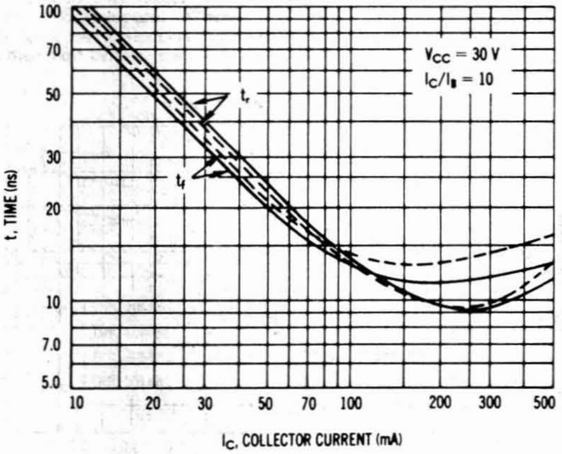


FIGURE 6 — RISE AND FALL TIMES

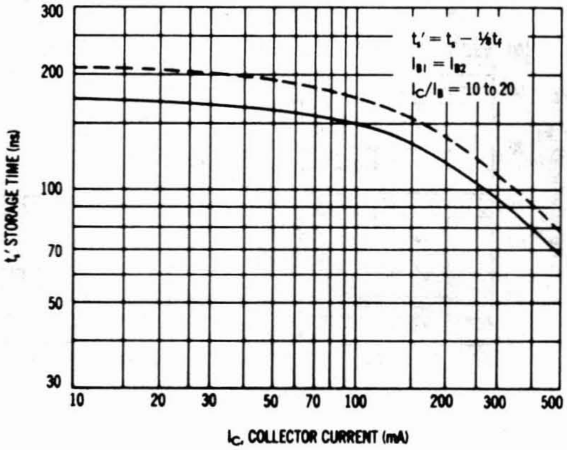


FIGURE 7 — STORAGE TIME

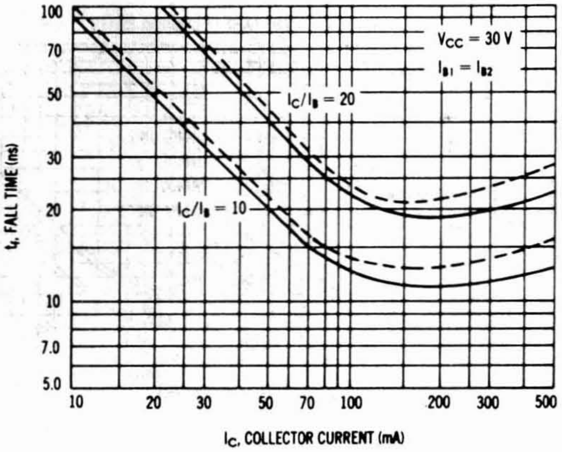


FIGURE 8 — FALL TIME

SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE

$V_{CE} = 10$ Vdc, $T_A = 25°C$

FIGURE 9 — FREQUENCY EFFECTS

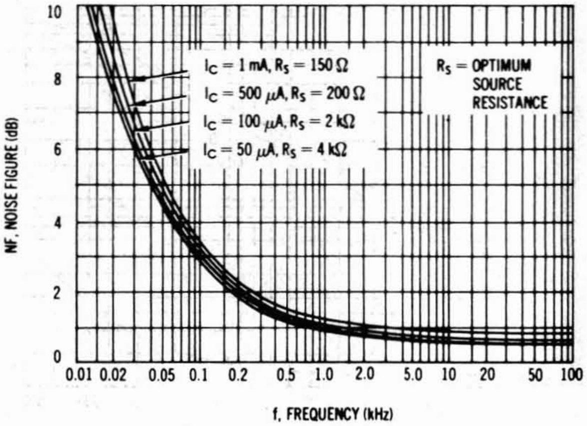
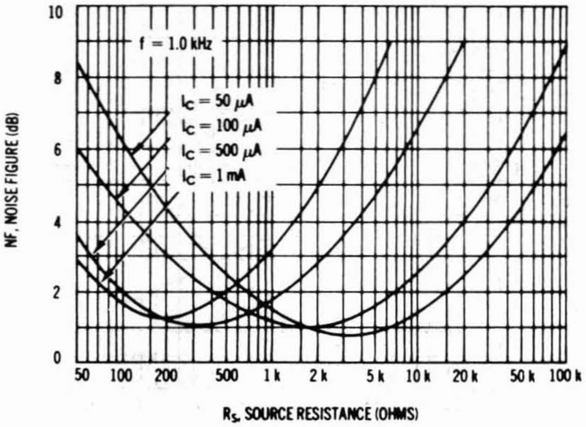


FIGURE 10 — SOURCE RESISTANCE EFFECTS



h PARAMETERS

$V_{CE} = 10$ Vdc, $f = 1$ kHz, $T_A = 25°C$

This group of graphs illustrates the relationship between h_{fe} and other "h" parameters for this series of transistors. To obtain these curves, a high-gain and a low-gain unit were selected from both the 2N4400 and 2N4401 lines, and the same units were used to develop the correspondingly numbered curves on each graph.

FIGURE 11 — CURRENT GAIN

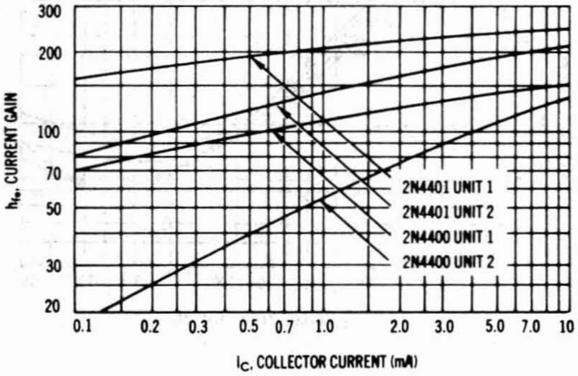


FIGURE 12 — INPUT IMPEDANCE

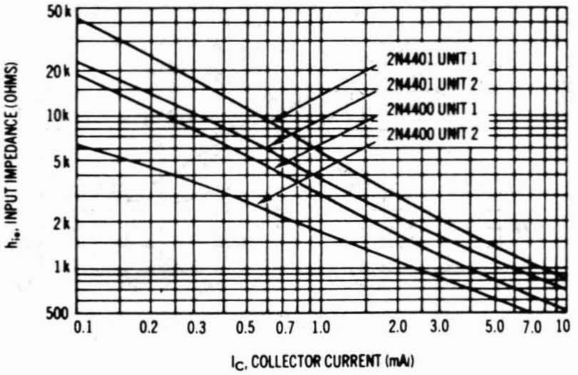


FIGURE 13 — VOLTAGE FEEDBACK RATIO

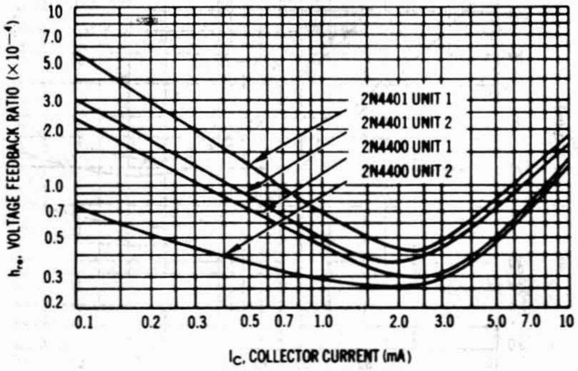
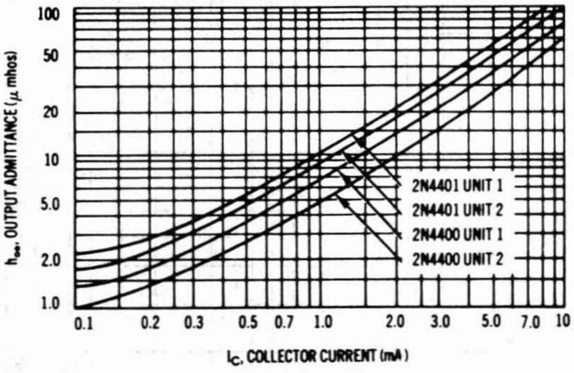


FIGURE 14 — OUTPUT ADMITTANCE



STATIC CHARACTERISTICS

FIGURE 15 — DC CURRENT GAIN

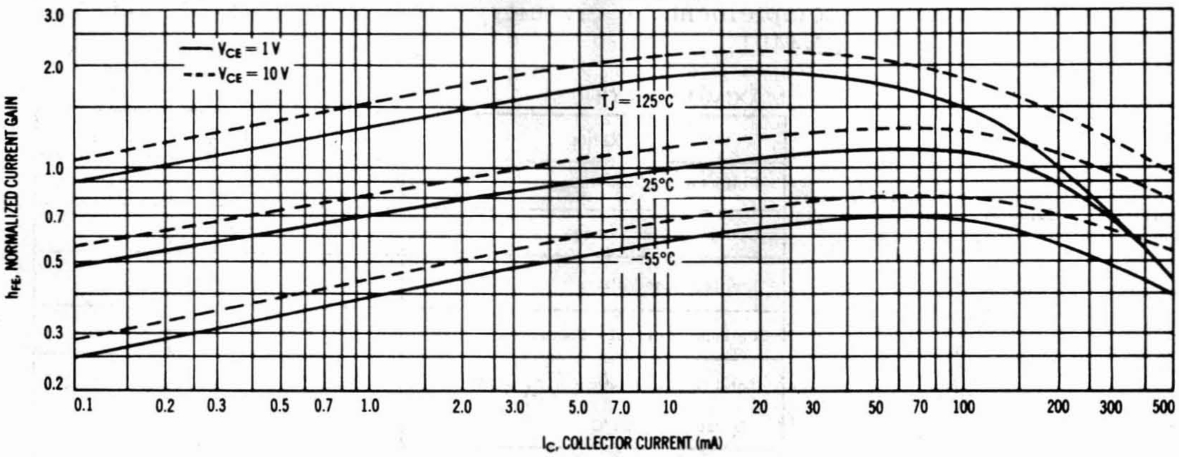


FIGURE 16 — COLLECTOR SATURATION REGION

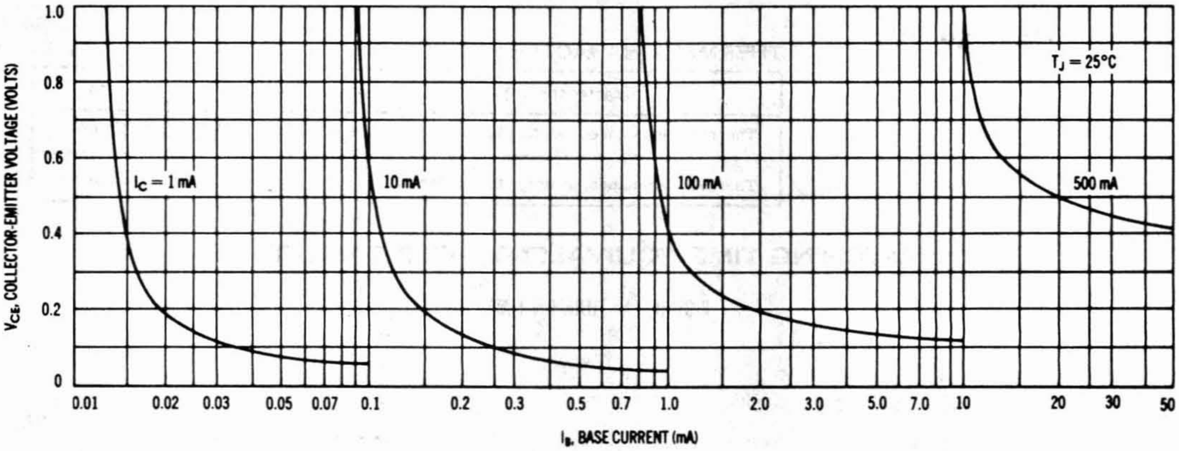


FIGURE 17 — "ON" VOLTAGES

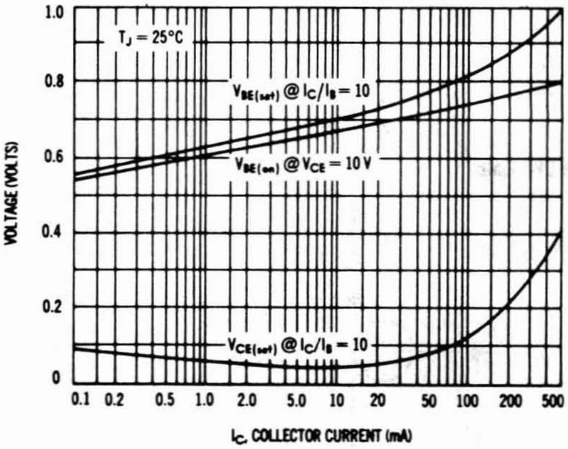
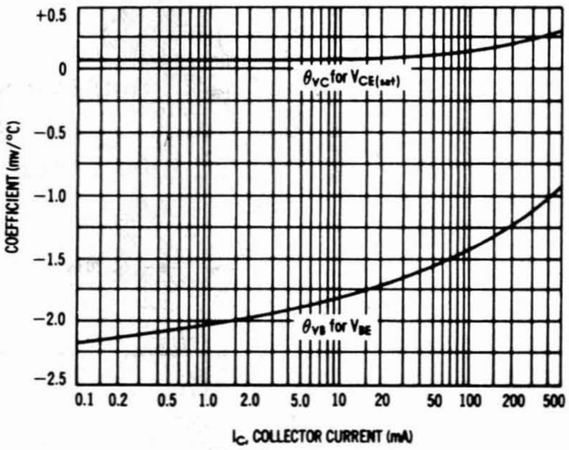
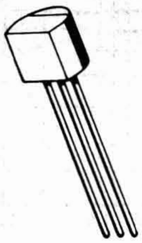


FIGURE 18 — TEMPERATURE COEFFICIENTS



2N4402 (SILICON)
2N4403

PNP silicon annular transistors designed for general purpose switching and amplifier applications and for complementary circuitry with NPN types 2N4400 and 2N4401.



CASE 29 (1)
TO-92

MAXIMUM RATINGS

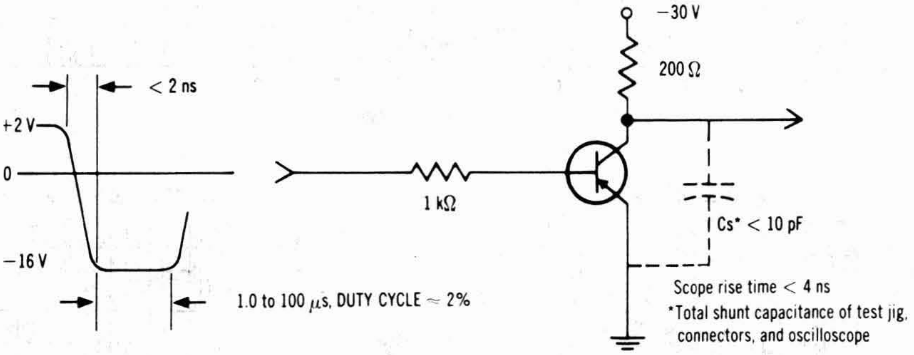
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current - Continuous	I_C	600	mAdc
Total Device Dissipation $T_A = 25^oC$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.137	°C/mW
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

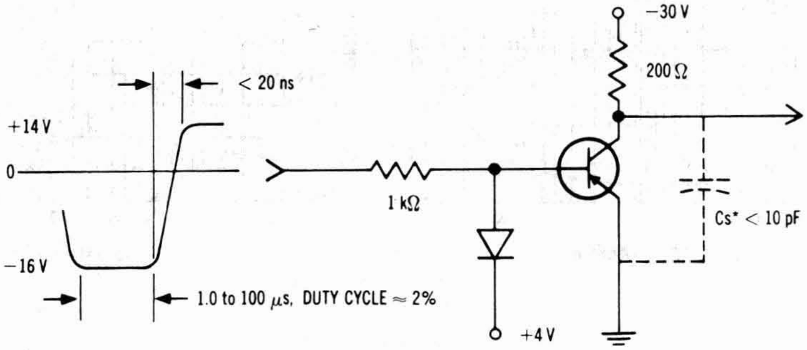
SWITCHING TIME EQUIVALENT TEST CIRCUIT

FIGURE 1 — TURN-ON TIME


< 2 ns
+2 V
0
−16 V
1.0 to 100 μs, DUTY CYCLE ≈ 2%
1 kΩ
−30 V
200 Ω
Cs* < 10 pF

Scope rise time < 4 ns
*Total shunt capacitance of test jig, connectors, and oscilloscope

FIGURE 2 — TURN-OFF TIME


< 20 ns
+14 V
0
−16 V
1.0 to 100 μs, DUTY CYCLE ≈ 2%
1 kΩ
+4 V
−30 V
200 Ω
Cs* < 10 pF

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 1 mAdc, I_B = 0)		BV_{CEO}*	40	—	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)		BV_{CBO}	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)		BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current (V_{CE} = 35 Vdc, $V_{BE(off)}$ = 0.4 Vdc)		I_{CEX}	—	0.1	μAdc
Base Cutoff Current (V_{CE} = 35 Vdc, $V_{BE(off)}$ = 0.4 Vdc)		I_{BL}	—	0.1	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 1 Vdc) 2N4403	15	h_{FE}	30	—	
(I_C = 1 mAdc, V_{CE} = 1 Vdc) 2N4402 2N4403			30 60	— —	
(I_C = 10 mAdc, V_{CE} = 1 Vdc) 2N4402 2N4403			50 100	— —	
(I_C =150 mAdc, V_{CE} = 2 Vdc)* 2N4402 2N4403			50 100	150 300	
(I_C = 500 mAdc, V_{CE} = 2 Vdc)*			20	—	
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	16, 17, 18	$V_{CE(sat)}$	— —	0.4 0.75	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	17, 18	$V_{BE(sat)}$	0.75 —	0.95 1.3	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz) 2N4402 2N4403		f_T	150 200	— —	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz, emitter guarded)	3	C_{cb}	—	8.5	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz, collector guarded)	3	C_{eb}	—	30	pF
Input Impedance (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz) 2N4402 2N4403	12	h_{ie}	750 1.5k	7.5k 15k	ohms
Voltage Feedback Ratio (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	13	h_{re}	0.1	8.0	X 10^{-4}
Small-Signal Current Gain (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz) 2N4402 2N4403	11	h_{fe}	30 60	250 500	—
Output Admittance (I_C = 1 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	14	h_{oe}	1.0	100	μmhos
SWITCHING CHARACTERISTICS					
Delay Time — V_{CC} = 30 Vdc, $V_{BE(off)}$ = 2 Vdc,	1, 5	t_d	—	15	ns
Rise Time — I_C = 150 mAdc, I_{B1} = 15 mAdc	1, 5, 6	t_r	—	20	ns
Storage Time — V_{CC} = 30 Vdc, I_C = 150 mAdc,	2, 7	t_s	—	225	ns
Fall Time — I_{B1} = I_{B2} = 15 mAdc	2, 8	t_f	—	30	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2%

2N4402, 2N4403 (continued)

TRANSIENT CHARACTERISTICS

—— 25°C – – – 100°C

FIGURE 3 — CAPACITANCES

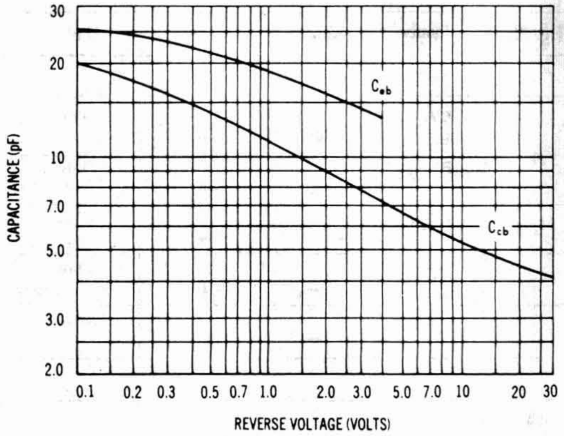


FIGURE 4 — CHARGE DATA

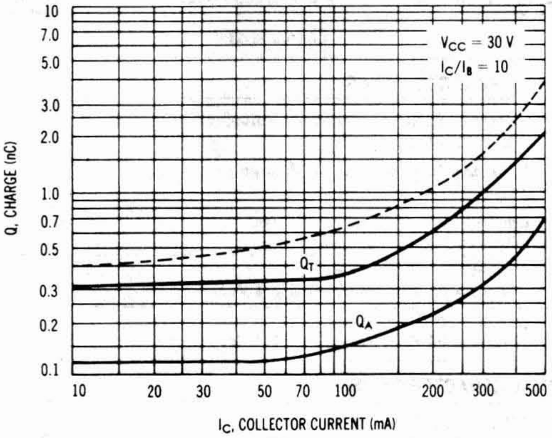


FIGURE 5 — TURN-ON TIME

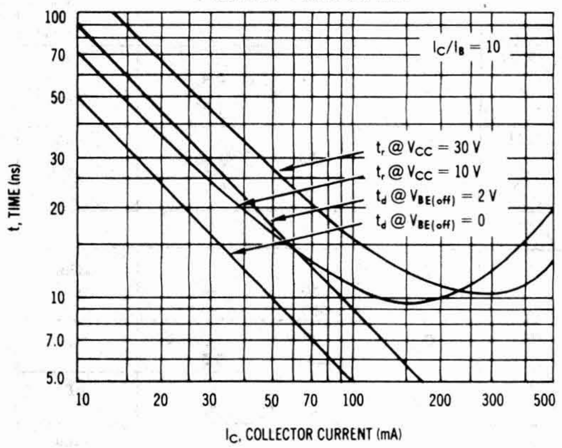


FIGURE 6 — RISE TIME

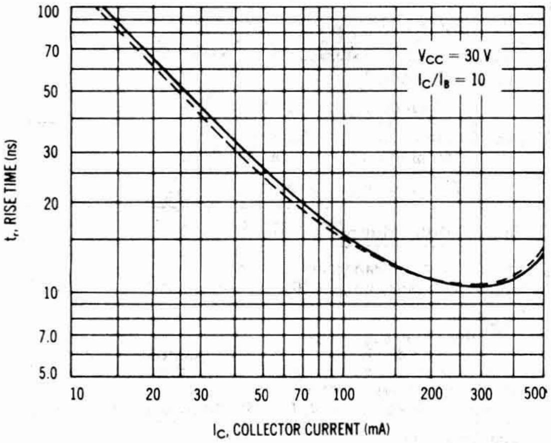


FIGURE 7 — STORAGE TIME

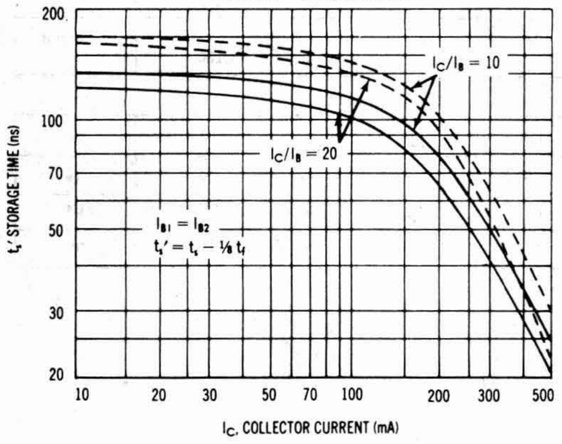
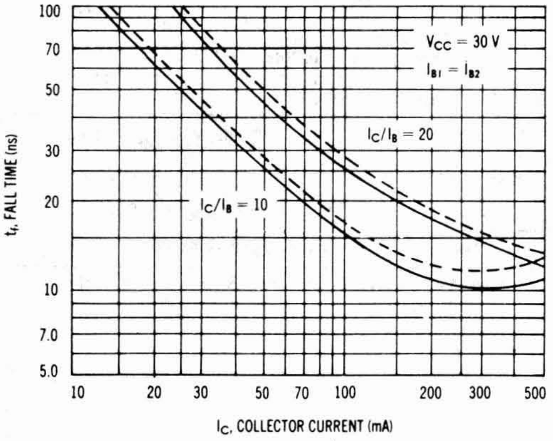


FIGURE 8 — FALL TIME



SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE

$V_{CE} = 10$ Vdc, $T_A = 25°C$

FIGURE 9 — FREQUENCY EFFECTS

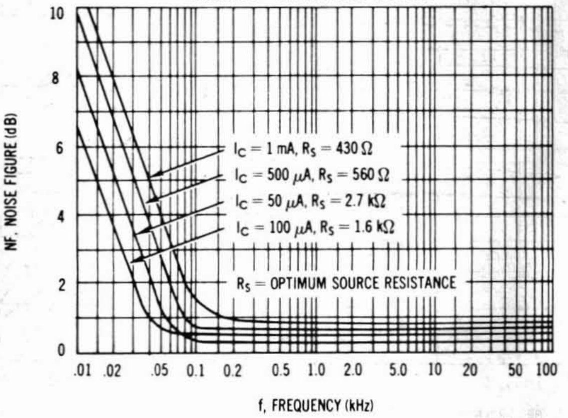
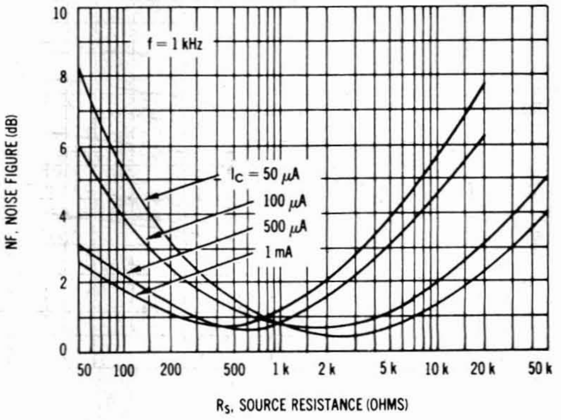


FIGURE 10 — SOURCE RESISTANCE EFFECTS



h PARAMETERS

$V_{CE} = 10$ Vdc, f = 1 kHz, $T_A = 25°C$

This group of graphs illustrates the relationship between h_{fe} and other "h" parameters for this series of transistors. To obtain these curves, a high-gain and a low-gain unit were selected from both the 2N4402 and 2N4403 lines, and the same units were used to develop the correspondingly-numbered curves on each graph.

FIGURE 11 — CURRENT GAIN

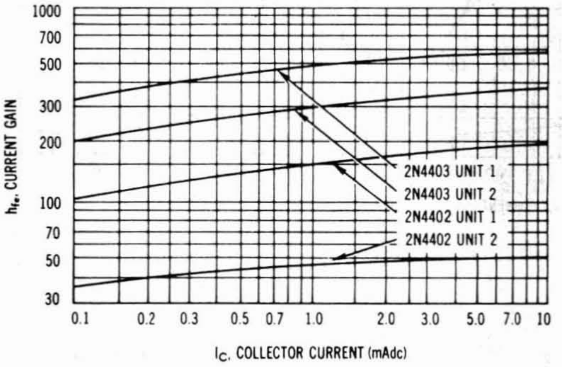


FIGURE 12 — INPUT IMPEDANCE

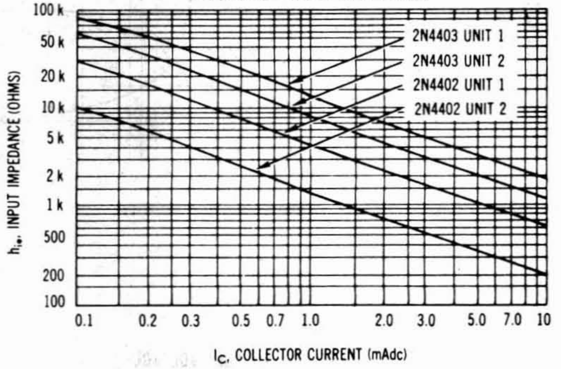


FIGURE 13 — VOLTAGE FEEDBACK RATIO

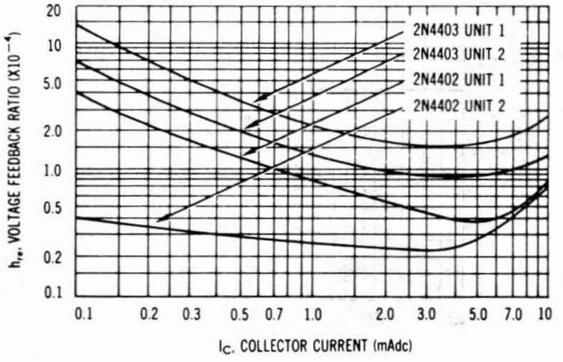
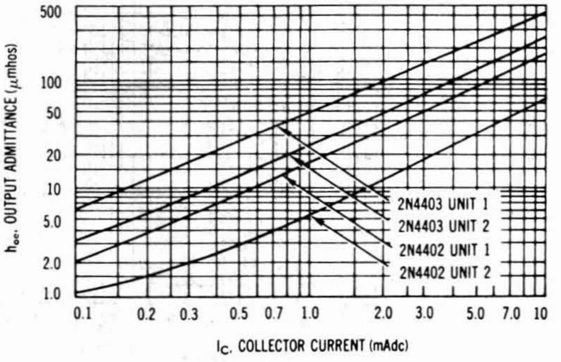


FIGURE 14 — OUTPUT ADMITTANCE



STATIC CHARACTERISTICS

FIGURE 15 — DC CURRENT GAIN

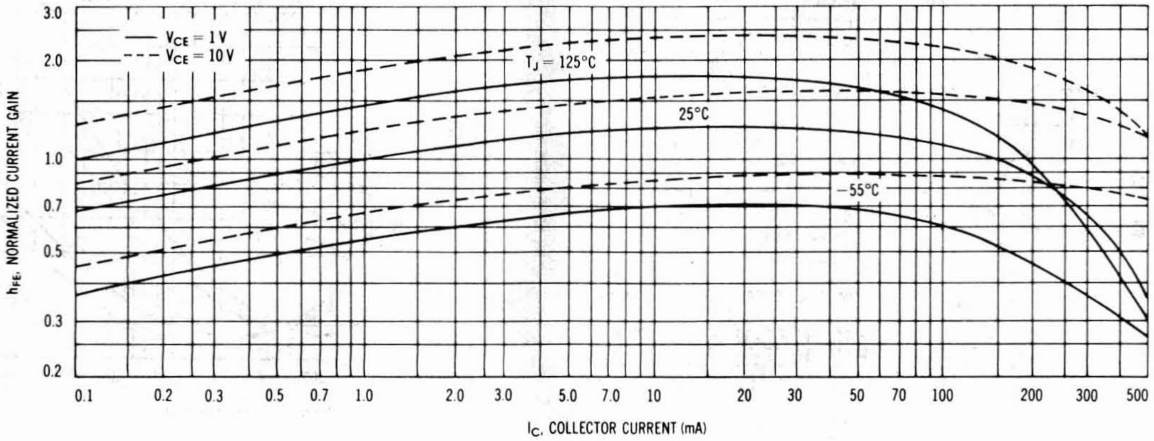


FIGURE 16 — COLLECTOR SATURATION REGION

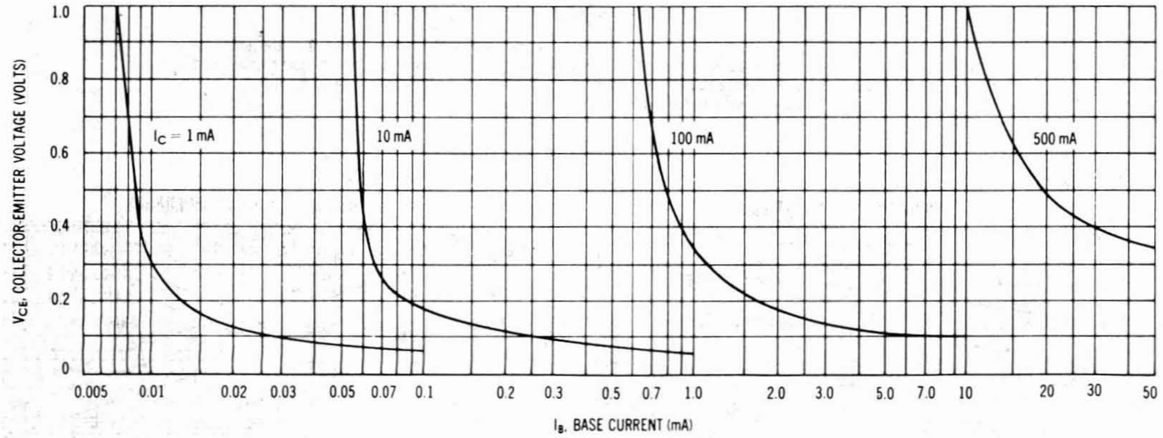


FIGURE 17 — "ON" VOLTAGE

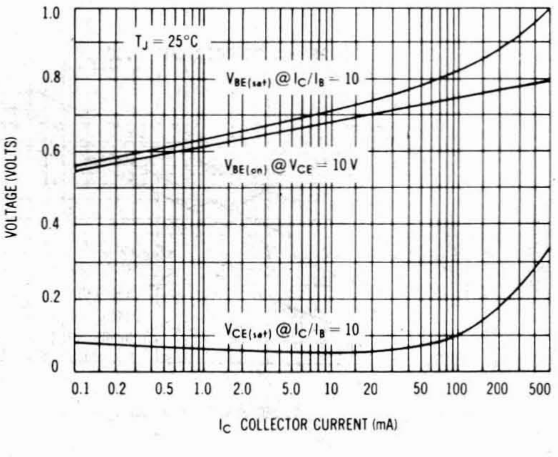
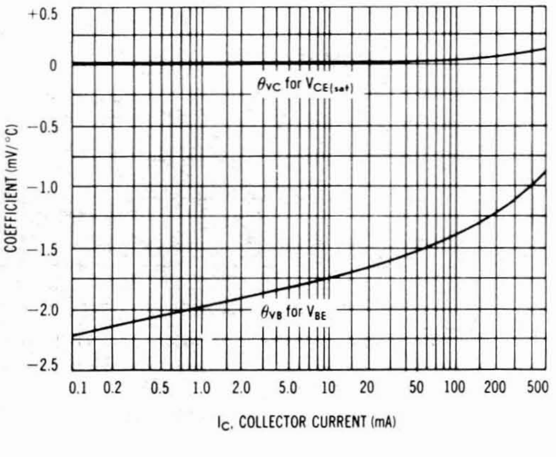
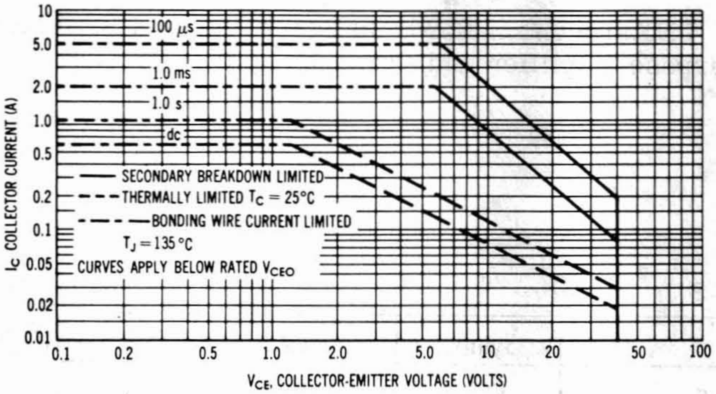


FIGURE 18 — TEMPERATURE COEFFICIENTS



RATINGS AND THERMAL DATA

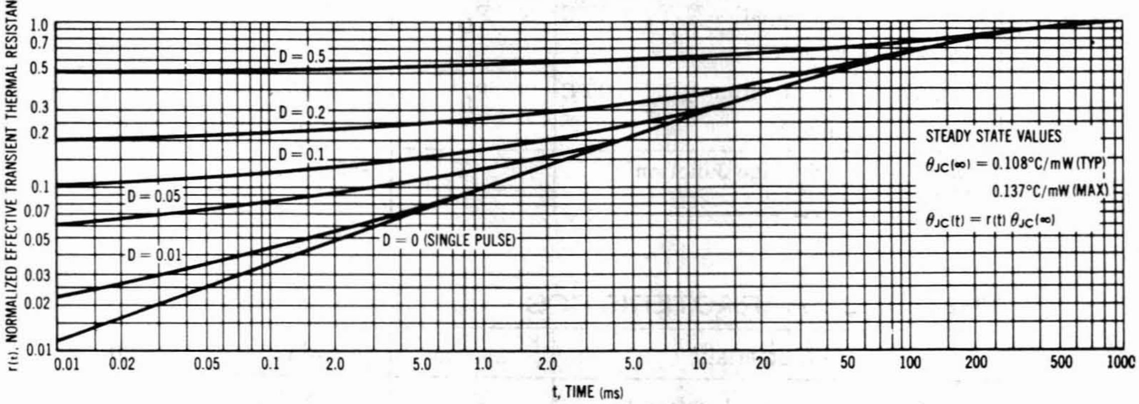
FIGURE 19 — ACTIVE-REGION SAFE OPERATING AREA



The safe operating area curves indicate I_C-V_{CE} limits of the transistor that must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

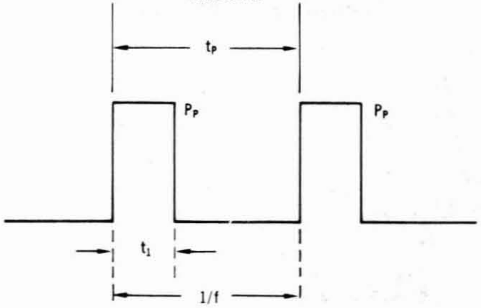
The data of Figure 19 is based upon $T_{J(pk)} = 135°C$; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} \leq 135°C$. $T_{J(pk)}$ may be calculated from the data in Figure 20. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by the secondary breakdown.

FIGURE 20 — THERMAL RESPONSE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



DUTY CYCLE $D = t_1 f = \frac{t_1}{t_P}$

PEAK PULSE POWER = P_P

A train of periodical power pulses can be represented by the model as shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 20 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 20 by the steady state value $\theta_{JC}(\infty)$.

Example:

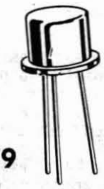
The 2N4402 is dissipating 2.0 watts under the following conditions: $t_1 = 1.0$ ms, $t_P = 5.0$ ms. $(D = 0.2)$

Using Figure 20, at a pulse width of 1.0 ms and D = 0.2, the reading of r (t) is 0.27.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P_P \times \theta_{JC}(\infty) = 0.27 \times 2000 \times 0.137 = 74.0°C$$

2N4404 (SILICON)
2N4405



CASE 79
(TO-39)

PNP silicon annular transistors designed for general-purpose amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	80	Vdc
Collector-Base Voltage	V_{CB}	80	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	1.0	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.25 7.15	Watts mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	7.0 40	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	25	°C/W
Thermal Resistance, Junction to Ambient (Lead Length 1/4")	θ_{JA}	140	°C/W

SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 – TURN-ON

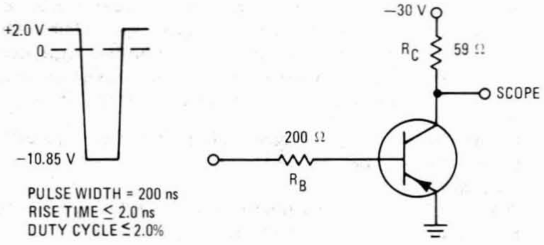
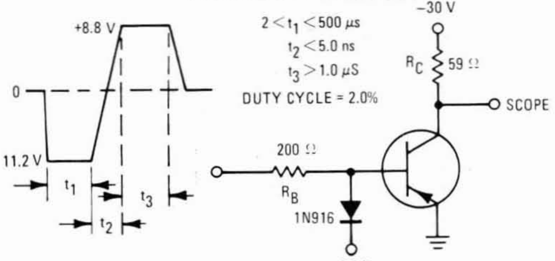

+2.0 V
0
−10.85 V
PULSE WIDTH = 200 ns
RISE TIME ≤ 2.0 ns
DUTY CYCLE ≤ 2.0%
−30 V
R_C
59 Ω
SCOPE
200 Ω
R_B

FIGURE 2 – TURN-OFF


+8.8 V
0
11.2 V
t_1
t_2
t_3
$2 < t_1 < 500\ \mu s$
$t_2 < 5.0$ ns
$t_3 > 1.0\ \mu S$
DUTY CYCLE = 2.0%
−30 V
R_C
59 Ω
SCOPE
200 Ω
R_B
1N916
+3.0 V

To obtain data for curves, voltage levels are approximately as shown, R_B and R_C are varied.

2N4404, 2N4405 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)		BV_{CEO}*	80	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	80	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)		I_{CBO}	-	25	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)		I_{EBO}	-	25	nAdc

ON CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 1.0 Vdc)	2N4404 2N4405	h_{FE}	30 75	- -	-
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	2N4404 2N4405		40 100	- -	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc)*	2N4404 2N4405		40 100	120 300	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)*	2N4404 2N4405		15 25	- -	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 150 mAdc, I_B = 15 mAdc)* (I_C = 500 mAdc, I_B = 50 mAdc)*		$V_{CE(sat)}$	- - -	0.15 0.2 0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)*		$V_{BE(sat)}$	- 0.85	0.8 1.2	Vdc
Base-Emitter On Voltage* (I_C = 150 mAdc, V_{CE} = 1.0 Vdc)		$V_{BE(on)}$*	-	0.9	Vdc

DYNAMIC CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		f_T	200	600	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)		C_{cb}	-	10	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)		C_{eb}	-	75	pF

SWITCHING CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Delay Time	(V_{CC} = 30 Vdc, $V_{BE(off)}$ = 2.0 Vdc, I_C = 500 mAdc, I_{B1} = 50 mAdc) (Figure 1)	t_d	-	15	ns
Rise Time		t_r	-	25	ns
Storage Time	(V_{CC} = 30 Vdc, I_C = 500 mAdc, I_{B1} = I_{B2} = 50 mAdc) (Figure 2)	t_s	-	175	ns
Fall Time		t_f	-	35	ns

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

TRANSIENT CHARACTERISTICS

——— 25°C   – – –100°C

FIGURE 3 – CAPACITANCES

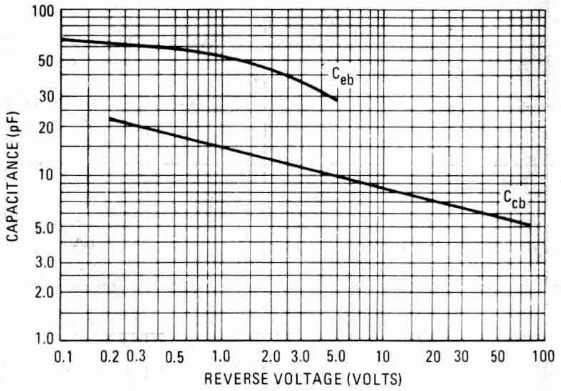


FIGURE 4 – CHARGE DATA

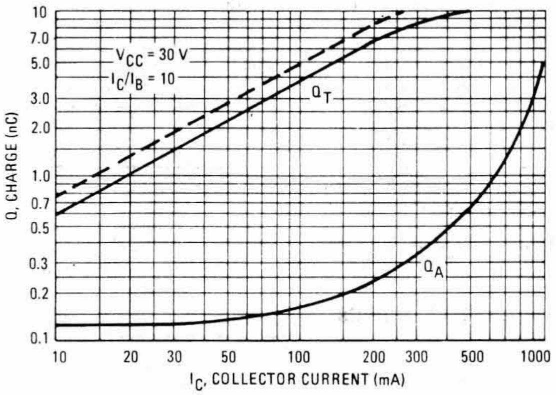


FIGURE 5 – DELAY TIME

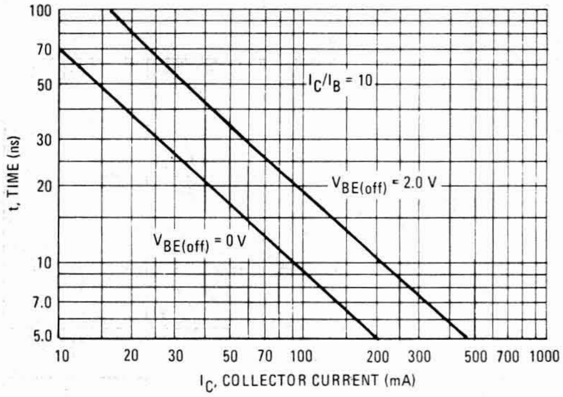


FIGURE 6 – RISE TIME

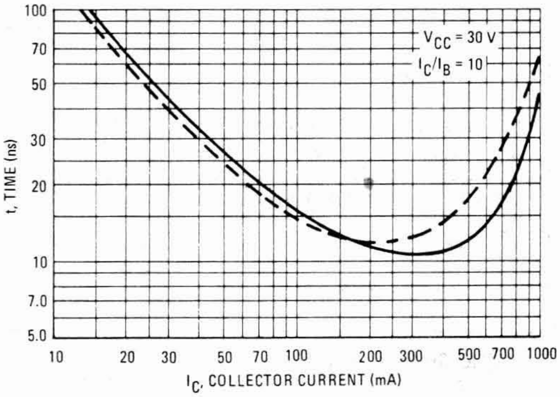


FIGURE 7 – STORAGE TIME

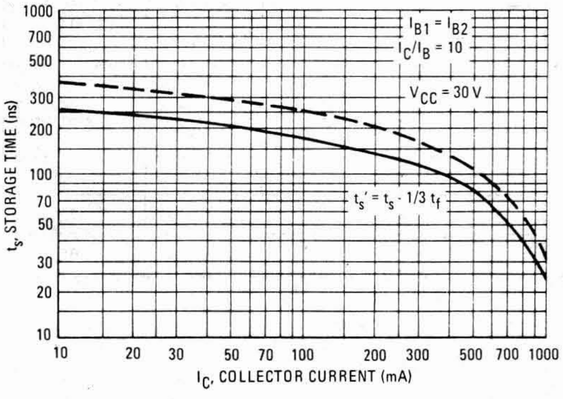
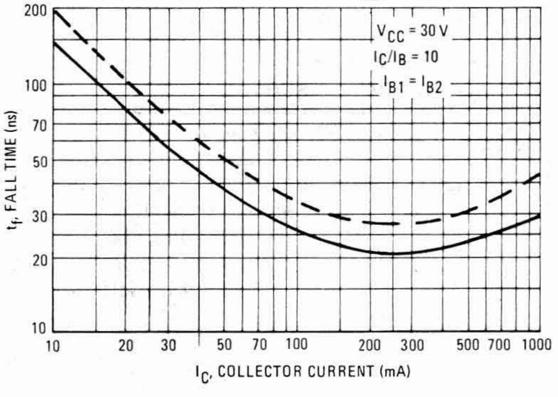


FIGURE 8 – FALL TIME



SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE

$V_{CE} = 10$ Vdc, $T_A = 25°C$

FIGURE 9 – FREQUENCY EFFECTS

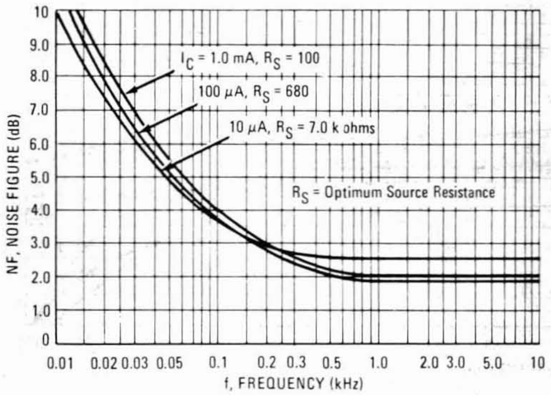
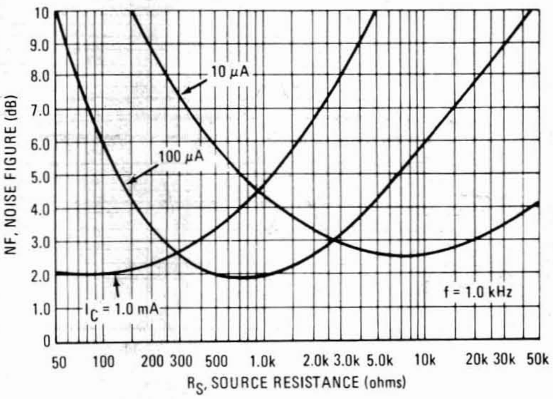


FIGURE 10 – SOURCE RESISTANCE EFFECTS



h PARAMETERS

$V_{CE} = 10$ Vdc, f = 1.0 kHz, $T_A = 25°C$

This group of graphs illustrates the relationship of the "h" parameters for this series of transistors. To obtain these curves, 4 units were selected and identified by number – the same units were used to develop curves on each graph.

FIGURE 11 – CURRENT GAIN

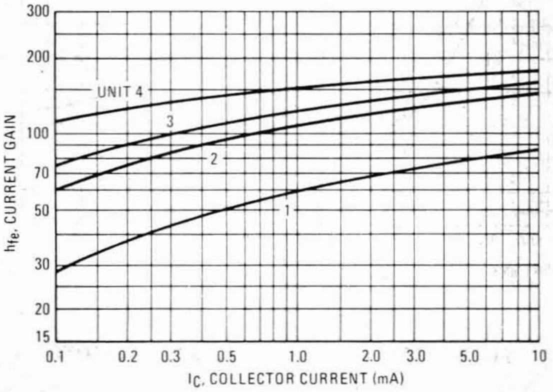


FIGURE 12 – INPUT IMPEDANCE

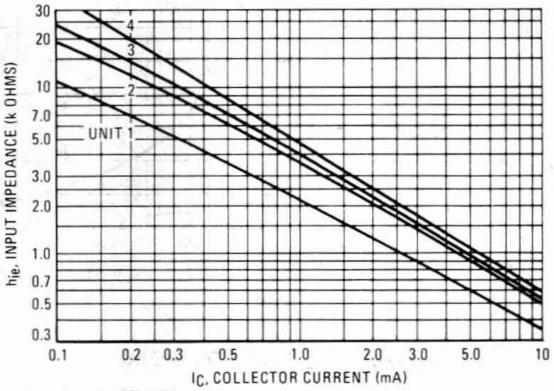


FIGURE 13 – VOLTAGE FEEDBACK RATIO

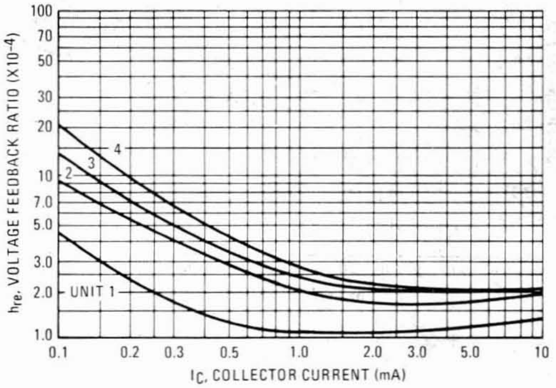
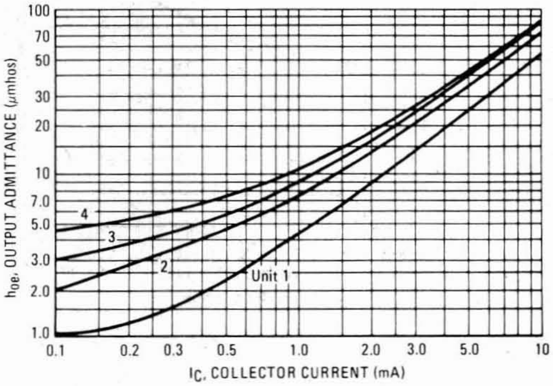


FIGURE 14 – OUTPUT ADMITTANCE



STATIC CHARACTERISTICS

FIGURE 15 – DC CURRENT GAIN

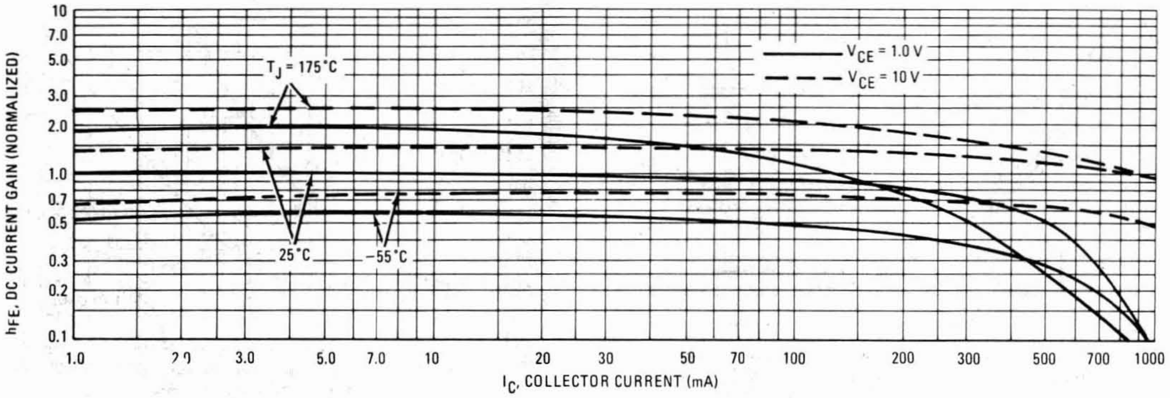


FIGURE 16 – COLLECTOR SATURATION REGION

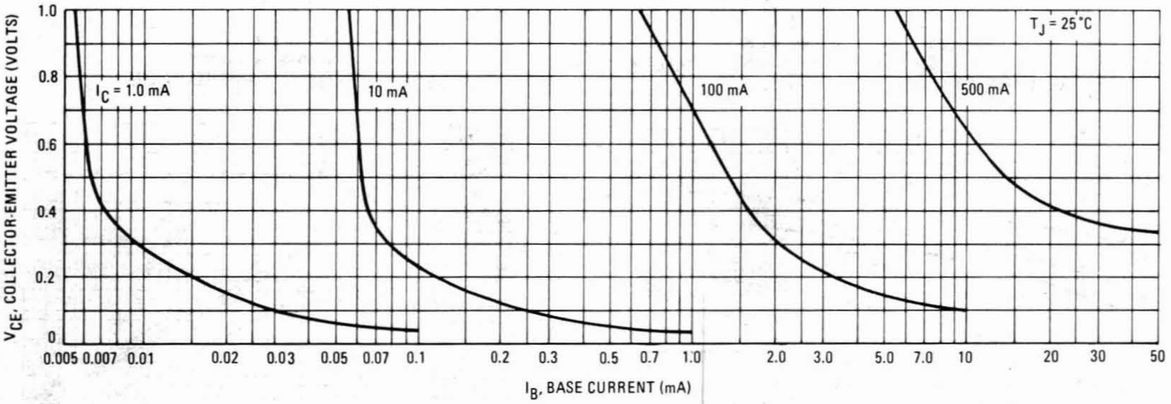


FIGURE 17 – "ON" VOLTAGES

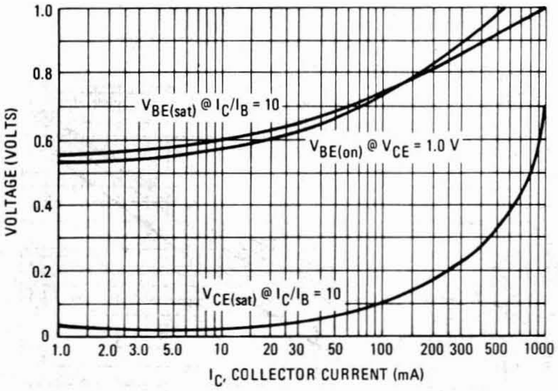
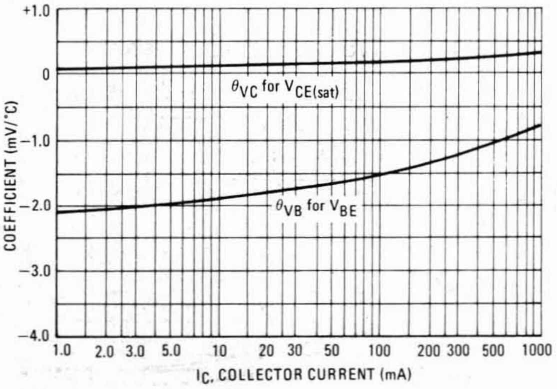
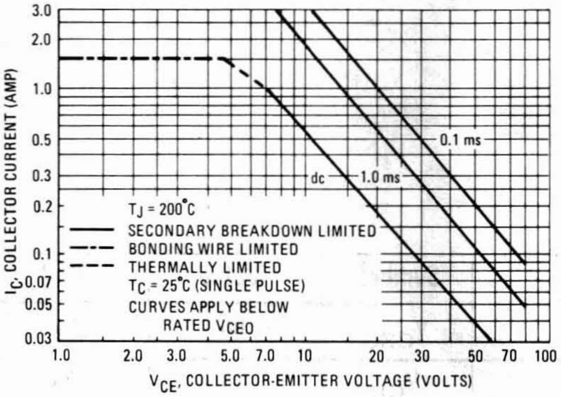


FIGURE 18 – TEMPERATURE COEFFICIENTS



RATINGS AND THERMAL DATA

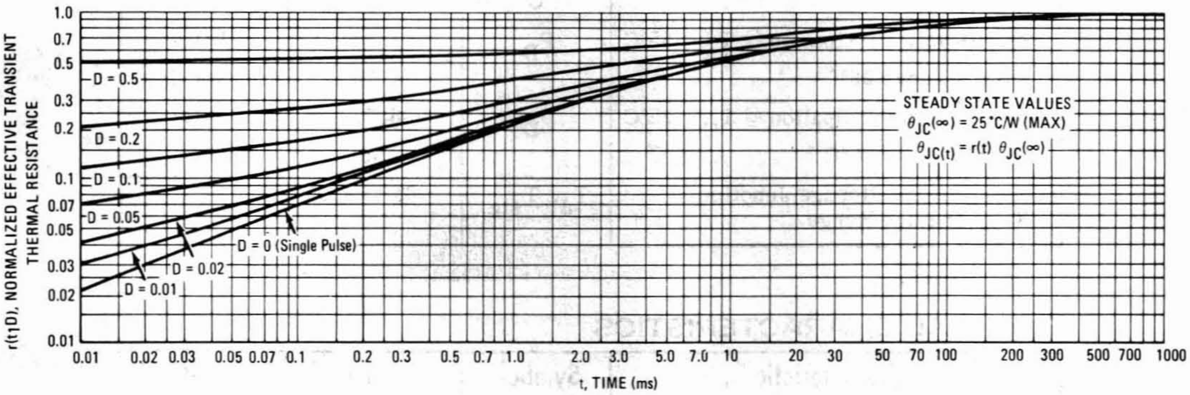
FIGURE 19 – SAFE OPERATING AREA



The safe operating area curves indicate I_C-V_{CE} limits of the transistor that must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

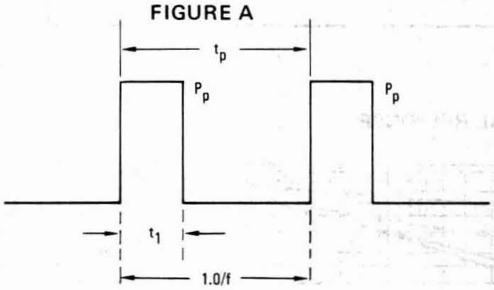
The data of Figure 19 is based upon $T_{J(pk)}$ = 200°C; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} \leqq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 20. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

FIGURE 20 – THERMAL RESPONSE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



DUTY CYCLE $D = t_1 f = \frac{t_1}{t_p}$

PEAK PULSE POWER = P_p

A train of periodical power pulses can be represented by the model as shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 20 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 20 by the steady state value $\theta_{JC}(\infty)$.

Example:

If the 2N4404 is dissipating 8.0 watts peak under the following conditions: t_1 = 1.0 ms, t_p = 5.0 ms, (D = 0.2), find ΔT.

Using Figure 20 at a pulse width of 1.0 ms and D = 0.2, the reading of $r(t_1 D)$ is 0.4.

The peak rise in junction temperature above case temperature is, therefore, $\Delta T = r(t_1 D) \times P_p \times \theta_{JC}(\infty) = 0.4 \times 8.0 \times 25 = 80°C$.

2N4406 (SILICON)
2N4407

CASE 79
(TO-39)

PNP silicon annular transistors designed for general-purpose amplifier and switching applications.

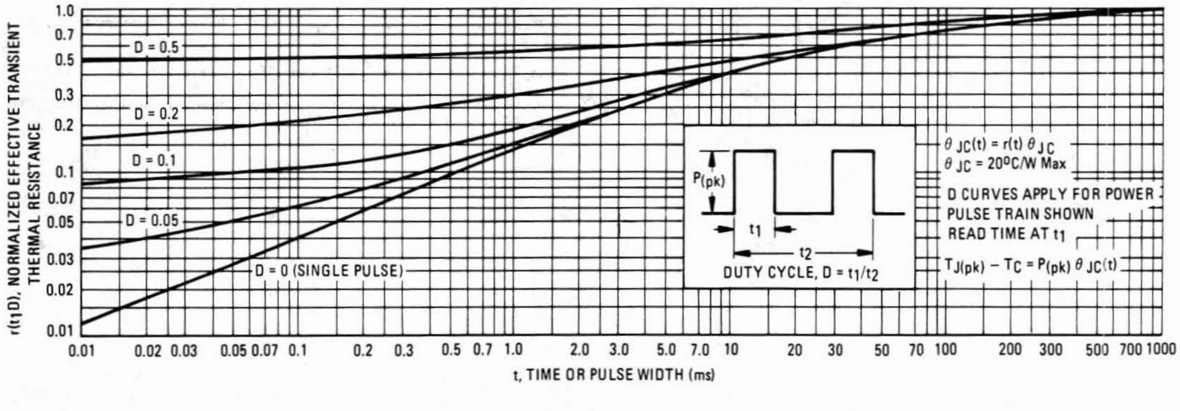
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	80	Vdc
Collector-Base Voltage	V_{CB}	80	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	2.0	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.25 7.15	Watts mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	8.75 50	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	20	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	140	°C/W

FIGURE 1 - THERMAL RESPONSE



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	80	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	80	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)	I_{CBO}	-	25	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	25	nAdc
ON CHARACTERISTICS				
DC Current Gain*	h_{FE}*			-
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc) 2N4406		30	-	
2N4407		80	-	
(I_C = 150 mAdc, V_{CE} = 1.0 Vdc) 2N4406		25	100	
2N4407		75	225	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc) 2N4406		20	-	
2N4407		35	-	
(I_C = 1.0 Adc, V_{CE} = 1.0 Vdc) 2N4406		10	-	
2N4407		15	-	
(I_C = 1.5 Adc, V_{CE} = 5.0 Vdc) 2N4406, 2N4407		10	-	
Collector-Emitter Saturation Voltage*	$V_{CE(sat)}$*			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	0.2	
(I_C = 500 mAdc, I_B = 50 mAdc)		-	0.4	
(I_C = 1.0 Adc, I_B = 100 mAdc)		-	0.7	
(I_C = 1.5 Adc, I_B = 150 mAdc)		-	1.5	
Base-Emitter Saturation Voltage*	$V_{BE(sat)}$*			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	0.9	
(I_C = 1.0 Adc, I_B = 100 mAdc)		0.9	1.3	
(I_C = 1.5 Adc, I_B = 150 mAdc)		-	1.5	
Base-Emitter On Voltage* (I_C = 500 mAdc, V_{CE} = 1.0 Vdc)	$V_{BE(on)}$*	-	1.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	150	750	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{cb}	-	15	pF
Collector-Emitter Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{eb}	-	160	pF

SWITCHING CHARACTERISTICS

Delay Time	(V_{CC} = 30 Vdc, $V_{BE(off)}$ = 2.0 Vdc, I_C = 1.0 Adc, I_{B1} = 100 mAdc) (Figure 11)	t_d	-	15	ns
Rise Time		t_r	-	60	ns
Storage Time	(V_{CC} = 30 Vdc, I_C = 1.0 Adc, I_{B1} = I_{B2} = 100 mAdc) (Figure 12)	t_s	-	175	ns
Fall Time		t_f	-	50	ns

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

STATIC CHARACTERISTICS

FIGURE 2 - DC CURRENT GAIN

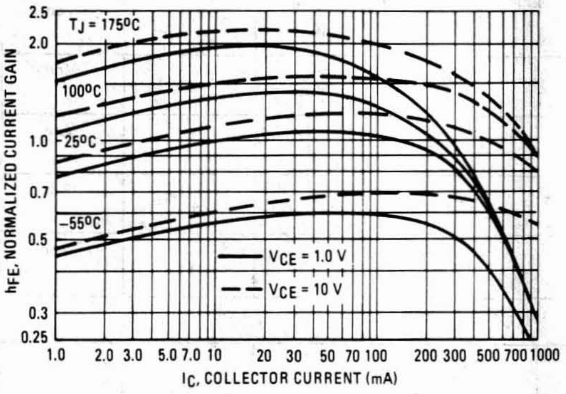


FIGURE 3 - COLLECTOR SATURATION REGION

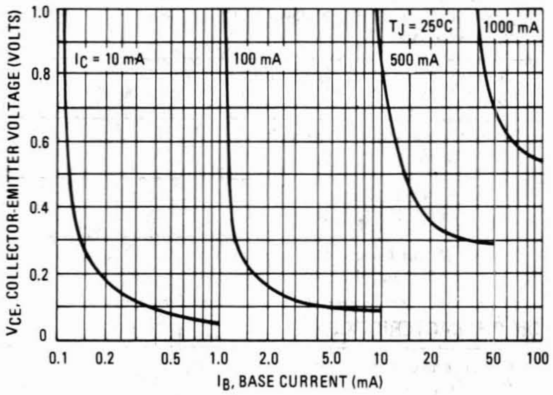


FIGURE 4 - "ON" VOLTAGES

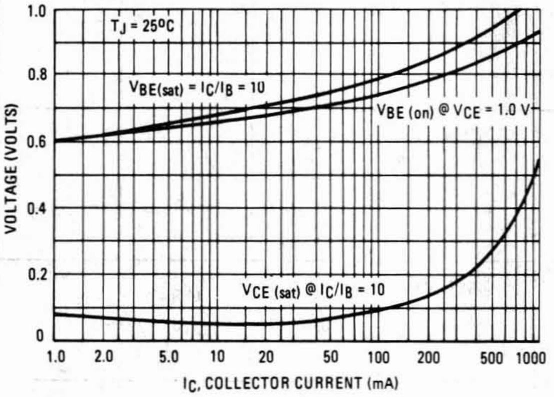


FIGURE 5 - TEMPERATURE COEFFICIENTS

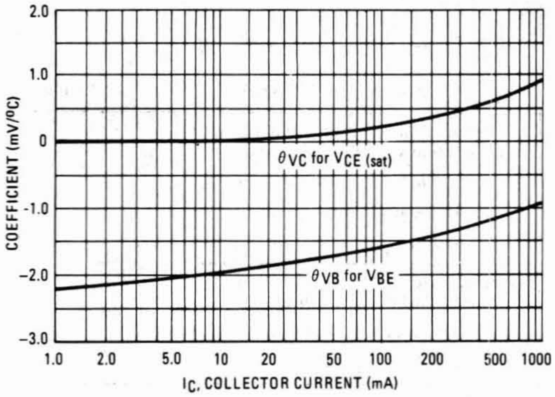
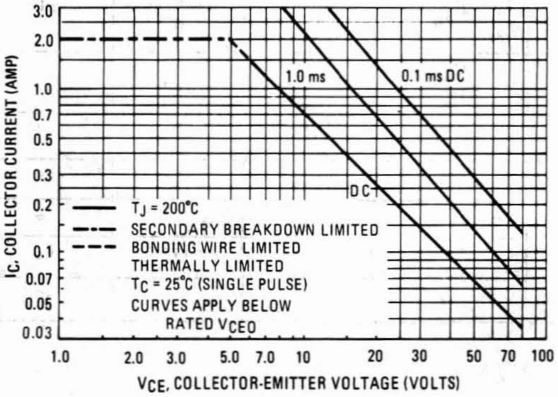


FIGURE 6 - SAFE OPERATING AREA



The safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

The data of Figure 6 is based upon $T_{J(pk)}$ = 200°C; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} \leqq$ 200°C. $T_{J(pk)}$ may be calculated from the data in Figure 1. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by second breakdown.

TRANSIENT CHARACTERISTICS

—— 25°C ---- 100°C

FIGURE 7 - CAPACITANCES

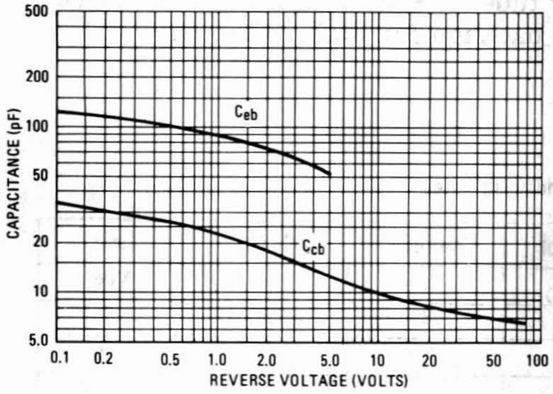


FIGURE 8 - CHARGE DATA

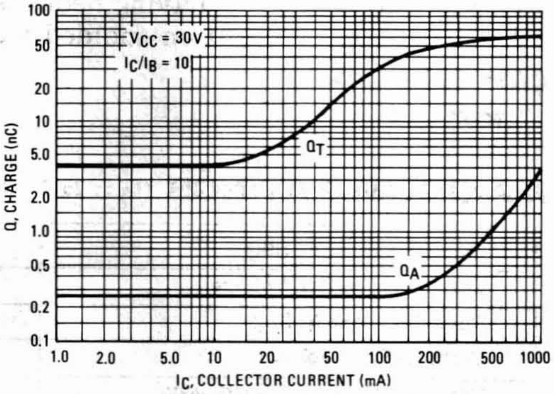


FIGURE 9 - TURN-ON TIME

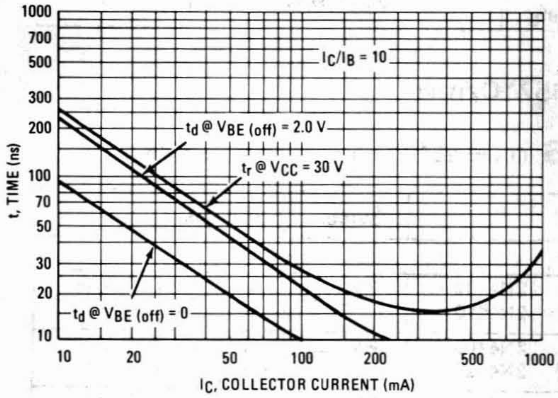
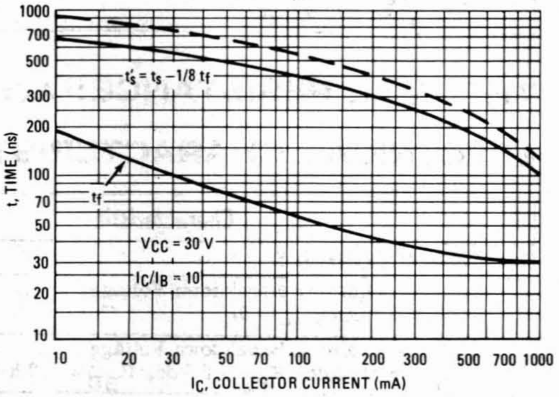


FIGURE 10 - TURN-OFF TIME



SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 11 - TURN-ON TIME

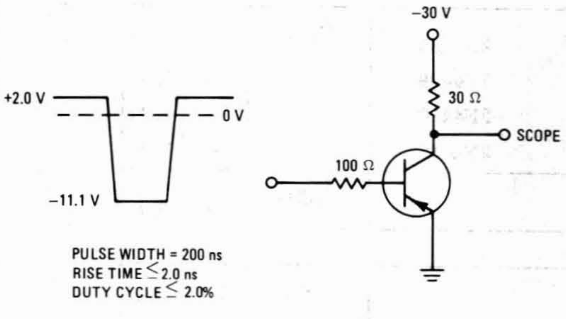
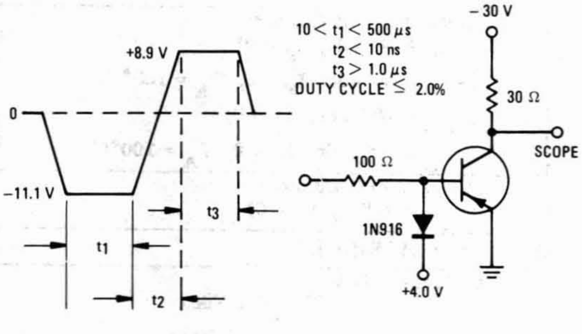
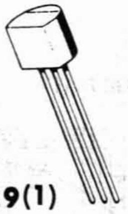

+2.0 V
0 V
−11.1 V
−30 V
30 Ω
SCOPE
100 Ω
PULSE WIDTH = 200 ns
RISE TIME ≤ 2.0 ns
DUTY CYCLE ≤ 2.0%

FIGURE 12 - TURN-OFF TIME


+8.9 V
0
−11.1 V
t_1
t_2
t_3
$10 < t_1 < 500\,\mu s$
$t_2 < 10$ ns
$t_3 > 1.0\,\mu s$
DUTY CYCLE ≤ 2.0%
−30 V
30 Ω
SCOPE
100 Ω
1N916
+4.0 V

2N4409 (SILICON)
2N4410



NPN silicon epitaxial transistors designed for driving neon display tubes. Features one-piece, injection-molded plastic package for high reliability.

CASE 29(1)
(TO-92)

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	2N4409	2N4410	Unit
Collector-Emitter Voltage	V_{CEO}	50	80	Vdc
Collector-Base Voltage	V_{CB}	80	120	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	Vdc
Collector Current - Continuous	I_C	250		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81		mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

THERMAL RESISTANCE: $\theta_{JA} = 0.357$°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)	2N4409 2N4410	BV_{CEO}	50 80	— —	Vdc
Collector-Emitter Breakdown Voltage (I_C = 500 µAdc, V_{BB} = 5 Vdc, R_{BE} = 8.2 k ohms)	2N4409 2N4410	BV_{CEX}	80 120	— —	Vdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_C = 0)	2N4409 2N4410	BV_{CBO}	80 120	— —	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)		BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) (V_{CB} = 60 Vdc, I_E = 0, T_A = 100°C) (V_{CB} = 100 Vdc, I_E = 0) (V_{CB} = 100 Vdc, I_E = 0, T_A = 100°C)	2N4409 2N4409 2N4410 2N4410	I_{CBO}	— — — —	0.01 1.0 0.01 1.0	µAdc
Emitter Cutoff Current (V_{BE} = 4 Vdc, I_C = 0)		I_{EBO}	—	0.1	µAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 1 mAdc, V_{CE} = 1 Vdc) (I_C = 10 mAdc, V_{CE} = 1 Vdc)		h_{FE}	60 60	400 —	—
Collector-Emitter Saturation Voltage (I_C = 1 mAdc, I_B = 0.1 mAdc)		$V_{CE(sat)}$	—	0.2	Vdc
Base-Emitter Saturation Voltage (I_C = 1 mAdc, I_B = 0.1 mAdc)		$V_{BE(sat)}$	—	0.8	Vdc
Base-Emitter On Voltage (I_C = 1 mAdc, V_{CE} = 5 Vdc)		$V_{BE(on)}$	—	0.8	Vdc

2N4409, 2N4410 (continued)

DYNAMIC CHARACTERISTICS

Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 30 MHz)	f_T	60	300	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz, emitter guarded)	C_{cb}	—	12	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz, collector guarded)	C_{eb}	—	50	pF

TYPICAL DC CHARACTERISTICS

FIGURE 1 — CURRENT GAIN

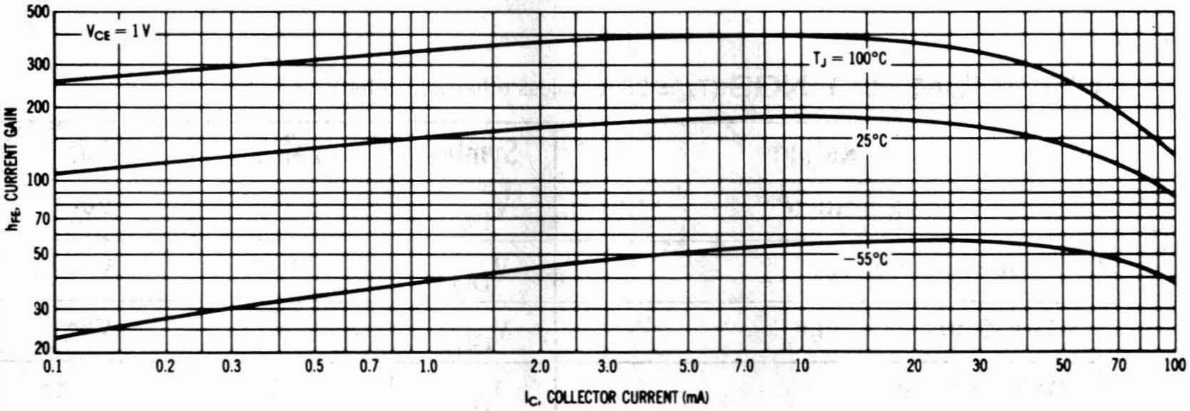


FIGURE 2 — SATURATION VOLTAGES

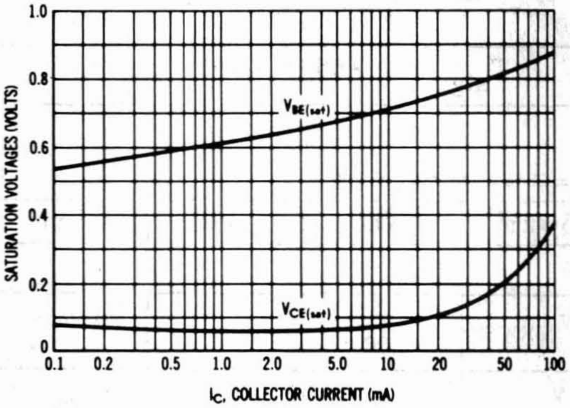


FIGURE 3 — TEMPERATURE COEFFICIENTS

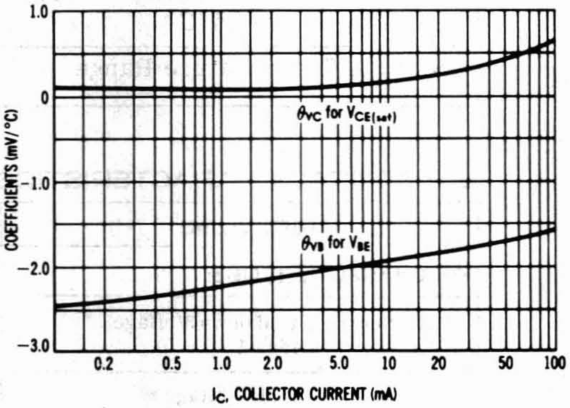


FIGURE 4 — CUTOFF CURRENT

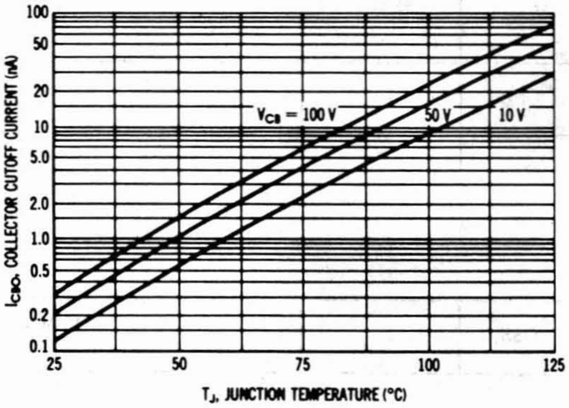
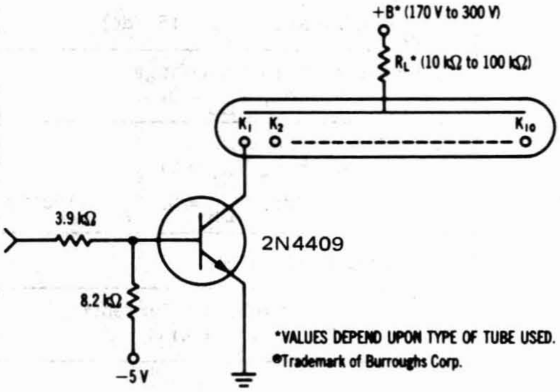


FIGURE 5 — TYPICAL NIXIE® DRIVER APPLICATION



*VALUES DEPEND UPON TYPE OF TUBE USED.
®Trademark of Burroughs Corp.

2N4416 (SILICON)

CASE 20 (1)
(TO-72)

Silicon N-channel junction field-effect transistor designed for VHF/UHF amplifier applications.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	30	Vdc
Gate Current	I_G	10	mAdc
Total Device Dissipation @ T_A @ 25°C Derate above 25°C	P_D	300 1.7	mW mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

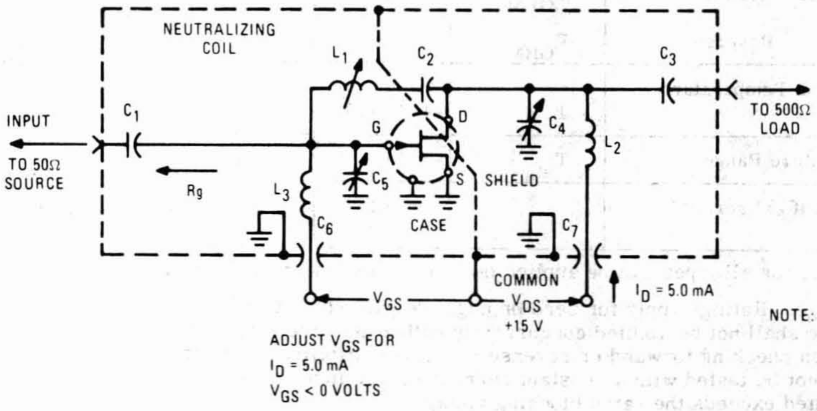
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_G = -1.0 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	30	-	Vdc
Gate-Source Cutoff Voltage (I_D = 1.0 nAdc, V_{DS} = 15 Vdc)	$V_{GS(off)}$	-	6.0	Vdc
Gate-Source Voltage (I_D = 0.5 mAdc, V_{DS} = 15 Vdc)	V_{GS}	1.0	5.5	Vdc
Gate-Source Forward Voltage (I_G = 1.0 mAdc, V_{DS} = 0)	$V_{GS(f)}$	-	1.0	Vdc
Gate Reverse Current (V_{GS} = -20 Vdc, V_{DS} = 0) (V_{GS} = -20 Vdc, V_{DS} = 0, T_A = +150°C)	I_{GSS}	- -	100 200	pAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0)	I_{DSS}*	5.0	15	mAdc

SMALL-SIGNAL CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Forward Transfer Admittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	$\|y_{fs}{}^{*}\|$	4500	7500	μmhos
Real Part of Forward Transconductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)	$RE(y_{fs})$	4000	-	μmhos
Real Part of Input Conductance	$RE(y_{is})$			μmhos
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)		-	100	
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)		-	1000	
Output Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	$\|y_{os}\|$	-	50	μmhos
Real Part of Output Conductance	$RE(y_{os})$			μmhos
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)		-	75	
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)		-	100	
Imaginary Part of Input Susceptance	$IM(y_{is})$			μmhos
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)		-	2500	
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)		-	10,000	
Imaginary Part of Output Susceptance	$IM(y_{os})$			μmhos
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)		-	1000	
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)		-	4000	
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	-	4.0	pF
Common-Source Output Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{osp}	-	2.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	-	0.8	pF
Common-Source Spot Noise Figure (Figure 1)	NF			dB
(V_{DS} = 15 Vdc, I_D = 5.0 mAdc, R_g ≈ 1000 ohms, f = 100 MHz)		-	2.0	
(V_{DS} = 15 Vdc, I_D = 5.0 mAdc, R_g ≈ 1000 ohms, f = 400 MHz)		-	4.0	
Small-Signal Power Gain (Figure 1)	G_{ps}			dB
(V_{DS} = 15 Vdc, I_D = 5.0 mAdc, f = 100 MHz)		18	-	
(V_{DS} = 15 Vdc, I_D = 5.0 mAdc, f = 400 MHz)		10	-	

* Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1.0%.

FIGURE 1 – 100 MHz & 400 MHz NEUTRALIZED AMPLIFIER



Reference Designation	VALUE	
	100 MHZ	400 MHz
C_1	7.0 pF	1.8 pF
C_2	1000 pF	17 pF
C_3	3.0 pF	1.0 pF
C_4	1-12 pF	0.8-8.0 pF
C_5	1-12 pF	0.8-8.0 pF
C_6	0.0015 μF	0.001 μF
C_7	0.0015 μF	0.001 μF
L_1	3.0 μH*	0.2 μH**
L_2	0.15 μH*	0.03 μH**
L_3	0.14 μH*	0.022 μH**

NOTE: The noise source is a hot-cold body (AIL type 70 or equivalent) with a test receiver (AIL type 136 or equivalent).

* L_1 17 turns, (approx. – depends upon circuit layout) AWG #28 enameled copper wire, close wound on 9/32" ceramic coil form. Tuning provided by a powdered iron slug.

L_2 4 1/2 turns, AWG #18 enameled copper wire, 5/16" long, 3/8" I.D. (AIR CORE).

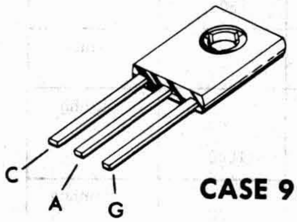
L_3 3 1/2 turns, AWG #18 enameled copper wire, 1/4" long, 3/8" I.D. (AIR CORE).

** L_1 6 turns, (approx. – depends upon circuit layout) AWG #24 enameled copper wire, close wound on 7/32" ceramic coil form. Tuning provided by an aluminum slug.

L_2 1 turn, AWG #16 enameled copper wire, 3/8" I.D. (AIR CORE).

L_3 1/2 turn, AWG #16 enameled copper wire, 1/4" I.D. (AIR CORE).

2N4441 thru 2N4444 (SILICON)



CASE 90(1)

Plastic thyristors (silicon controlled rectifiers) designed for high-volume consumer phase-control applications such as motor speed, temperature, and light controls and for switching applications in ignition and starting systems, voltage regulators, vending machines, and lamp drivers,etc.

MAXIMUM RATINGS (T_J = 100° C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage (Note 1) 2N4441	$V_{ROM(rep)}$	50	Volts
2N4442		200	
2N4443		400	
2N4444		600	
Peak Reverse Blocking Voltage (Non-Recurrent, t = 5.0 ms (max) duration) 2N4441	$V_{ROM(non\ rep)}$	75	Volts
2N4442		300	
2N4443		500	
2N4444		700	
Forward Current RMS (All Conduction Angles)	I_f	8.0	Amps
Peak Forward Surge Current (1/2 cycle, 60 Hz, T_J = -40 to +100°C)	$I_{FM(surge)}$	80	Amps
Circuit Fusing Considerations (T_J = -40 to +100°C; t = 1.0 to 8.3 ms)	I^2t	25	A^2s
Peak Gate Power - Forward	P_{GFM}	5.0	Watts
Average Gate Power - Forward	$P_{GF(AV)}$	0.5	Watt
Peak Gate Current - Forward	I_{GFM}	2.0	Amps
Peak Gate Voltage - Forward	V_{GFM}	10	Volts
Reverse	V_{GRM}	10	
Operating Junction Temperature Range	T_J	-40 to +100	°C
Storage Temperature Range	T_{stg}	-40 to +150	°C
Mounting Torque (6-32 screw) (Note 2)	-	12	in. lb.

1. V_{FOM} and V_{ROM} for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for zero or negative gate voltage but positive gate voltage shall not be applied concurrently with a negative potential on the anode. When checking forward or reverse blocking capability, thyristor devices should not be tested with a constant current source in a manner that the voltage applied exceeds the rated blocking voltage.
2. Torque rating applies with use of torque washer (Shakeproof WD19522 #6 or equivalent). Mounting torque in excess of 8 in. lbs. does not appreciably lower case-to-sink thermal resistance. Anode lead and heatsink contact pad are common.

For soldering purposes (either terminal connection or device mounting), soldering temperatures shall not exceed +225°C. For optimum results, an activated flux (oxide removing) is recommended.

2N4441 thru 2N4444 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristics	Symbol	Min	Typ	Max	Unit
Peak Forward Blocking Voltage ($T_J = 100°C$) Note 1 2N4441 2N4442 2N4443 2N4444	V_{FOM}	 50 200 400 600	 - - - -	 - - - -	Volts
Peak Forward Blocking Current (Rated V_{FOM} @ $T_J = 100°C$, gate open)	I_{FOM}	-	-	2.0	mA
Peak Reverse Blocking Current (Rated V_{ROM} @ $T_J = 100°C$, gate open)	I_{ROM}	-	-	2.0	mA
Forward "On" Voltage ($I_F = 5.0$ A peak) ($I_F = 15.7$ A peak)	V_F	 - -	 1.0 -	 1.5 2.5 ‡	Volts
Gate Trigger Current (Continuous dc) (Anode Voltage - 7.0 Vdc, $R_L = 100$ ohms) $T_C = 25°C$ $T_C = -40°C$	I_{GT}	 - -	 10 -	 30 60 ‡	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7.0 Vdc, $R_L = 100$ ohms) $T_C = 25°C$ (Anode Voltage = 7.0 Vdc, $R_L = 100$ ohms) $T_C = -40°C$ (Anode Voltage = Rated V_{FOM}, $R_L = 100$ ohms) $T_J = 100°C$	 V_{GT} V_{GT} V_{GNT}	 - - 0.2 ‡	 0.7 - -	 1.5 2.5 ‡ -	Volts
Holding Current (Anode Voltage = 7.0 Vdc, gate open) $T_C = 25°C$ $T_C = -40°C$	I_{HO}	 - -	 10 -	 40 70 ‡	mA
Turn-On Time ($I_F = 5.0$ A, $I_{GT} = 20$ mA)	t_{on}	-	1.0	-	μs
Turn-Off Time ($I_F = 5.0$ A, $I_R = 5.0$ A) ($I_F = 5.0$ A, $I_R = 5.0$ A, $T_J = 100°C$)	t_{off}	 - -	 15 20	 - -	μs
Forward Voltage Application Rate ($T_J = 100°C$)	dv/dt	-	50	-	V/μs
Thermal Resistance, Junction to Case	θ_{JC}	-	-	2.5	°C/W
Thermal Resistance, Case to Ambient	θ_{CA}	-	40	-	°C/W

‡JEDEC registered, non-production line tests.

1. V_{FOM} and V_{ROM} for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for zero or negative gate voltage but positive gate voltage shall not be applied concurrently with a negative potential on the anode. When checking forward or reverse blocking capability, thyristor devices should not be tested with a constant current source in a manner that the voltage applied exceeds the rated blocking voltage.

FIGURE 1 — CURRENT DERATING — HALF WAVE

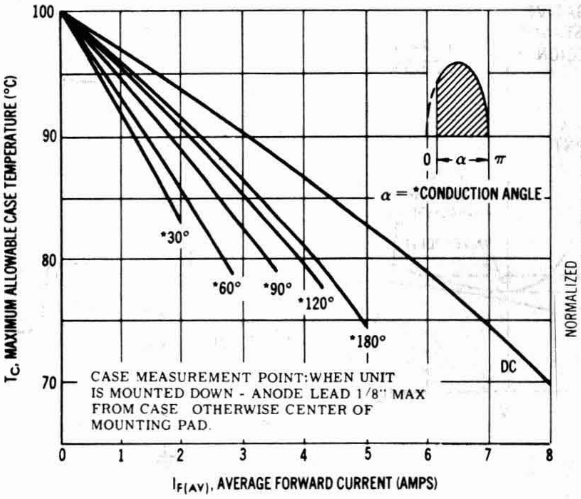
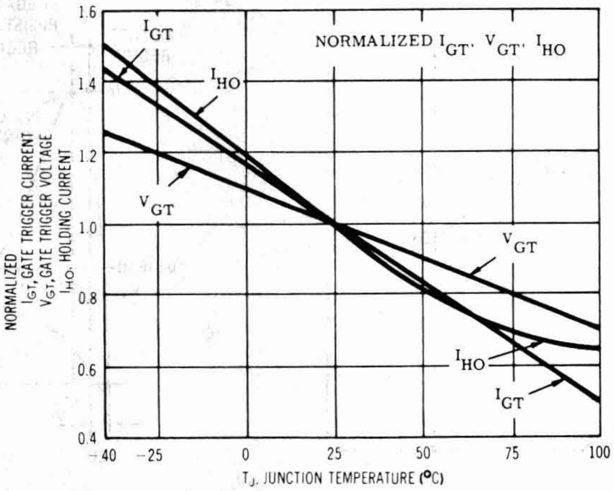


FIGURE 2 — TYPICAL PARAMETER VARIATIONS vs TEMPERATURE



2N4851 thru 2N4853 (SILICON)

CASE 22A
(TO-18 Modified)
Lead 3 connected to case

Silicon annular unijunction transistors designed for pulse and timing circuits, sensing circuits, and thyristor trigger circuits.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	$P_D{}^*$	300	mW
RMS Emitter Current	I_e	50	mA
Peak-Pulse Emitter Current **	$i_e{}^{**}$	1.5	Amp
Emitter Reverse Voltage	V_{B2E}	30	Volts
Interbase Voltage †	$V_{B2B1}{}^{\dagger}$	35	Volts
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

* Derate 3.0 mW/°C increase in ambient temperature.
** Duty cycle ≦ 1%, PRR = 10 PPS (see figure 6)
† Based upon power dissipation at T_A = 25°C

FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

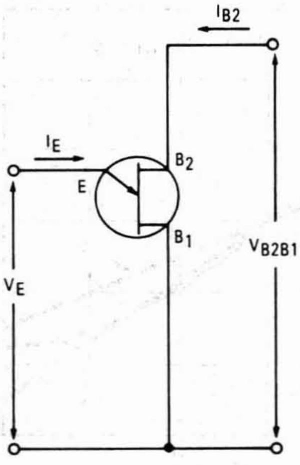


FIGURE 2 — STATIC EMITTER CHARACTERISTICS CURVES

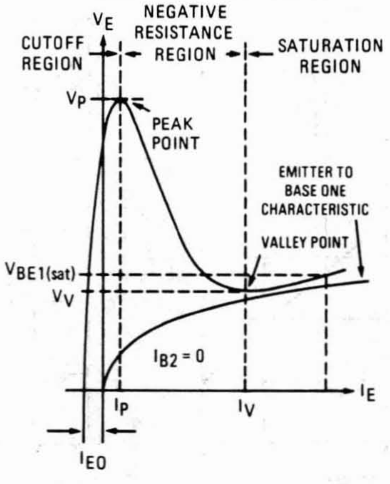
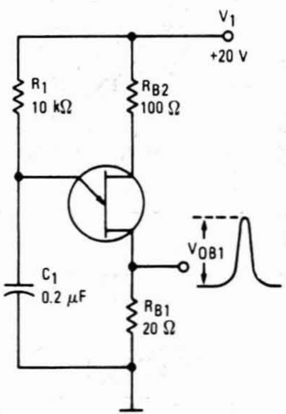


FIGURE 3 — V_{OB1} TEST CIRCUIT



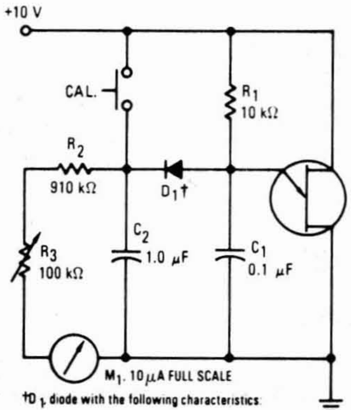
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Figure No.	Symbol	Min	Typ	Max	Unit
Intrinsic Standoff Ratio*	4, 8	η*				—
(V_{B2B1} = 10 V) 2N4851			0.56	—	0.75	
2N4852, 2N4853			0.70	—	0.85	
Interbase Resistance (V_{B2B1} = 3.0 V, I_E = 0)	11, 12	R_{BB}	4.7	—	9.1	k ohms
Interbase Resistance Temperature Coefficient (V_{B2B1} = 3.0 V, I_E = 0, T_A = -65 to +125°C)	12	αR_{BB}	0.2	—	0.8	%/°C
Emitter Saturation Voltage** (V_{B2B1} = 10 V, I_E = 50 mA)		$V_{EB1(sat)}$**	—	2.5	—	Volts
Modulated Interbase Current (V_{B2B1} = 10 V, I_E = 50 mA)		$I_{B2(mod)}$	—	15	—	mA
Emitter Reverse Current	7	I_{EB2O}				µA
(V_{B2E} = 30 V, I_{B1} = 0) 2N4851, 2N4852			—	—	0.1	
2N4853			—	—	0.05	
Peak-Point Emitter Current	9, 10	I_P				µA
(V_{B2B1} = 25 V) 2N4851, 2N4852			—	—	2.0	
2N4853			—	—	0.4	
Valley-Point Current**	13, 14	I_V**				mA
(V_{B2B1} = 20 V, R_{B2} = 100 ohms) 2N4851			2.0	—	—	
2N4852			4.0	—	—	
2N4853			6.0	—	—	
Base-One Peak Pulse Voltage 2N4851	3, 17	V_{OB1}	3.0	—	—	Volts
2N4852			5.0	—	—	
2N4853			6.0	—	—	
Maximum Frequency of Oscillation	5	$f_{(max)}$	1.0	1.25	—	MHz

* η, Intrinsic standoff ratio, is defined in terms of the peak-point voltage, V_P, by means of the equation: $V_P = \eta V_{B2B1} + V_F$, where V_F is about 0.49 volt at 25°C @ I_F = 10 µA and decreases with temperature at about 2.5 mV/°C. The test circuit is shown in Figure 4. Components R_1, C_1, and the UJT form a relaxation oscillator; the remaining circuitry serves as a peak-voltage detector. The forward drop of Diode D_1 compensates for V_F. To use, the "cal" button is pushed, and R_3 is adjusted to make the current meter, M_1, read full scale. When the "cal" button is released, the value of η is read directly from the meter, if full scale on the meter reads 1.0.

** Use pulse techniques: PW ≈ 300 µs, duty cycle ≤ 2.0% to avoid internal heating, which may result in erroneous readings.

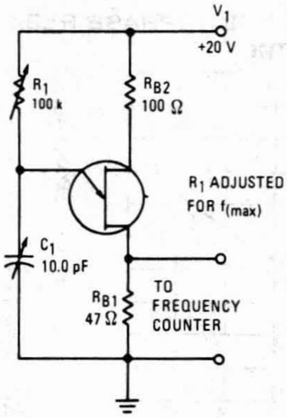
FIGURE 4 — η TEST CIRCUIT



+10 V
CAL.
R1
10 kΩ
R2
910 kΩ
D1†
R3
100 kΩ
C2
1.0 µF
C1
0.1 µF
M1, 10µA FULL SCALE

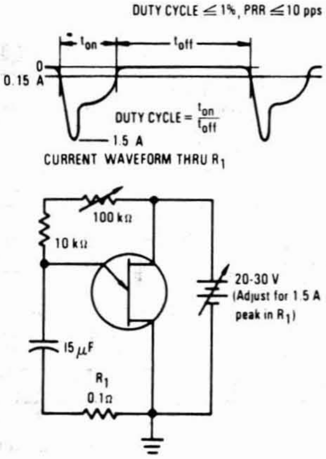
†D1, diode with the following characteristics:
V_F = 0.49 V @ I_F = 10 µA
I_R ≤ 2.0 µA @ V_R = 20 V

FIGURE 5 — $f_{(max)}$ TEST CIRCUIT



V1
+20 V
R1
100 k
RB2
100 Ω
R1 ADJUSTED FOR f(max)
C1
10.0 pF
RB1
47 Ω
TO FREQUENCY COUNTER

FIGURE 6 — PRR TEST CIRCUIT AND WAVEFORM



DUTY CYCLE ≤ 1%, PRR ≤ 10 pps
ton
toff
0
0.15 A
DUTY CYCLE = ton/toff
1.5 A
CURRENT WAVEFORM THRU R1
100 kΩ
10 kΩ
20-30 V (Adjust for 1.5 A peak in R1)
15 µF
R1
0.1Ω

TYPICAL CHARACTERISTICS

FIGURE 7 — EMITTER REVERSE CURRENT

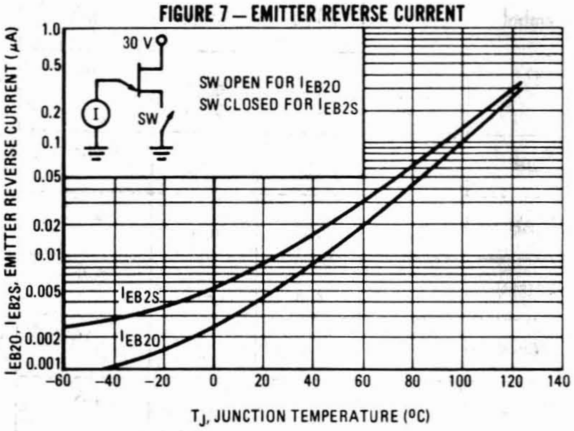
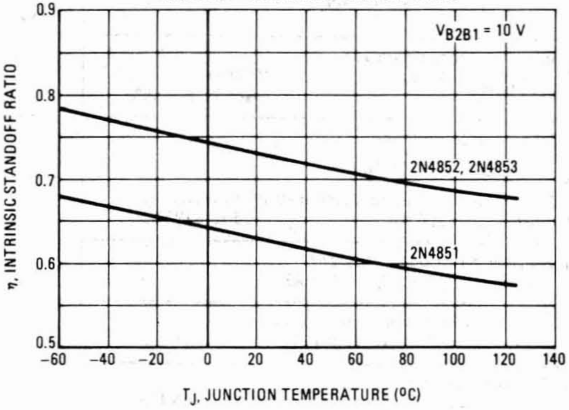


FIGURE 8 — INTRINSIC STANDOFF RATIO



PEAK POINT CURRENT

FIGURE 9 — EFFECT OF VOLTAGE

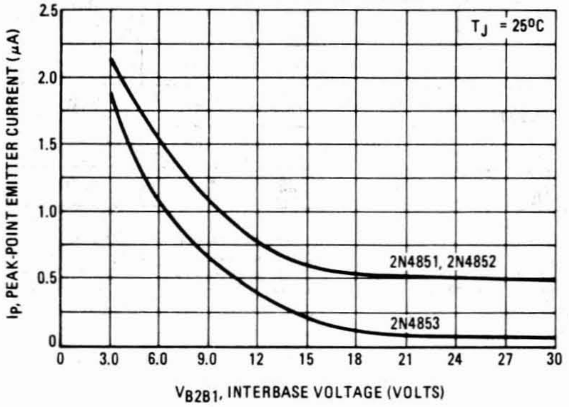
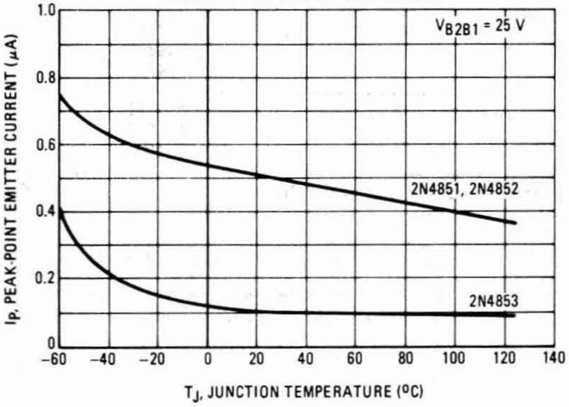


FIGURE 10 — EFFECT OF TEMPERATURE



INTERBASE RESISTANCE

FIGURE 11 — EFFECT OF VOLTAGE

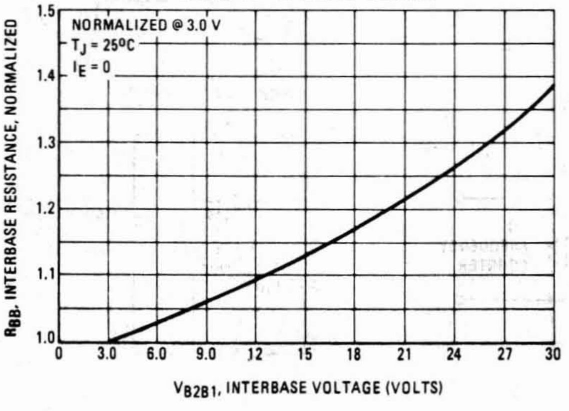
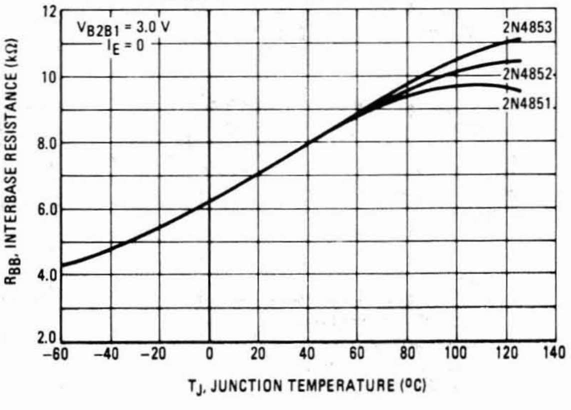


FIGURE 12 — EFFECT OF TEMPERATURE



TYPICAL CHARACTERISTICS

VALLEY CURRENT

FIGURE 13 — EFFECT OF VOLTAGE

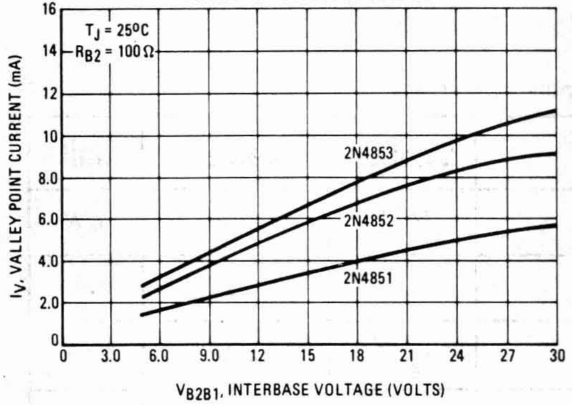
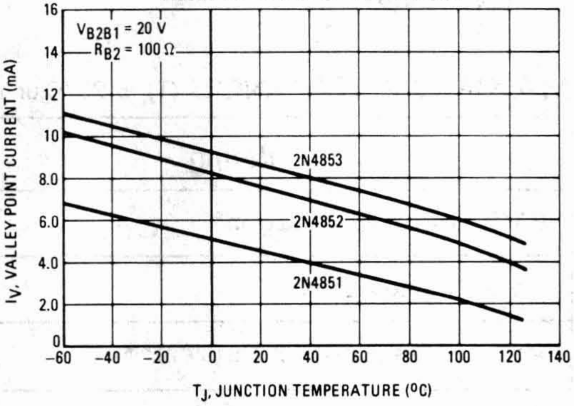


FIGURE 14 — EFFECT OF TEMPERATURE



VALLEY VOLTAGE

FIGURE 15 — EFFECT OF VOLTAGE

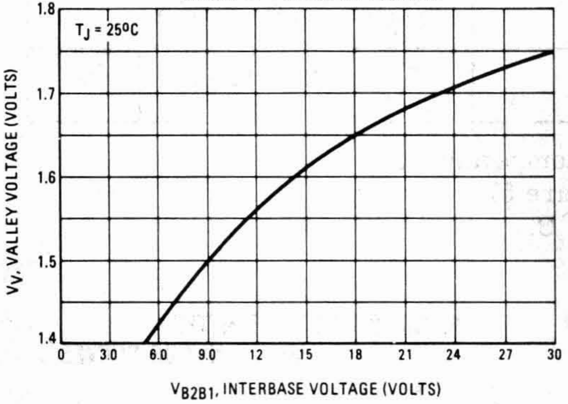


FIGURE 16 — EFFECT OF TEMPERATURE

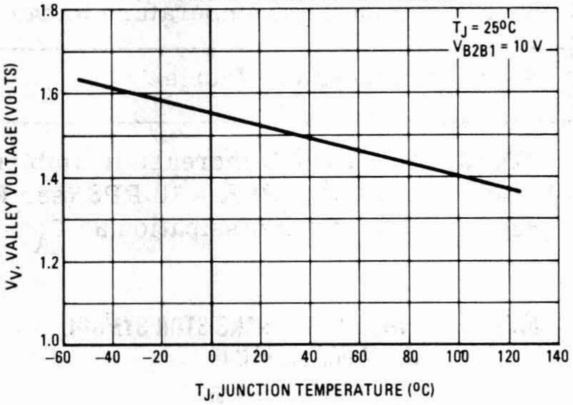
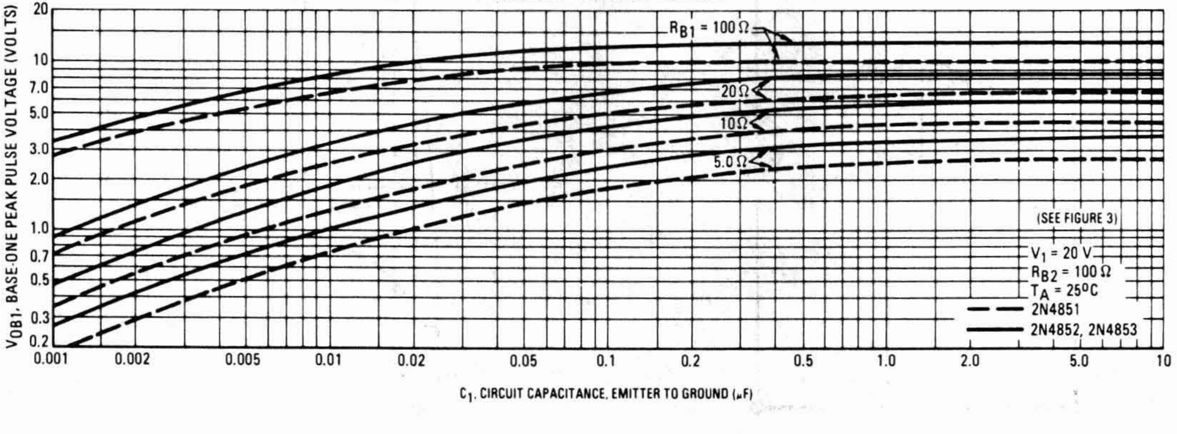
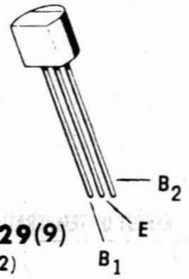


FIGURE 17 — OUTPUT VOLTAGE



2N4870 (SILICON)
2N4871



CASE 29(9)
(TO-92)

PN unijunction transistors designed for use in pulse and timing circuits, sensing circuits and thyristor trigger circuits.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	P_D*	300	mW
RMS Emitter Current	I_e	50	mA
Peak-Pulse Emitter Current**	i_e**	1.5	Amp
Emitter Reverse Voltage	V_{B2E}	30	Volts
Interbase Voltage†	V_{B2B1}†	35	Volts
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

*Derate 3.0 mW/°C increase in ambient temperature.
**Duty cycle ≦ 1%, PRR = 10 PPS (see Figure 5).
†Based upon power dissipation at T_A = 25°C.

FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

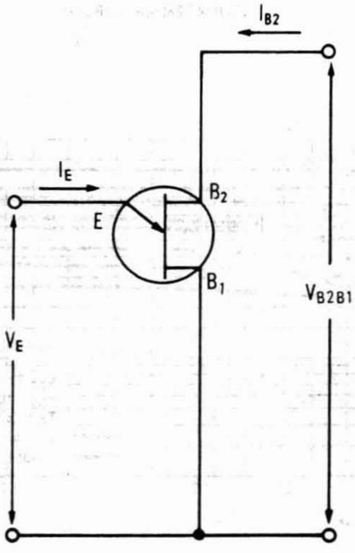
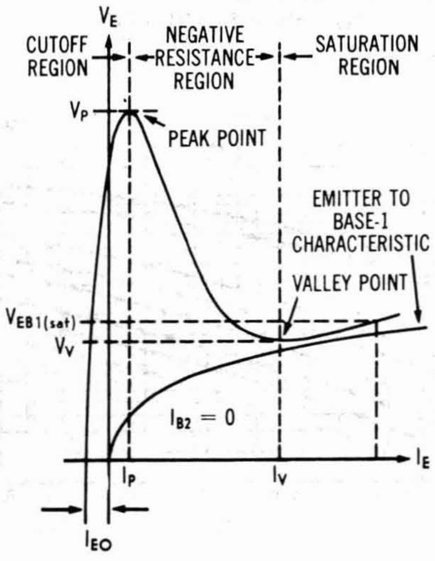


FIGURE 2 — STATIC EMITTER CHARACTERISTICS CURVES



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Typ	Max	Unit
Intrinsic Standoff Ratio* (V_{B2B1} = 10 V)	2N4870 2N4871	4, 7	η*	0.56 0.70	- -	0.75 0.85	-
Interbase Resistance (V_{B2B1} = 3.0 V, I_E = 0)		10, 11	R_{BB}	4.0	6.0	9.1	k ohms
Interbase Resistance Temperature Coefficient (V_{B2B1} = 3.0 V, I_E = 0, T_A = -65 to +125°C)		11	αR_{BB}	0.10	-	0.90	%/°C
Emitter Saturation Voltage** (V_{B2B1} = 10 V, I_E = 50 mA)			$V_{EB1(sat)}$**	-	2.5	-	Volts
Modulated Interbase Current (V_{B2B1} = 10 V, I_E = 50 mA)			$I_{B2(mod)}$	-	15	-	mA
Emitter Reverse Current (V_{B2E} = 30 V, I_{B1} = 0)		6	I_{EB2O}	-	0.005	1.0	μA
Peak-Point Emitter Current (V_{B2B1} = 25 V)		8, 9	I_P	-	1.0	5.0	μA
Valley-Point Current** (V_{B2B1} = 20 V, R_{B2} = 100 ohms)	2N4870 2N4871	12, 13	I_V**	2.0 4.0	5.0 7.0	- -	mA
Base-One Peak Pulse Voltage	2N4870 2N4871	3, 16	V_{OB1}	3.0 5.0	6.0 8.0	- -	Volts

* η Intrinsic standoff ratio, is defined in terms of peak-point voltage, V_P, by means of the equation: $V_P = \eta V_{B2B1} + V_F$, where V_F is approximately 0.49 volt at 25°C @ I_F = 10 μA and decreases with temperature at approximately 2.5 mV/°C. The test circuit is shown in Figure 4. Components R_1, C_1, and the UJT form a relaxation oscillator, the remaining circuitry serves as a peak-voltage detector. The forward drop of Diode D_1 compensates for V_F. To use, the "cal" button is pushed, and R_3 is adjusted to make the current meter, M_1, read full scale. When the "cal" button is released, the value of η is read directly from the meter, if full scale on the meter reads 1.0.

** Use pulse techniques: PW ≈ 300 μs, duty cycle ≦ 2.0% to avoid internal heating, which may result in erroneous readings.

FIGURE 3 — V_{OB1} TEST CIRCUIT

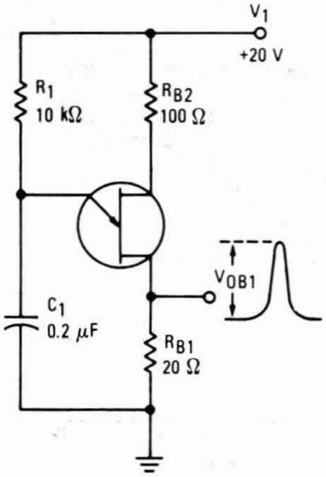
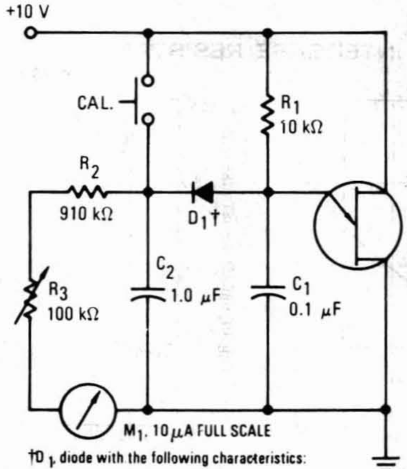
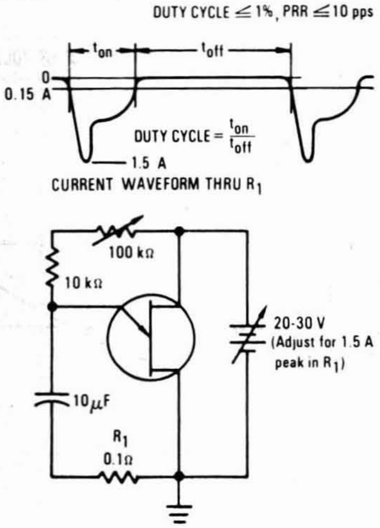

V1
+20 V
R1
10 kΩ
RB2
100 Ω
VOB1
C1
0.2 μF
RB1
20 Ω

FIGURE 4 — η TEST CIRCUIT


+10 V
CAL.
R1
10 kΩ
R2
910 kΩ
D1†
C2
1.0 μF
C1
0.1 μF
R3
100 kΩ
M1, 10 μA FULL SCALE

†D1, diode with the following characteristics:
V_F = 0.49 V @ I_F = 10 μA
I_R ≦ 2.0 μA @ V_R = 20 V

FIGURE 5 — PRR TEST CIRCUIT AND WAVEFORM


DUTY CYCLE ≦ 1%, PRR ≦ 10 pps
ton
toff
0
0.15 A
DUTY CYCLE = ton/toff
1.5 A
CURRENT WAVEFORM THRU R1
100 kΩ
10 kΩ
20-30 V
(Adjust for 1.5 A peak in R1)
10 μF
R1
0.1 Ω

TYPICAL CHARACTERISTICS

FIGURE 6 — EMITTER REVERSE CURRENT

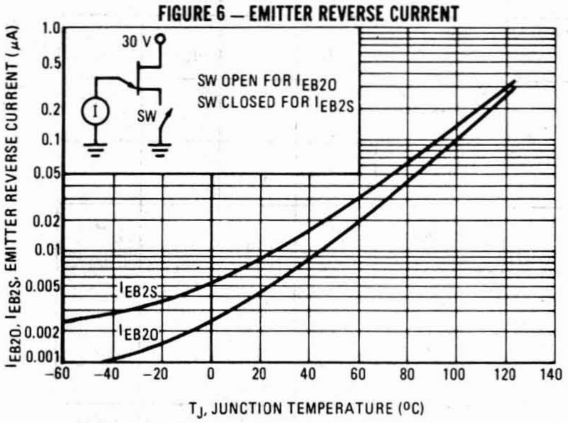
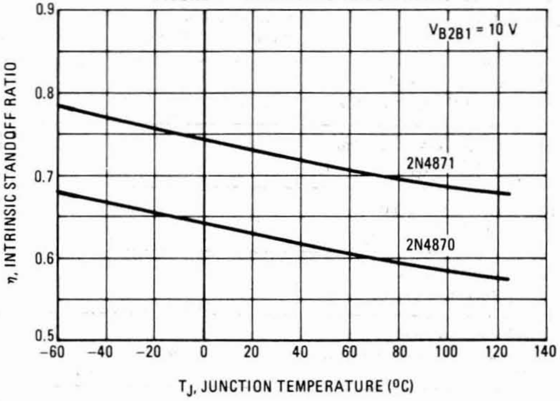


FIGURE 7 — INTRINSIC STANDOFF RATIO



PEAK POINT CURRENT

FIGURE 8 — EFFECT OF VOLTAGE

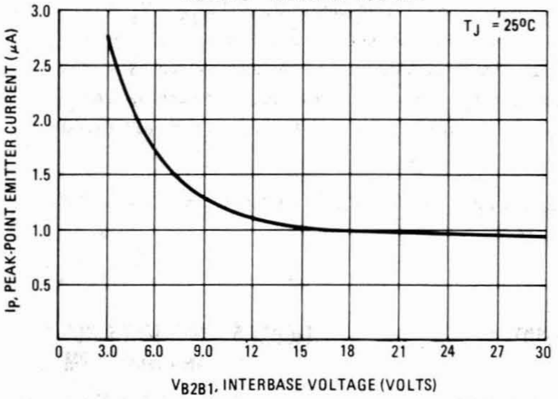
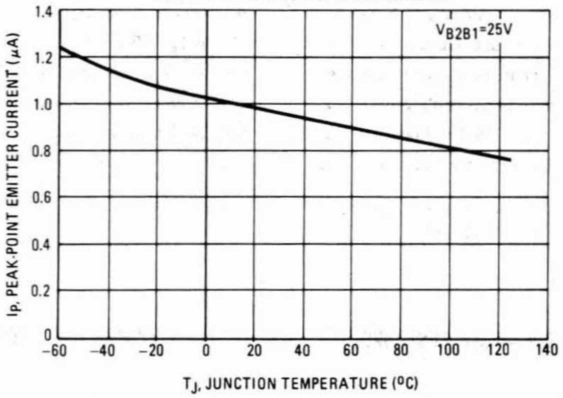


FIGURE 9 — EFFECT OF TEMPERATURE



INTERBASE RESISTANCE

FIGURE 10 — EFFECT OF VOLTAGE

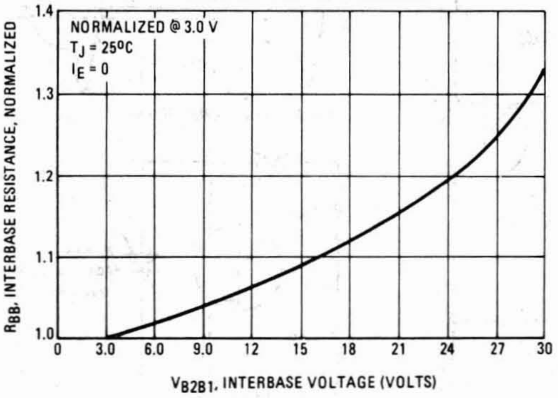
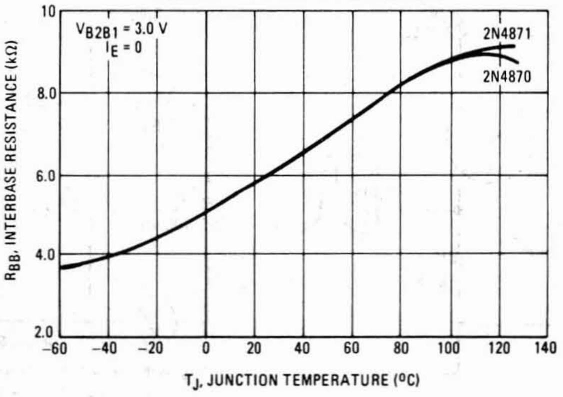


FIGURE 11 — EFFECT OF TEMPERATURE



TYPICAL CHARACTERISTICS

VALLEY CURRENT

FIGURE 12 — EFFECT OF VOLTAGE

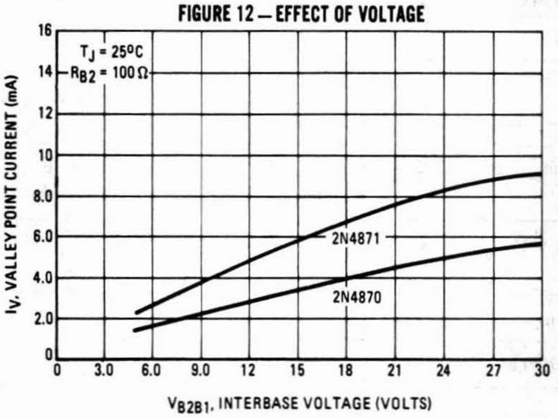
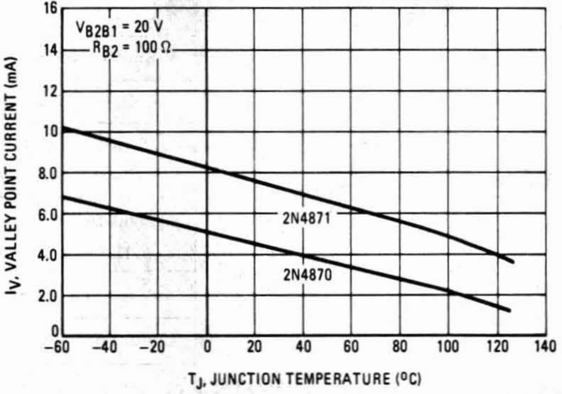


FIGURE 13 — EFFECT OF TEMPERATURE



VALLEY VOLTAGE

FIGURE 14 — EFFECT OF VOLTAGE

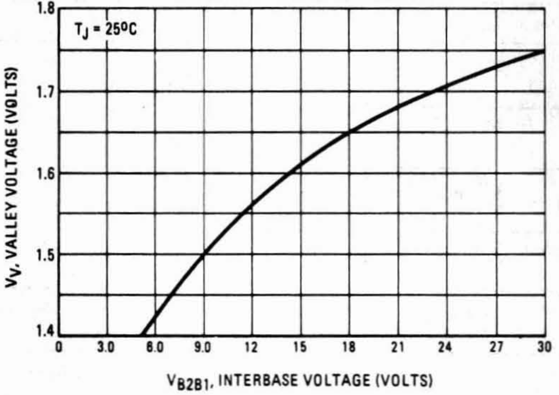


FIGURE 15 — EFFECT OF TEMPERATURE

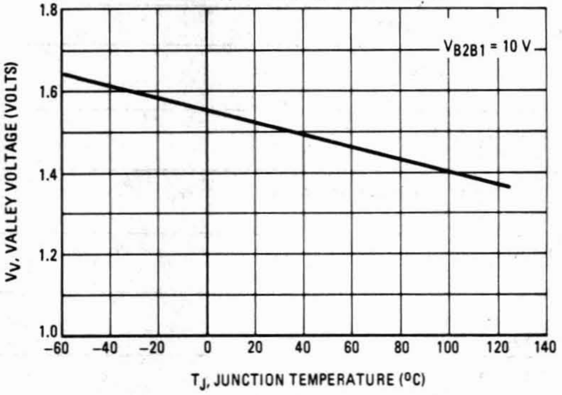
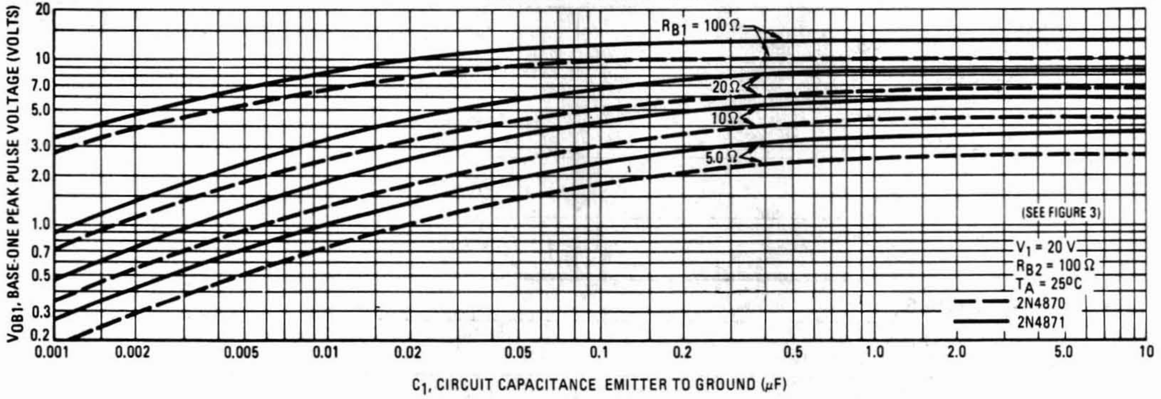
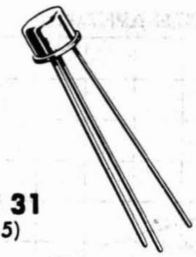


FIGURE 16 — OUTPUT VOLTAGE



2N4890 (SILICON)

PNP silicon annular transistor designed for medium-current switching and amplifier applications.



CASE 31
(TO-5)

MAXIMUM RATINGS

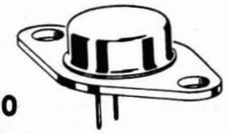
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current-Continuous	I_C	700	mAdc
Total Device Dissipation @ $T_A = 25^{o}C$ Derate above $25^{o}C$	P_D	1.0 5.7	Watts W ^{o}C
Total Device Dissipation @ $T_C = 25^{o}C$ Derate above $25^{o}C$	P_D	5 28.6	Watts W ^{o}C
Operating Junction Temperature Range	T_J	200	^{o}C
Storage Temperature Range	T_{stg}	-65 to -200	^{o}C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 100\ \mu Adc$, $I_B = 0$)	BV_{CEO}	40	—	Vdc
Collector-Emitter Breakdown Voltage ($I_C = 10$ mAdc, $R_{BE} = 10$ ohms)	BV_{CER}	50	—	Vdc
Collector-Base Breakdown Voltage ($I_C = 100\ \mu Adc$, $I_E = 0$)	BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu Adc$, $I_C = 0$)	BV_{EBO}	5	—	Vdc
Collector Cutoff Current ($V_{CE} = 60$ Vdc, $V_{BE\ (off)} = 1.5$ Vdc)	I_{CEX}	—	0.25	μAdc
Base Cutoff Current ($V_{CE} = 60$ Vdc, $V_{BE\ (off)} = 1.5$ Vdc)	I_{BL}	—	0.25	μAdc
ON CHARACTERISTICS				
DC Current Gain * ($I_C = 150$ mAdc, $V_{CE} = 2.5$ Vdc) ($I_C = 150$ mAdc, $V_{CE} = 10$ Vdc)*	h_{FE}*	 25 50	 — 250	—
Collector-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{CE(sat)}$	—	1.4	Vdc
Base-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{BE(sat)}$	—	1.7	Vdc
Base-Emitter On Voltage ($I_C = 150$ mAdc, $V_{CE} = 2.5$ Vdc)	$V_{BE(on)}$	—	1.7	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc, f = 20 MHz)	f_T	100	—	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 140 kHz)	C_{ob}	–	15	pF
Input Capacitance ($V_{BE} = 0.5$ Vdc, $I_C = 0$, f = 140 kHz)	C_{ib}	—	80	pF

*Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2%

2N4898 thru 2N4900 (SILICON)



CASE 80
(TO-66)

Medium-power PNP silicon transistors designed for driver circuits, switching, and amplifier applications. Complement to NPN 2N4910 thru 2N4912.

Collector connected to case

MAXIMUM RATINGS

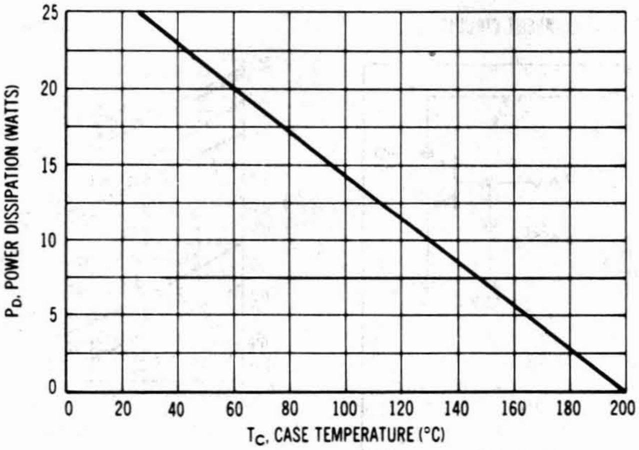
Rating	Symbol	2N4898	2N4899	2N4900	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current — Continuous *	I_C*	← 1.0 → ← 4.0 →			Adc
Base Current	I_B	← 1.0 →			Adc
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	← 25 → ← 0.143 →			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	7.0	°C/W

* The 1.0 Amp maximum I_C value is based upon JEDEC current gain requirements. The 4.0 Amp maximum value is based upon actual current-handling capability of the device (see Figure 5).

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 0.1 Adc, I_B = 0) 2N4898 2N4899 2N4900	-	$BV_{CEO(sus)}$*	 40 60 80	 - - -	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, I_B = 0) 2N4898 (V_{CE} = 30 Vdc, I_B = 0) 2N4899 (V_{CE} = 40 Vdc, I_B = 0) 2N4900		I_{CEO}	 - - -	 0.5 0.5 0.5	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{BE(off)}$ = 1.5 Vdc) (V_{CE} = Rated V_{CEO}, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	12	I_{CEX}	 - -	 0.1 1.0	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)	-	I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	-	I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 50 mAdc, V_{CE} = 1.0 Vdc) (I_C = 500 mAdc, V_{CE} = 1.0 Vdc) (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	8	h_{FE}*	 40 20 10	 - 100 -	-
Collector-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	9 11 13	$V_{CE(sat)}$*	-	0.6	Vdc
Base-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	11 13	$V_{BE(sat)}$*	-	1.3	Vdc
Base-Emitter On Voltage* (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	11 13	$V_{BE(on)}$*	-	1.3	Vdc
SMALL SIGNAL CHARACTERISTICS					
Current-Gain–Bandwidth Product (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)	-	f_T	3.0	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	-	C_{ob}	-	100	pF
Small-Signal Current Gain (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	-	h_{fe}	25	-	-

* Pulse Test: PW ≈ 300 μs, Duty Cycle ≈ 2.0%

FIGURE 2 – SWITCHING TIME EQUIVALENT CIRCUIT

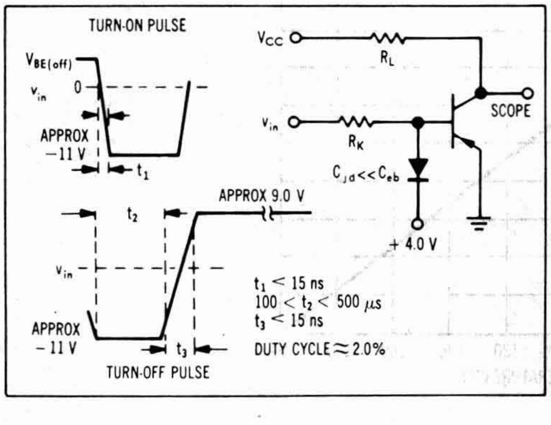

TURN-ON PULSE
$V_{BE(off)}$
v_{in}
0
APPROX
−11 V
t_1
t_2
APPROX 9.0 V
v_{in}
APPROX
− 11 V
t_3
TURN-OFF PULSE
V_{CC}
R_L
v_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
+ 4.0 V
$t_1 < 15$ ns
$100 < t_2 < 500$ μs
$t_3 < 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 3 – TURN-ON TIME

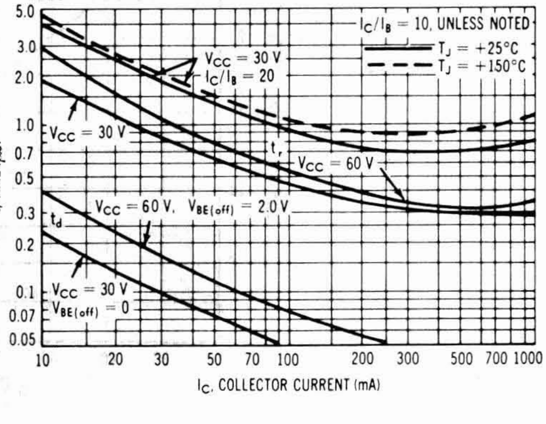


FIGURE 4 — THERMAL RESPONSE

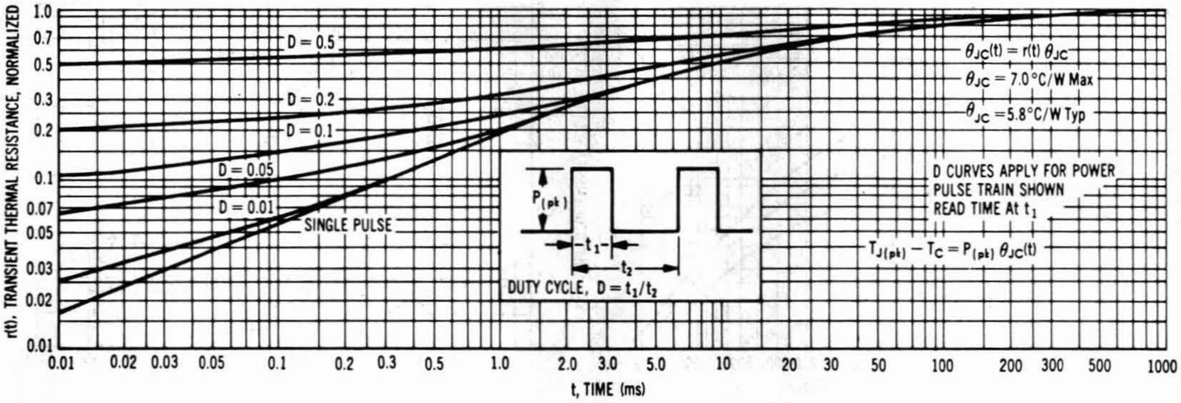
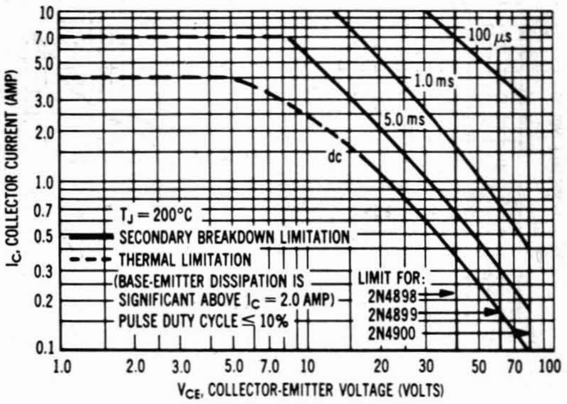


FIGURE 5 — ACTIVE-REGION SAFE OPERATING AREA



The safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor which must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

The data of Figure 5 is based upon $T_{J(pk)} = 200°C$; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} \le 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power which can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 — STORAGE TIME

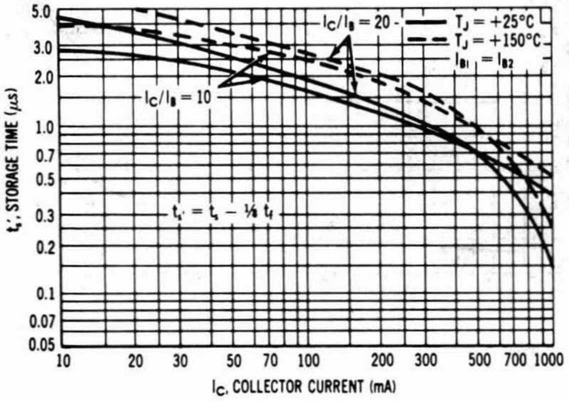


FIGURE 7 — FALL TIME

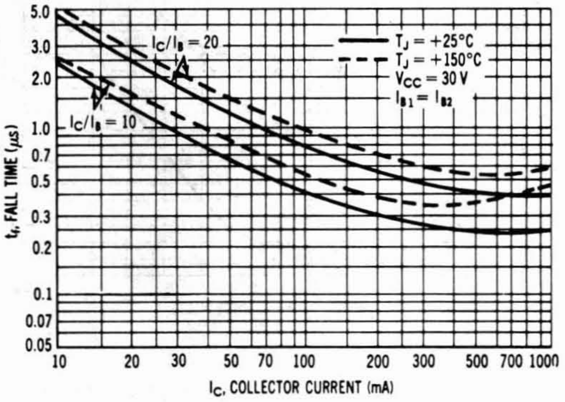


FIGURE 8 — CURRENT GAIN

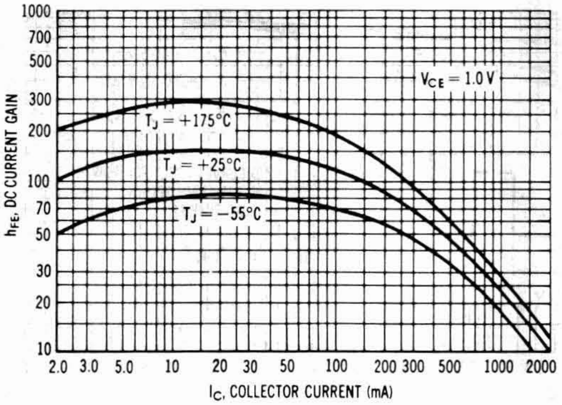


FIGURE 9 — COLLECTOR SATURATION REGION

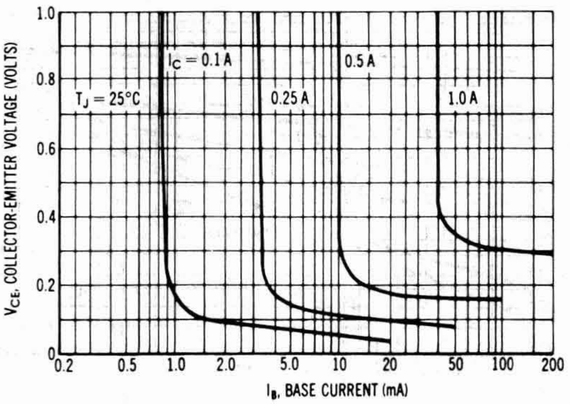


FIGURE 10 — EFFECTS OF BASE-EMITTER RESISTANCE

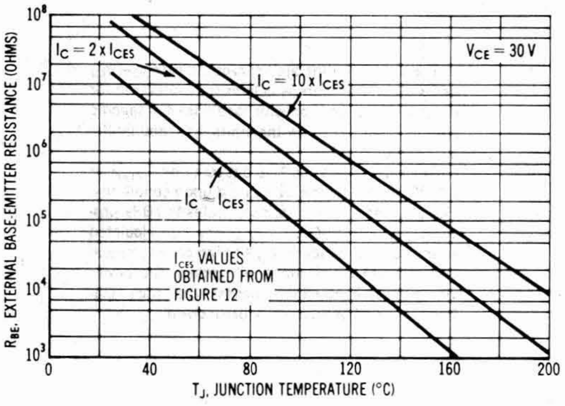


FIGURE 11 — "ON" VOLTAGE

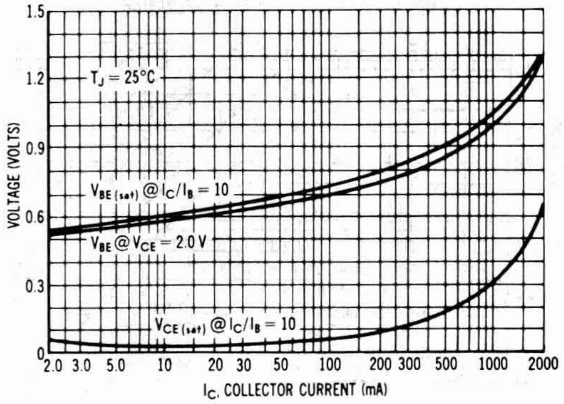


FIGURE 12 — COLLECTOR CUTOFF REGION

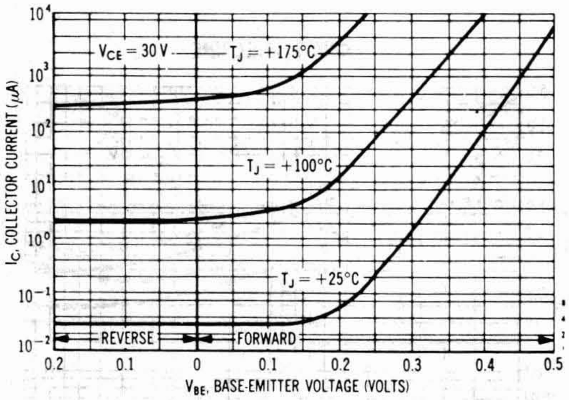
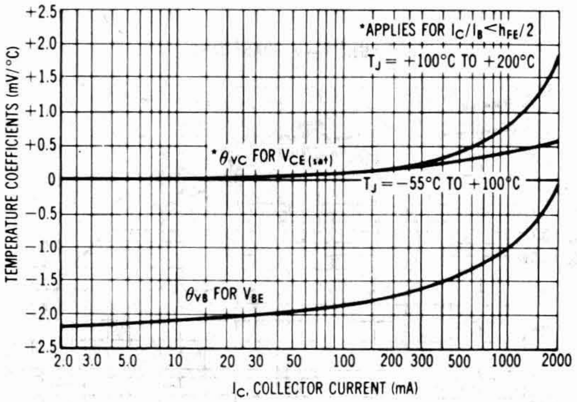
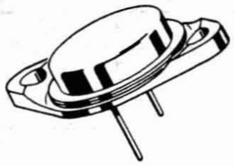


FIGURE 13 — TEMPERATURE COEFFICIENTS



2N4901 (SILICON)
2N4902
2N4903

PNP power transistors for use in power amplifier and switching circuits. Complement to NPN 2N5067, 2N5068, 2N5069.



CASE 11
(TO-3)

MAXIMUM RATINGS

Rating	Symbol	2N4901	2N4902	2N4903	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current – Continuous	I_C	← 5.0 →			Adc
Base Current	I_B	← 1.0 →			Adc
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	← 87.5 → ← 0.5 →			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	2.0	°C/W

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* ($I_C = 0.2$ Adc, $I_B = 0$) 2N4901 2N4902 2N4903	11	$V_{CEO(sus)}$*	40 60 80	- - -	Vdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $I_B = 0$)		I_{CEO}	-	1.0	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{BE(off)} = 1.5$ Vdc) (V_{CE} = Rated V_{CEO}, $V_{BE(off)} = 1.5$ Vdc, $T_C = 150°C$)	5, 6	I_{CEX}	- -	0.1 2.0	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, $I_E = 0$)		I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current ($V_{BE} = 5.0$ Vdc, $I_C = 0$)		I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain* ($I_C = 1.0$ Adc, $V_{CE} = 2.0$ Vdc) ($I_C = 5.0$ Adc, $V_{CE} = 2.0$ Vdc)	1	h_{FE}*	20 7.0	80 -	-
Collector-Emitter Saturation Voltage* ($I_C = 1.0$ Adc, $I_B = 0.1$ Adc ($I_C = 5.0$ Adc, $I_B = 1.0$ Adc)	2, 3, 4	$V_{CE(sat)}$*	- -	0.4 1.5	Vdc
Base-Emitter On Voltage* ($I_C = 1.0$ Adc, $V_{CE} = 2.0$ Vdc)	3, 4	$V_{BE(on)}$*	-	1.2	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain–Bandwidth Product ($I_C = 1.0$ Adc, $V_{CE} = 10$ Vdc, $f = 1.0$ MHz)		f_T	4.0	-	MHz
Small-Signal Current Gain ($I_C = 0.5$ Adc, $V_{CE} = 10$ Vdc, $f = 1.0$ kHz)		h_{fe}	20	-	-

* Pulse Test: PW = 300 μs, Duty Cycle ≈ 2.0%

FIGURE 1 — NORMALIZED DC CURRENT GAIN

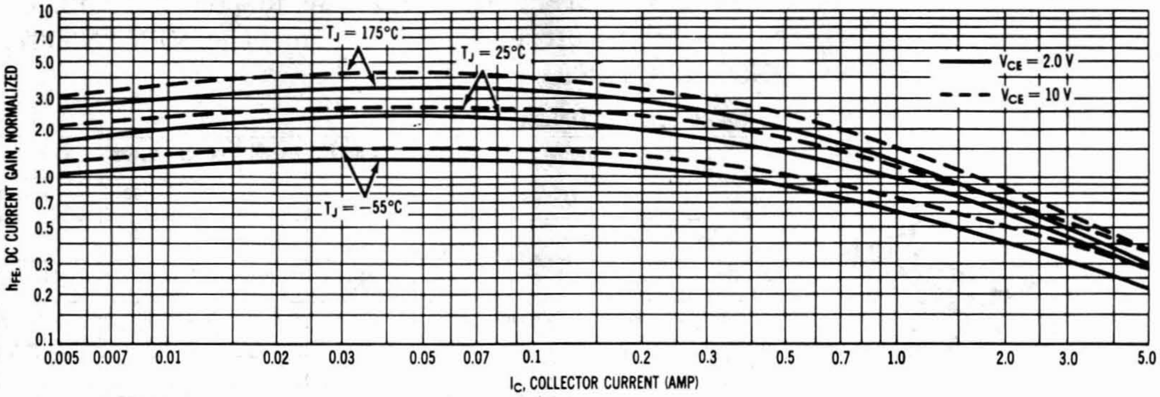


FIGURE 2 — COLLECTOR SATURATION REGION

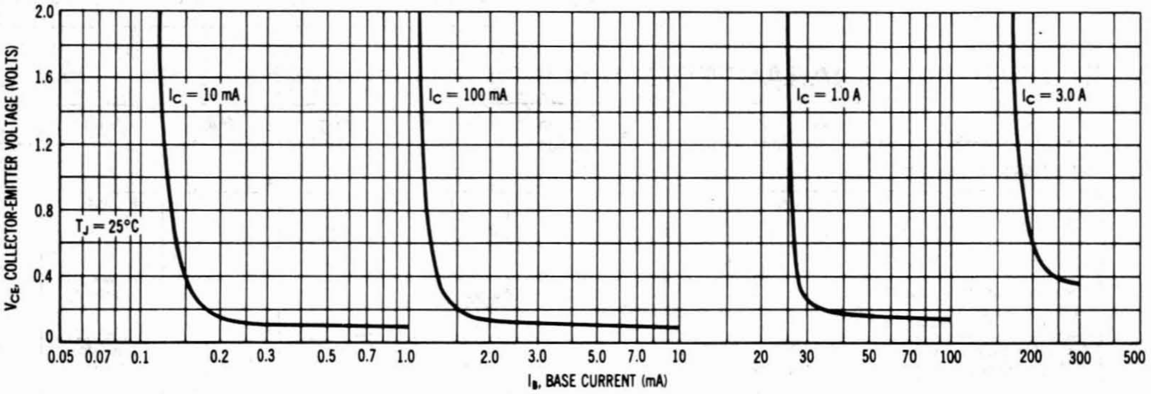


FIGURE 3 — "ON" VOLTAGE

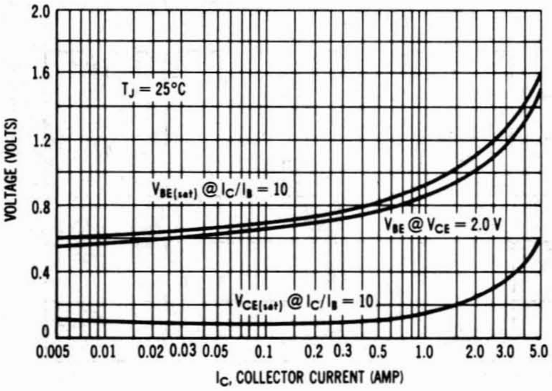
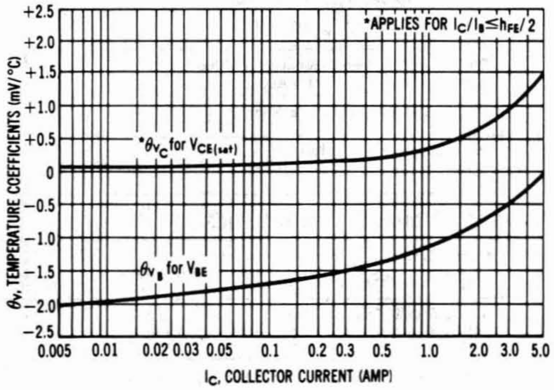


FIGURE 4 — TEMPERATURE COEFFICIENTS



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 5 — CUT-OFF REGION

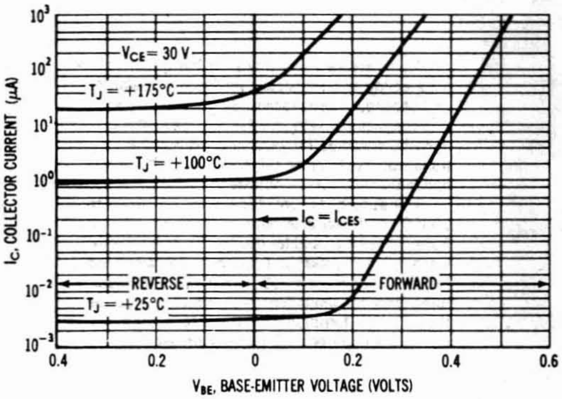


FIGURE 6 — EFFECTS OF BASE-EMITTER RESISTANCE

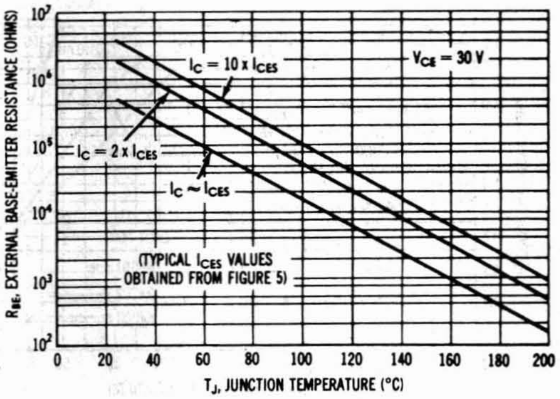


FIGURE 7 — SWITCHING TIME EQUIVALENT CIRCUIT

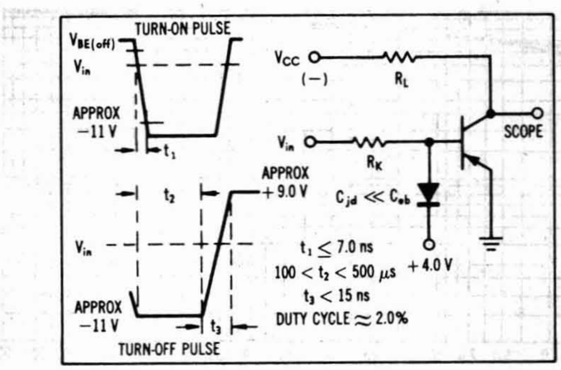

$V_{BE(off)}$
TURN-ON PULSE
V_{in}
APPROX −11 V
t_1
V_{CC}
(−)
R_L
SCOPE
V_{in}
R_K
APPROX +9.0 V
$C_{jd} \ll C_{eb}$
t_2
V_{in}
$t_1 \leq 7.0$ ns
$100 < t_2 < 500\ \mu s$
+4.0 V
$t_3 < 15$ ns
DUTY CYCLE $\approx$ 2.0%
APPROX −11 V
t_3
TURN-OFF PULSE

FIGURE 8 — CAPACITANCE

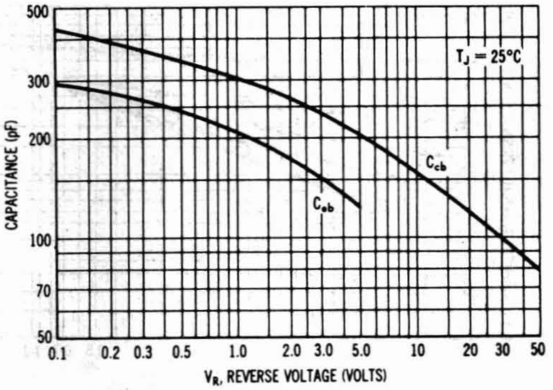


FIGURE 9 — TURN-ON TIME

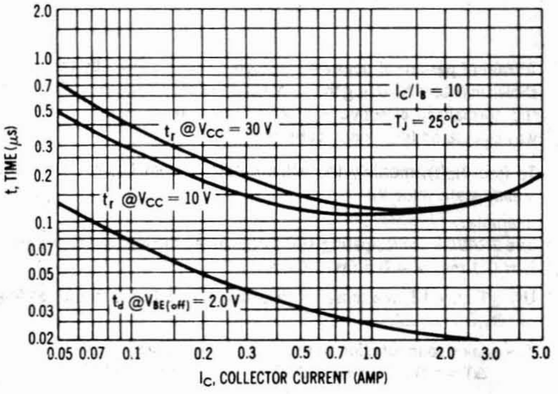
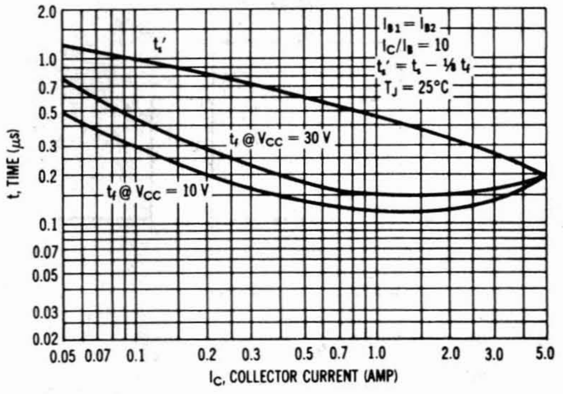
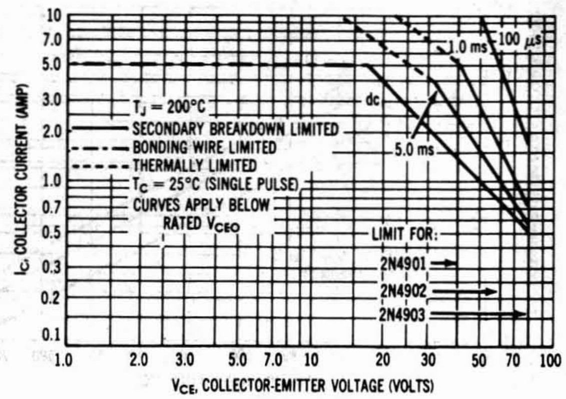


FIGURE 10 — TURN-OFF TIME



RATING AND THERMAL DATA

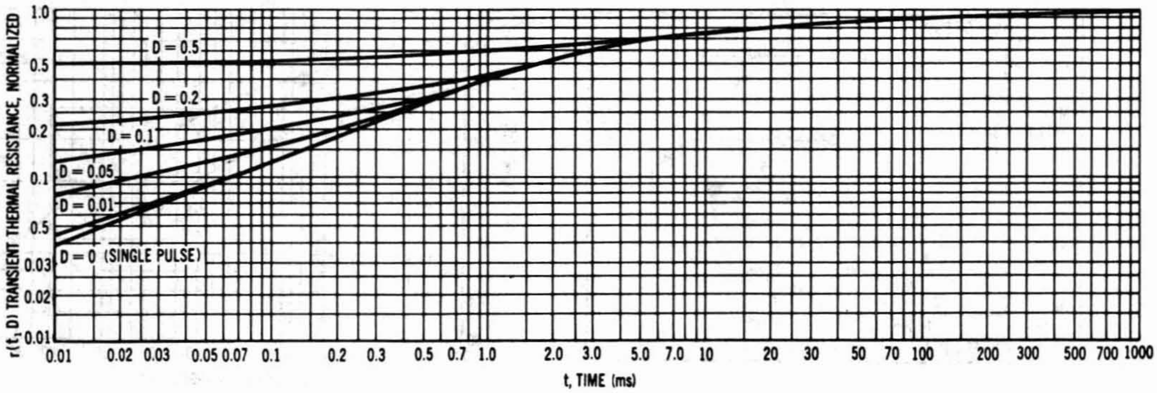
FIGURE 11 — ACTIVE-REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

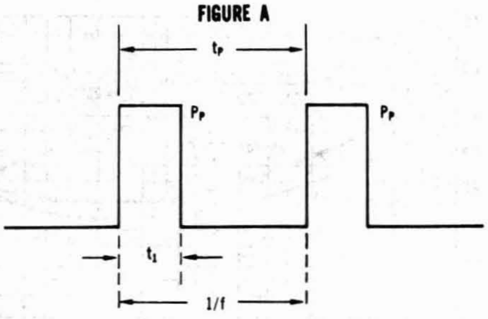
The data of Figure 11 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 12. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 12 — TRANSIENT THERMAL RESISTANCE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



DUTY CYCLE $D = t_1 \cdot f = \frac{t_1}{t_p}$

PEAK PULSE POWER = P_p

A train of periodical power pulses can be represented by the model shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 12 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 12 by the steady state value θ_{JC}.

Example:

The 2N4901 is dissipating 100 watts under the following conditions: $t_1 = 0.1$ ms, $t_p = 0.5$ ms. (D = 0.2)

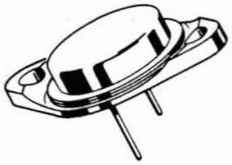
Using Figure 12, at a pulse width of 0.1 ms and D = 0.2, the reading of $r(t_1, D)$ is 0.27.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P_p \times \theta_{JC} = 0.27 \times 100 \times 2.0 = 54°C$$

2N4904 (SILICON)
2N4905
2N4906

PNP power transistors for use in power amplifier and switching circuits. Complement to NPN 2N4913 thru 2N4915.



CASE 11
(TO-3)

MAXIMUM RATINGS

Rating	Symbol	2N4904	2N4905	2N4906	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current – Continuous	I_C	← 5.0 →			Adc
Base Current	I_B	← 1.0 →			Adc
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	← 87.5 → ← 0.5 →			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	2.0	°C/W

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* ($I_C = 0.2$ Adc, $I_B = 0$) 2N4904 2N4905 2N4906	11	$V_{CEO(sus)}$*	40 60 80	- - -	Vdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $I_B = 0$)		I_{CEO}	-	1.0	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{BE(off)} = 1.5$ Vdc) (V_{CE} = Rated V_{CEO}, $V_{BE(off)} = 1.5$ Vdc, $T_C = 150°C$)	5, 6	I_{CEX}	- -	0.1 2.0	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, $I_E = 0$)		I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current ($V_{BE} = 5.0$ Vdc, $I_C = 0$)		I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain* ($I_C = 2.5$ Adc, $V_{CE} = 2.0$ Vdc) ($I_C = 5.0$ Adc, $V_{CE} = 2.0$ Vdc)	1	h_{FE}*	25 7.0	100 -	-
Collector-Emitter Saturation Voltage* ($I_C = 2.5$ Adc, $I_B = 0.25$ Adc) ($I_C = 5.0$ Adc, $I_B = 1.0$ Adc)	2, 3, 4	$V_{CE(sat)}$*	- -	1.0 1.5	Vdc
Base-Emitter On Voltage* ($I_C = 2.5$ Adc, $V_{CE} = 2.0$ Vdc)	3, 4	$V_{BE(on)}$*	-	1.4	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain–Bandwidth Product ($I_C = 1.0$ Adc, $V_{CE} = 10$ Vdc, f = 1.0 MHz)		f_T	4.0	-	MHz
Small-Signal Current Gain ($I_C = 0.5$ Adc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)		h_{fe}	40	-	

* Pulse Test: PW = 300 μs, Duty Cycle ≈ 2.0%

FIGURE 1 — NORMALIZED DC CURRENT GAIN

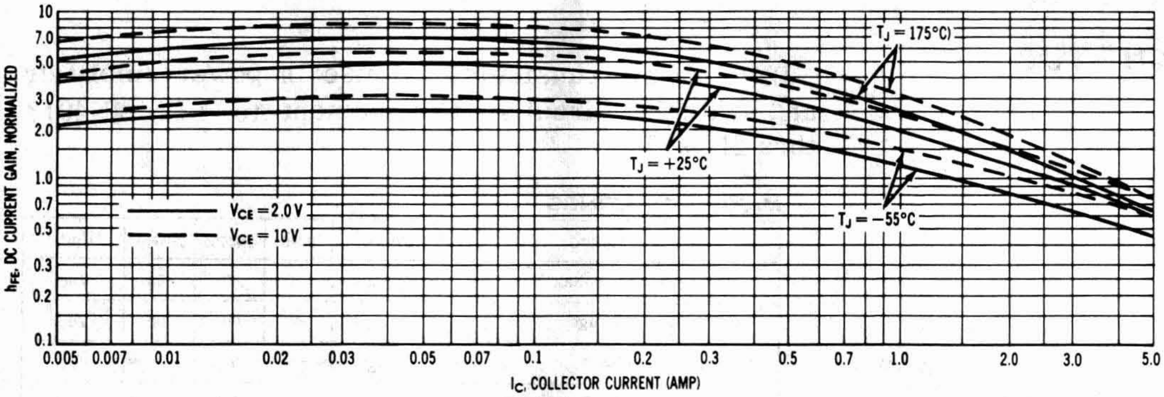


FIGURE 2 — COLLECTOR SATURATION REGION

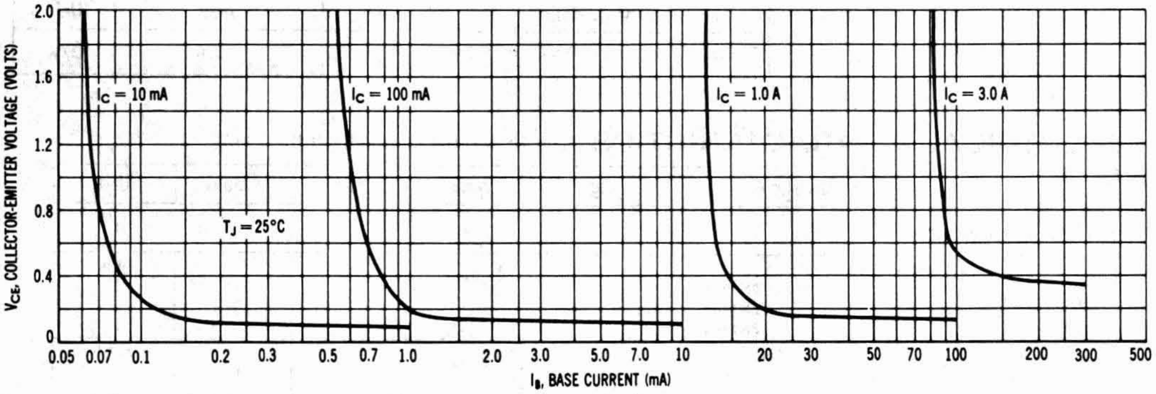


FIGURE 3 — "ON" VOLTAGE

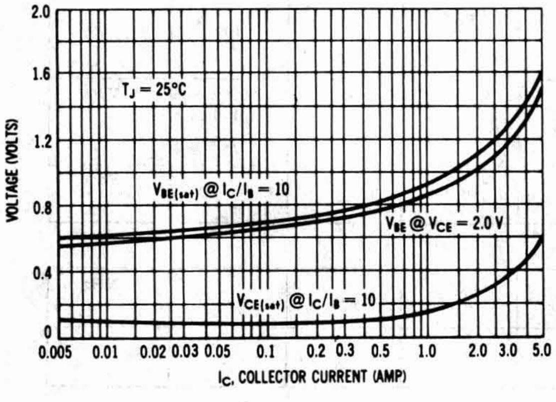
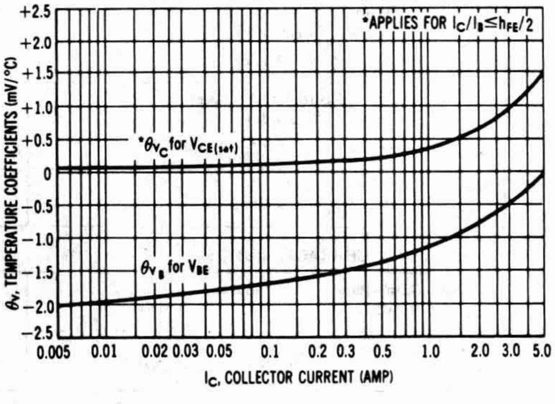


FIGURE 4 — TEMPERATURE COEFFICIENTS



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 5 — CUT-OFF REGION

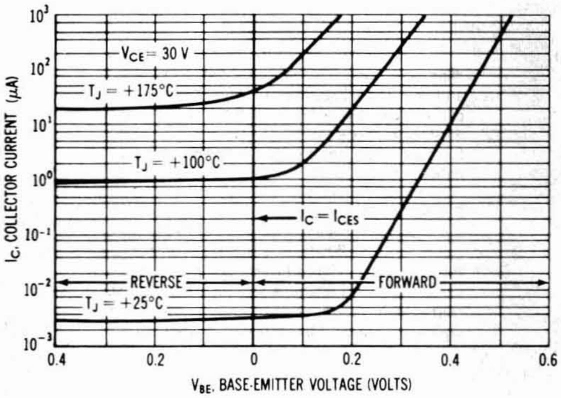


FIGURE 6 — EFFECTS OF BASE-EMITTER RESISTANCE

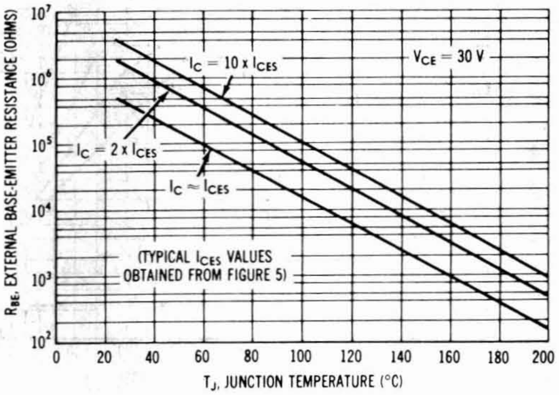


FIGURE 7 — SWITCHING TIME EQUIVALENT CIRCUIT

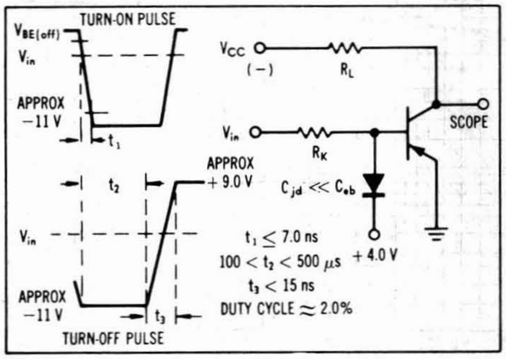

$V_{BE(off)}$
TURN-ON PULSE
V_{in}
APPROX −11 V
t_1
t_2
APPROX + 9.0 V
V_{in}
APPROX −11 V
t_3
TURN-OFF PULSE
V_{CC} (−)
R_L
SCOPE
V_{in}
R_K
$C_{jd} \ll C_{eb}$
+ 4.0 V
$t_1 \leq 7.0$ ns
$100 < t_2 < 500$ μs
$t_3 < 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 8 — CAPACITANCE

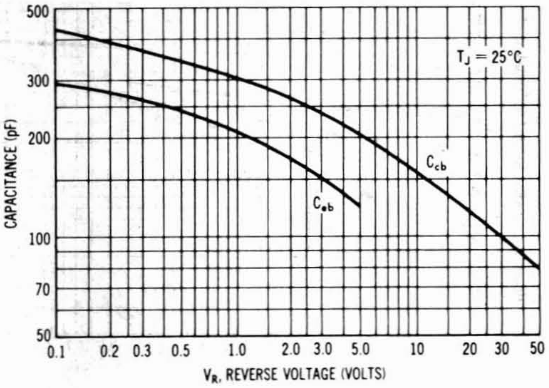


FIGURE 9 — TURN-ON TIME

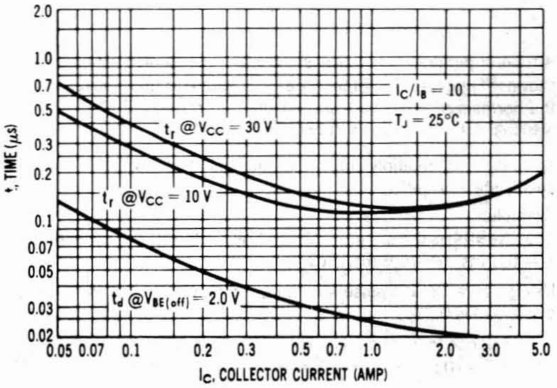
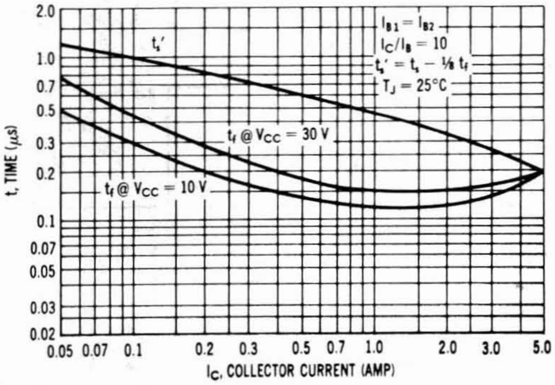
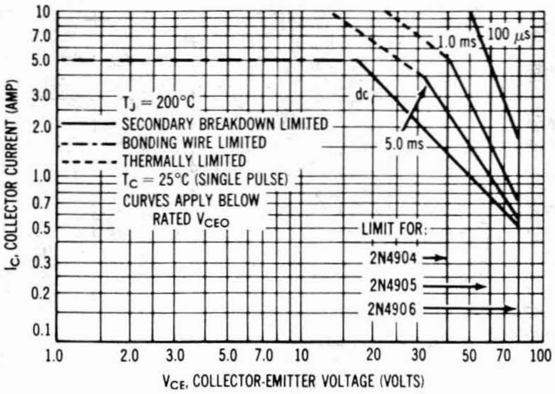


FIGURE 10 — TURN-OFF TIME



RATING AND THERMAL DATA

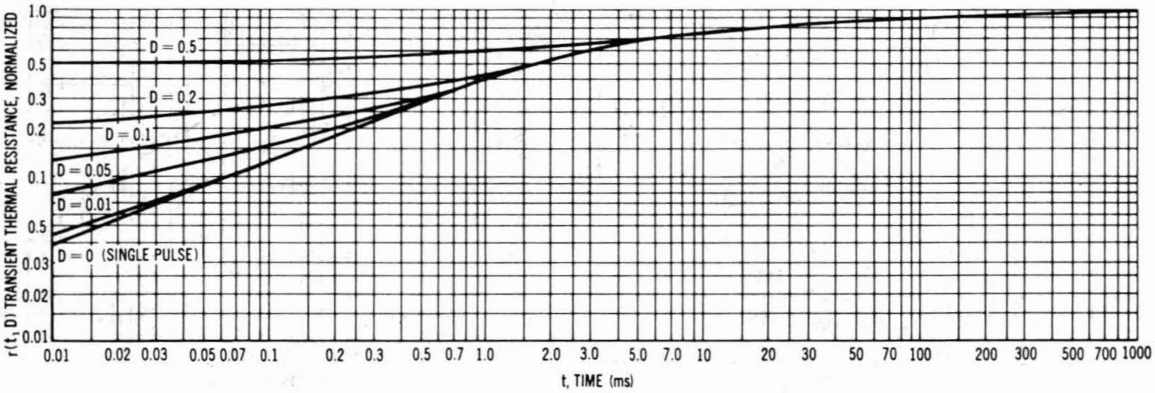
FIGURE 11 — ACTIVE-REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

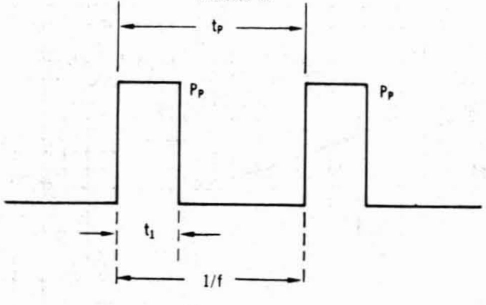
The data of Figure 11 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 12. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 12 — TRANSIENT THERMAL RESISTANCE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



DUTY CYCLE $D = t_1 \cdot f = \frac{t_1}{t_P}$

PEAK PULSE POWER = P_P

A train of periodical power pulses can be represented by the model shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 12 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 12 by the steady state value θ_{JC}.

Example:

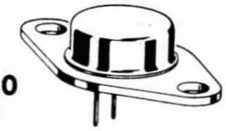
The 2N4904 is dissipating 100 watts under the following conditions: $t_1 = 0.1$ ms, $t_P = 0.5$ ms. $(D = 0.2)$

Using Figure 12, at a pulse width of 0.1 ms and D = 0.2, the reading of $r(t_1, D)$ is 0.27.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P_P \times \theta_{JC} = 0.27 \times 100 \times 2.0 = 54°C$$

2N4910 thru 2N4912 (SILICON)



CASE 80
(TO-66)

Medium-power NPN silicon transistors designed for driver circuits, switching, and amplifier applications. Complement to PNP 2N4898 thru 2N4900.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4910	2N4911	2N4912	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current — Continuous*	I_C*	← 1.0 → ← 4.0 →			Adc
Base Current — Continuous	I_B	← 1.0 →			Adc
Total Device Dissipation $T_C = 25°C$	P_D	← 25 →			Watts
Derate above 25°C		← 0.143 →			mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +200 →			°C

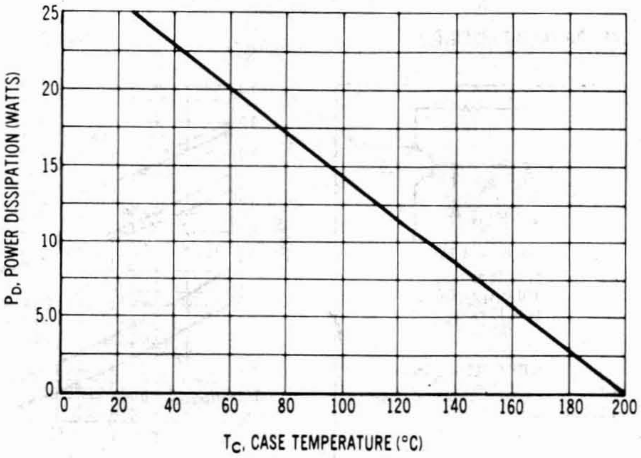
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	7.0	°C/W

* The 1.0 Amp maximum I_C value is based upon JEDEC current gain requirements.

The 4.0 Amp maximum value is based upon actual current-handling capability of the device (see Figure 5).

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



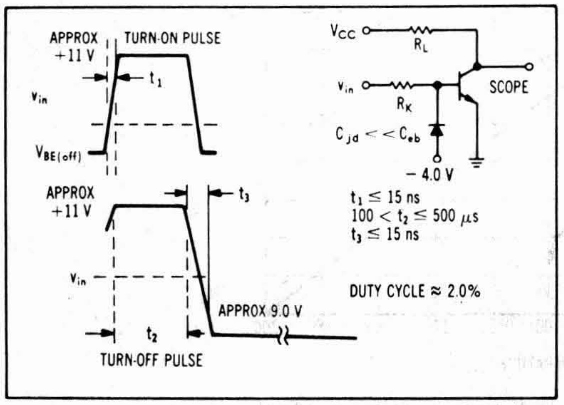
Safe Area Curves are indicated by Figure 5. All limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage*	-	$BV_{CEO(sus)}$*			Vdc
(I_C = 0.1 Adc, I_B = 0) 2N4910			40	-	
2N4911			60	-	
2N4912			80	-	
Collector Cutoff Current	-	I_{CEO}			mAdc
(V_{CE} = 20 Vdc, I_B = 0) 2N4910			-	0.5	
(V_{CE} = 30 Vdc, I_B = 0) 2N4911			-	0.5	
(V_{CE} = 40 Vdc, I_B = 0) 2N4912			-	0.5	
Collector Cutoff Current	12	I_{CEX}			mAdc
(V_{CE} = Rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc)			-	0.1	
(V_{CE} = Rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)			-	1.0	
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)	-	I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)	-	I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain *	8	h_{FE}*			-
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)			40	-	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)			20	100	
(I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)			10	-	
Collector-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	9 11 13	$V_{CE(sat)}$*	-	0.6	Vdc
Base-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	11 13	$V_{BE(sat)}$*	-	1.3	Vdc
Base-Emitter On Voltage* (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	11 13	$V_{BE(on)}$*	-	1.3	Vdc
SMALL SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)	-	f_T	3.0	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	-	C_{ob}	-	100	pF
Small-Signal Current Gain (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	-	h_{fe}	25	-	

* Pulse Test: PW ≈ 300 μs, Duty Cycle ≈ 2.0%

FIGURE 2 — SWITCHING TIME EQUIVALENT CIRCUIT



APPROX +11 V
TURN-ON PULSE
t_1
V_{in}
$V_{BE(off)}$
APPROX +11 V
t_3
V_{in}
t_2
APPROX 9.0 V
TURN-OFF PULSE
V_{CC}
R_L
V_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
− 4.0 V
$t_1 \leq 15$ ns
$100 < t_2 \leq 500\ \mu s$
$t_3 \leq 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 3 — TURN-ON TIME

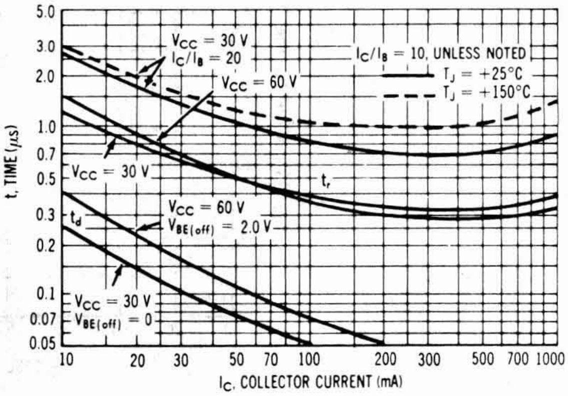


FIGURE 4 — THERMAL RESPONSE

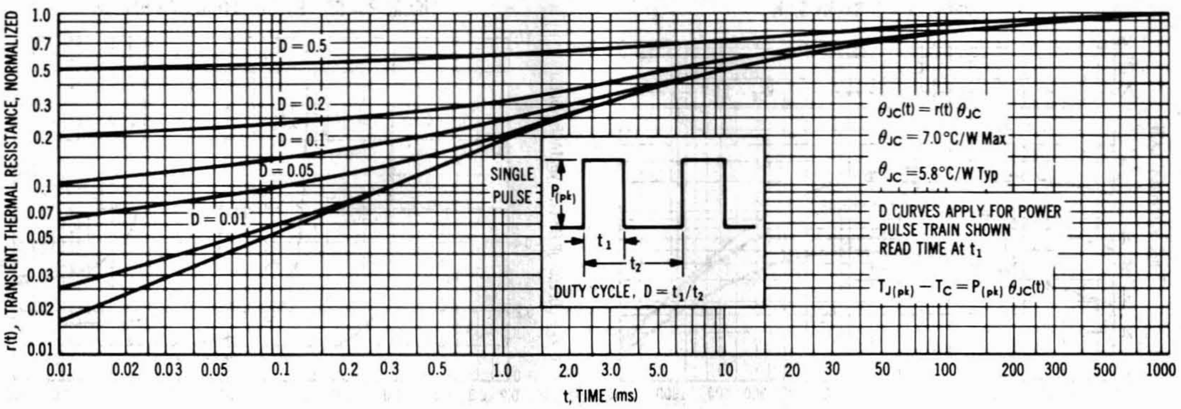
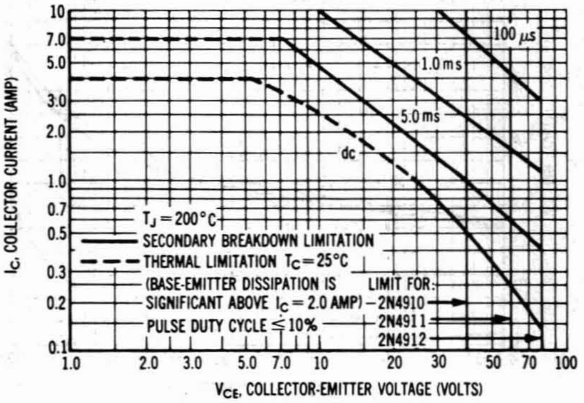


FIGURE 5 — ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 — STORAGE TIME

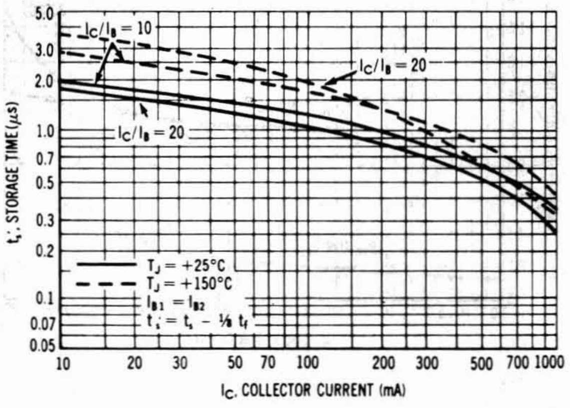
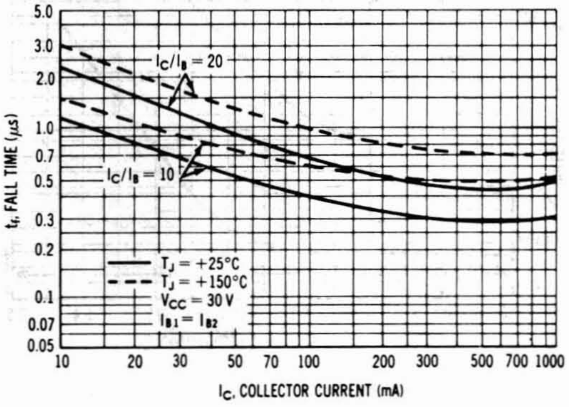


FIGURE 7 — FALL TIME



TYPICAL DC CHARACTERISTICS

FIGURE 8 — CURRENT GAIN

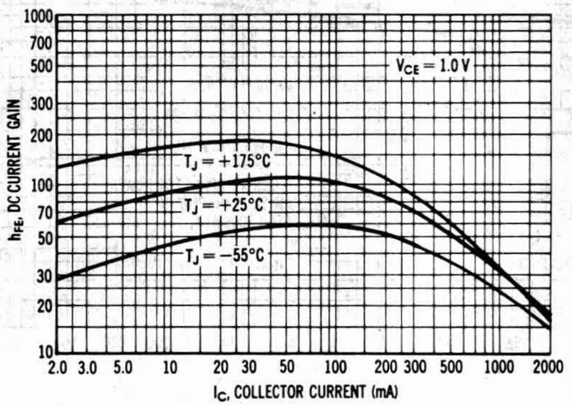


FIGURE 9 — COLLECTOR SATURATION REGION

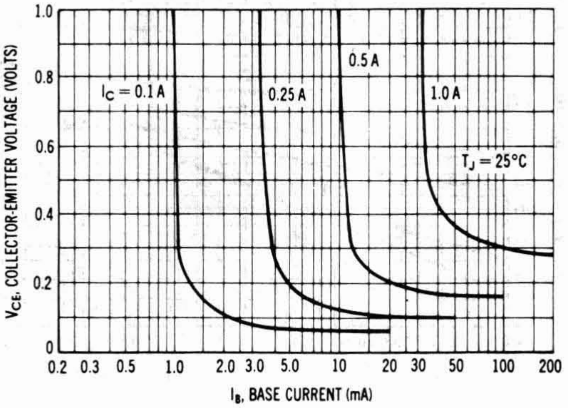


FIGURE 10 — EFFECTS OF BASE-EMITTER RESISTANCE

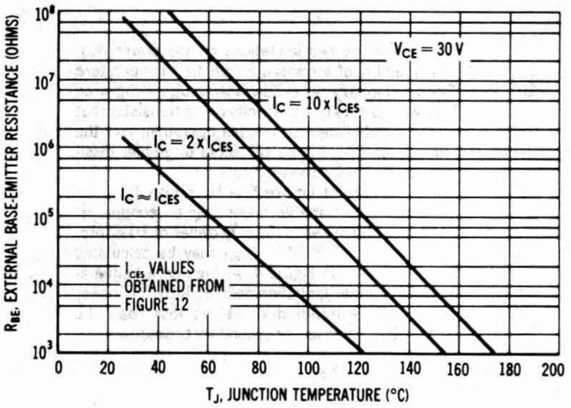


FIGURE 11 — "ON" VOLTAGE

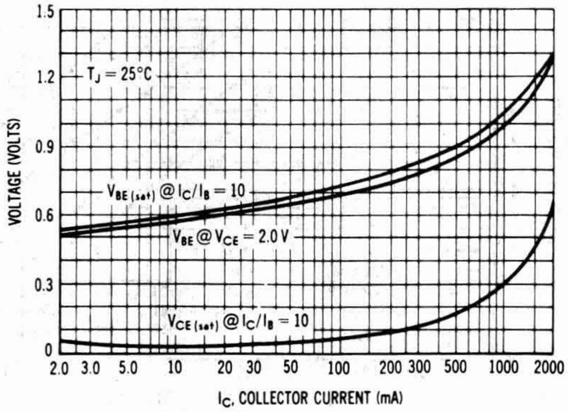


FIGURE 12 — COLLECTOR CUTOFF REGION

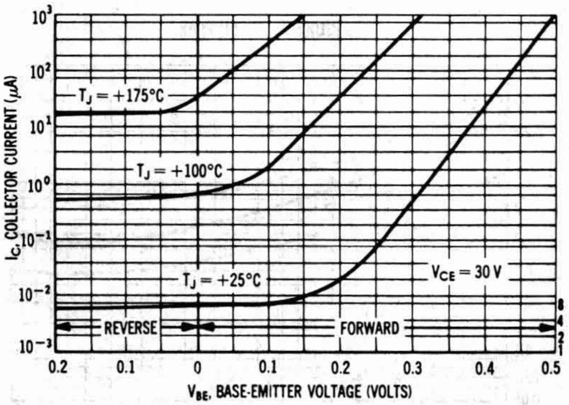
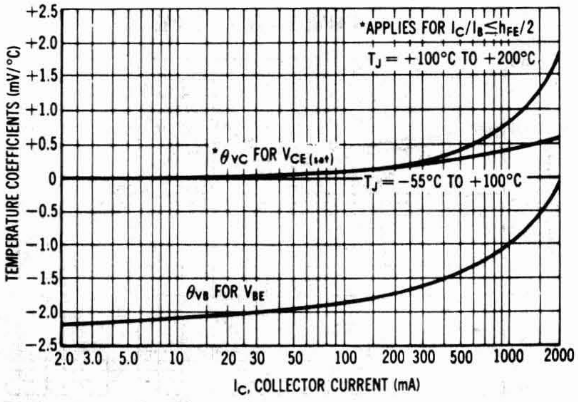
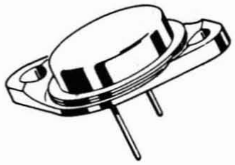


FIGURE 13 — TEMPERATURE COEFFICIENTS



2N4913 (SILICON)
2N4914
2N4915

NPN power transistors for use in power amplifier and switching circuits. Complement to PNP 2N4904 thru 2N4906.



CASE 11
(TO-3)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4913	2N4914	2N4915	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	5.0			Vdc
Collector Current — Continuous	I_C	5.0			Adc
Base Current - Continuous	I_B	1.0			Adc
Total Device Dissipation @ T_C = 25° C	P_D	87.5			Watts
Derate above 25° C		0.5			W/° C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200			° C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	2.0	° C/W

ELECTRICAL CHARACTERISTICS (T_C = 25 °C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 0.2 Adc, I_B = 0) 2N4913	11	$BV_{CEO(sus)}$*	40	-	Vdc
2N2914			60	-	
2N4915			80	-	
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, I_B = 0)		I_{CEO}	-	1.0	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc)		I_{CEX}	-	1.0	mAdc
(V_{CE} = Rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150° C)	5, 6		-	2.0	
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)	5, 6	I_{CBO}	-	1.0	mAdc
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 2.5 Adc, V_{CE} = 2.0 Vdc)	1	h_{FE}*	25	100	-
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)			7.0	-	
Collector-Emitter Saturation Voltage* (I_C = 2.5 Adc, I_B = 250 mAdc)	2, 3, 4	$V_{CE(sat)}$*	-	1.0	Vdc
(I_C = 5.0 Adc, I_B = 1.0 Adc)			-	1.5	
Base-Emitter On Voltage* (I_C = 2.5 Adc, V_{CE} = 2.0 Vdc)	3, 4	$V_{BE(on)}$*	-	1.4	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz)		f_T	4.0	-	MHz
Small-Signal Current Gain (I_C = 500 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{fe}	20	-	-

* Pulse Test, PW ≈300 μs, Duty Cycle ≈ 2.0%

2N4913, 2N4914, 2N4915 (continued)

FIGURE 1 — NORMALIZED DC CURRENT GAIN

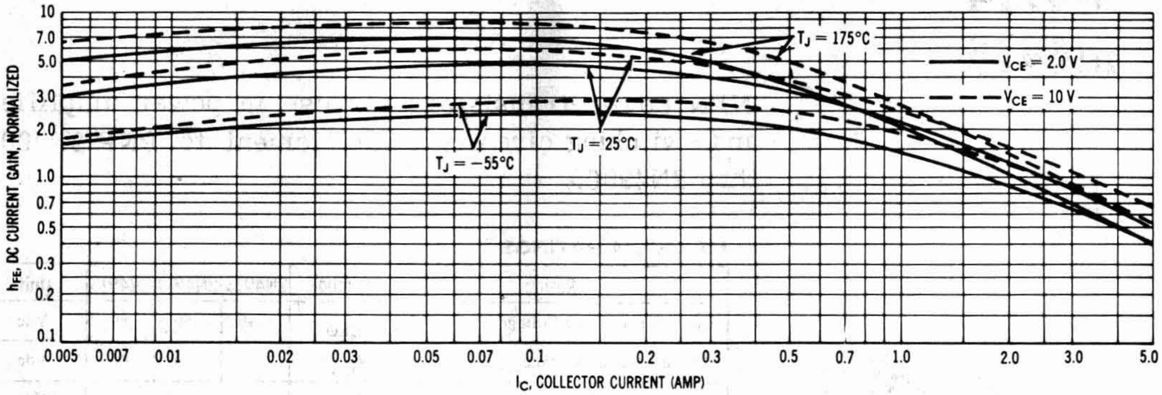


FIGURE 2 — COLLECTOR SATURATION REGION

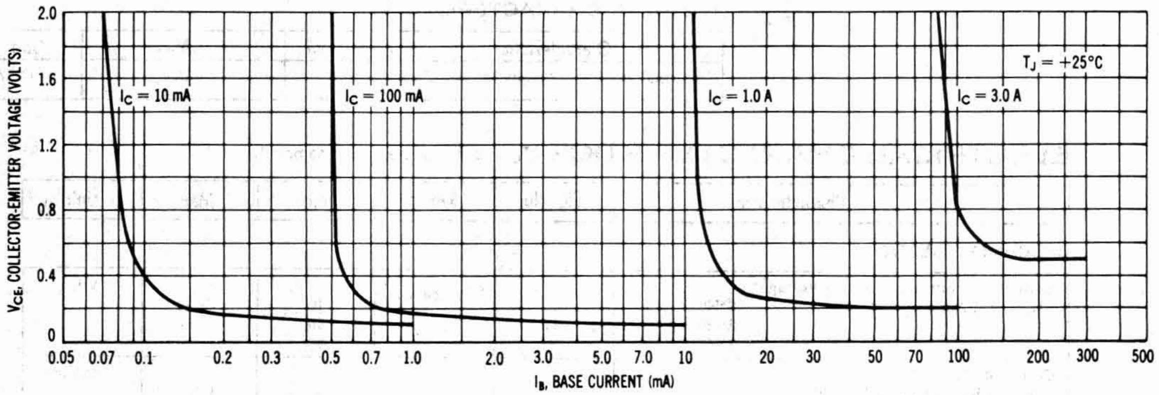


FIGURE 3 — "ON" VOLTAGES

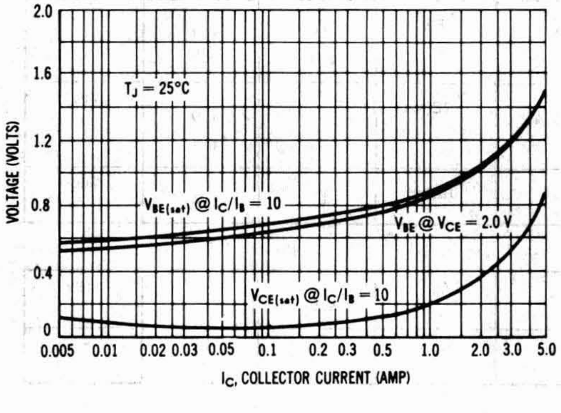
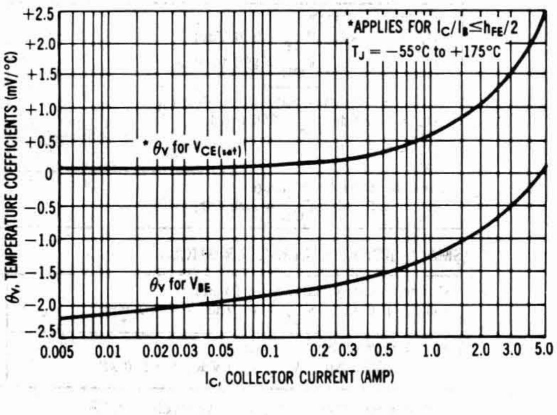


FIGURE 4 — TEMPERATURE COEFFICIENTS



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 5 — CUT-OFF REGION

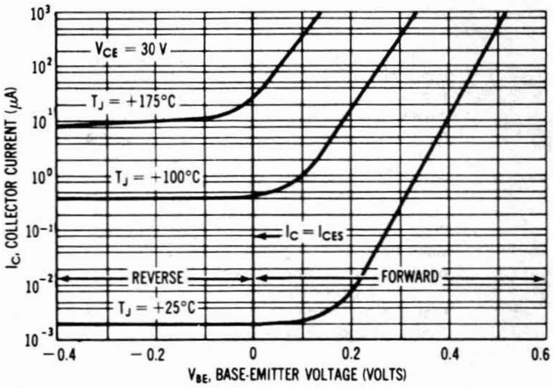


FIGURE 6 — EFFECTS OF BASE-EMITTER RESISTANCE

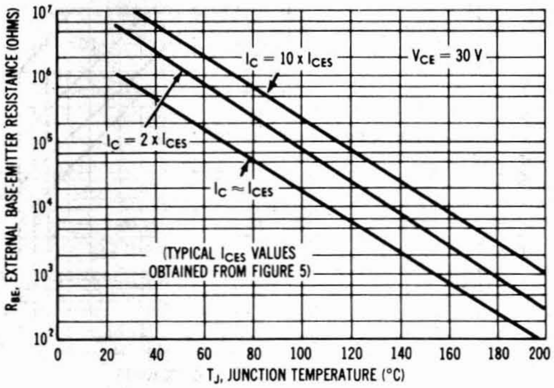
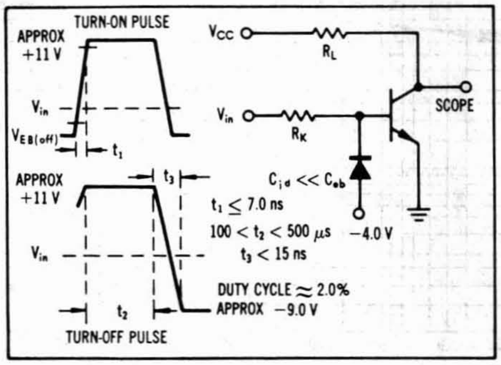


FIGURE 7 — SWITCHING TIME EQUIVALENT CIRCUIT



APPROX +11 V
TURN-ON PULSE
V_{in}
$V_{EB(off)}$
t_1
APPROX +11 V
t_3
V_{in}
t_2
TURN-OFF PULSE
V_{CC}
R_L
V_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
$t_1 \leq 7.0$ ns
$100 < t_2 < 500$ μs
$t_3 < 15$ ns
−4.0 V
DUTY CYCLE ≈ 2.0%
APPROX −9.0 V

FIGURE 8 — CAPACITANCE

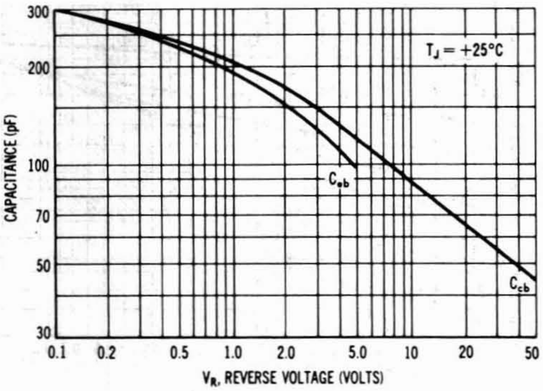


FIGURE 9 — TURN-ON TIME

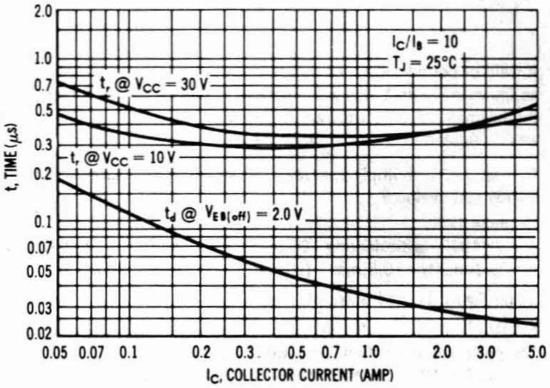
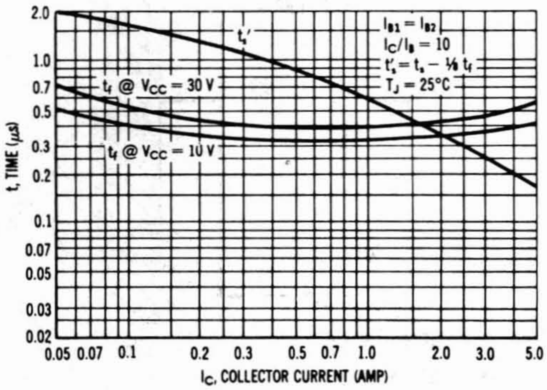
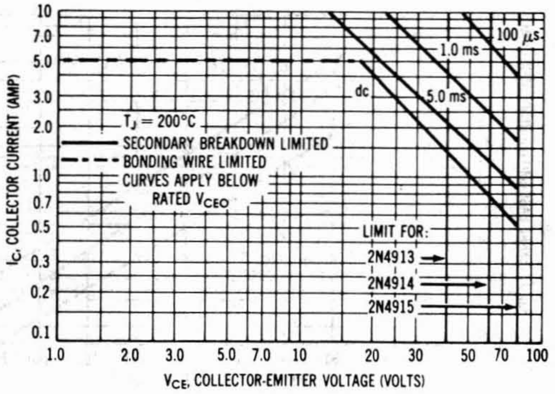


FIGURE 10 — TURN-OFF TIME



RATING AND THERMAL DATA

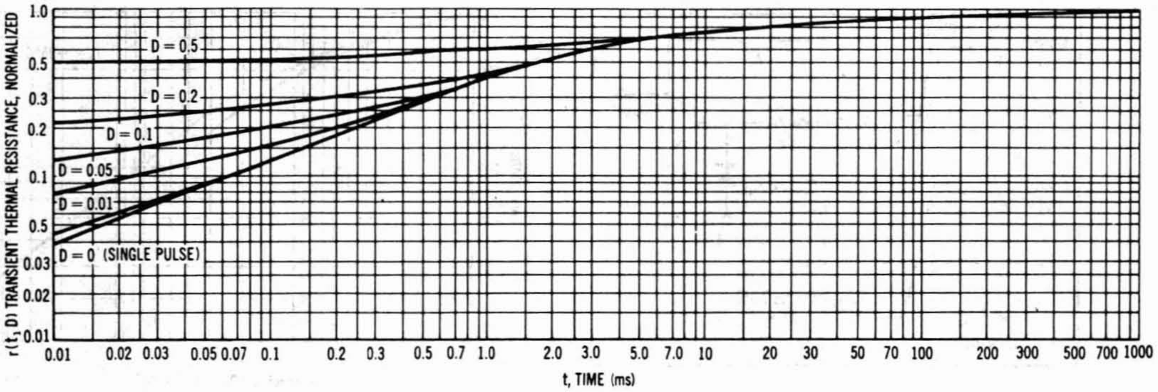
FIGURE 11 — ACTIVE-REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

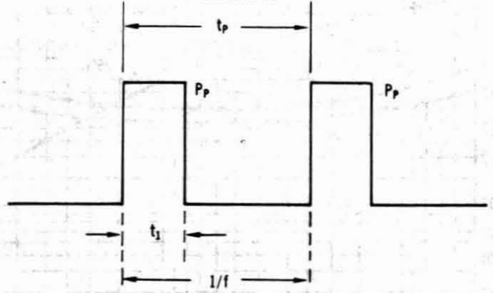
The data of Figure 11 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 12. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 12 — TRANSIENT THERMAL RESISTANCE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



DUTY CYCLE $D = t_1 \cdot f = \frac{t_1}{t_P}$

PEAK PULSE POWER = P_P

A train of periodical power pulses can be represented by the model as shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 12 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 12 by the steady state value θ_{JC}.

Example:

The 2N4913 is dissipating 100 watts under the following conditions: $t_1 = 0.1$ ms, $t_P = 0.5$ ms. ($D = 0.2$)

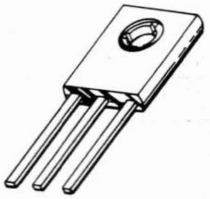
Using Figure 12, at a pulse width of 0.1 ms and $D = 0.2$, the reading of $r(t_1, D)$ is 0.28.

The peak rise in junction temperature is therefore

$$\Delta T = r(t) \times P_P \times \theta_{JC} = 0.28 \times 100 \times 2.0 = 56°C$$

2N4918 thru 2N4920 (SILICON)

CASE 77



Medium-power plastic PNP silicon transistors designed for driver circuits, switching, and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N4918	2N4919	2N4920	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	5.0			Vdc
Collector Current – Continuous*	I_C*	1.0 3.0			Adc
Base Current	I_B	1.0			Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	30 0.24			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150			°C

THERMAL CHARACTERISTICS **

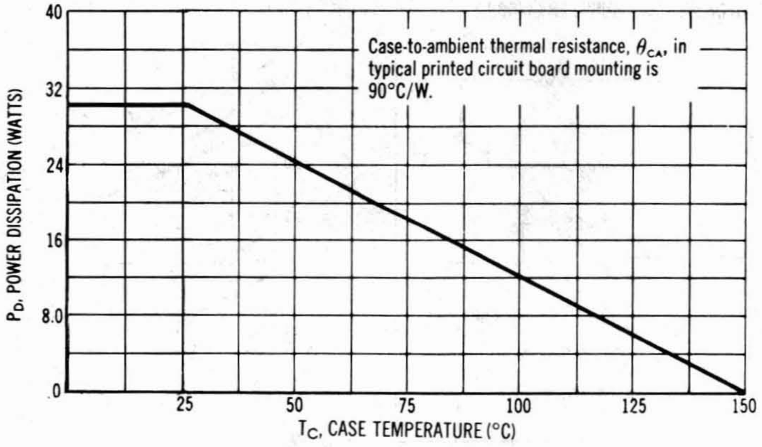
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	4.16	°C/W

* The 1.0 Amp maximum I_C value is based upon JEDEC current gain requirements.

The 3.0 Amp maximum value is based upon actual current-handling capability of the devic (see Figure 5).

** Recommend use of thermal compound for lowest thermal resistance.

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Case-to-ambient thermal resistance, θ_{CA}, in typical printed circuit board mounting is 90°C/W.

Safe Area Curves are indicated by Figure 5. All limits are applicable and must be observed.

2N4918 thru 2N4920 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 0.1 Adc, I_B = 0) 2N4918 2N4919 2N4920	-	$BV_{CEO(sus)}$*	 40 60 80	 - - -	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, I_B = 0) (V_{CE} = 30 Vdc, I_B = 0) (V_{CE} = 40 Vdc, I_B = 0)	-	I_{CEO}	 - - -	 0.5 0.5 0.5	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{BE(off)}$ = 1.5 Vdc) (V_{CE} = Rated V_{CEO}, $V_{BE(off)}$ = 1.5 Vdc, T_C = 125°C)	12	I_{CEX}	 - -	 0.1 0.5	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)	-	I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	-	I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 50 mAdc, V_{CE} = 1.0 Vdc) (I_C = 500 mAdc, V_{CE} = 1.0 Vdc) (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	8	h_{FE}*	 40 20 10	 - 100 -	-
Collector-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	9 11 13	$V_{CE(sat)}$*	-	0.6	Vdc
Base-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	11 13	$V_{BE(sat)}$*	-	1.3	Vdc
Base-Emitter On Voltage* (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	11 13	$V_{BE(on)}$*	-	1.3	Vdc
SMALL SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)	-	f_T	3.0	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	-	C_{ob}	-	100	pF
Small-Signal Current Gain (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	-	h_{fe}	25	-	-

* Pulse Test: PW ≈ 300 μs, Duty Cycle ≈ 2.0%

FIGURE 2 — SWITCHING TIME EQUIVALENT CIRCUIT

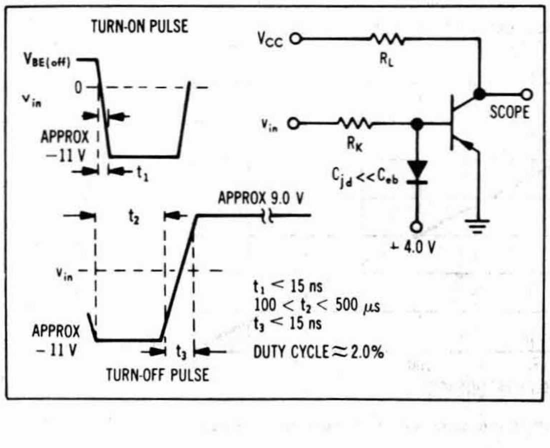

TURN-ON PULSE
$V_{BE(off)}$
0
v_{in}
APPROX −11 V
t_1
V_{CC}
R_L
v_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
+4.0 V
APPROX 9.0 V
t_2
v_{in}
APPROX −11 V
t_3
TURN-OFF PULSE
$t_1 < 15$ ns
$100 < t_2 < 500$ μs
$t_3 < 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 3 — TURN-ON TIME

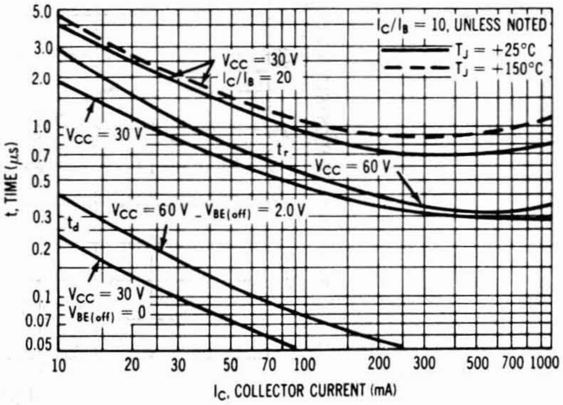


FIGURE 4 — THERMAL RESPONSE

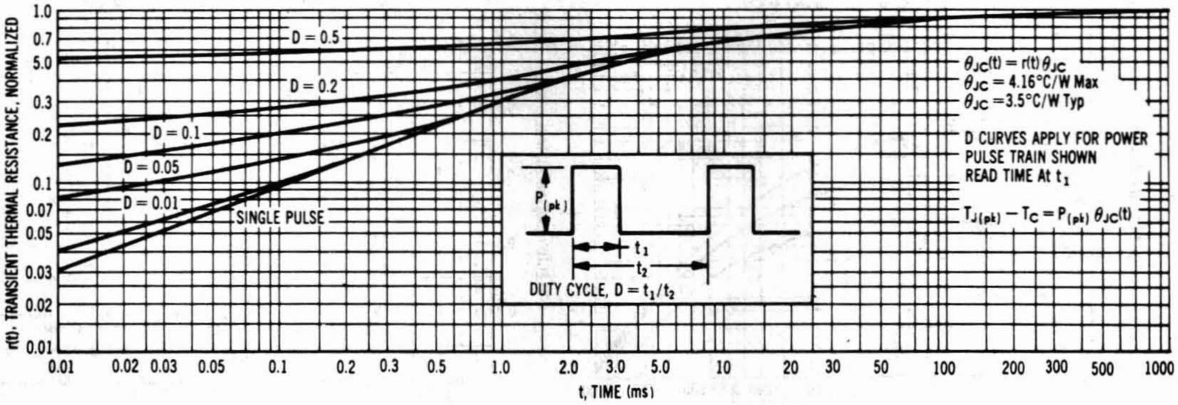
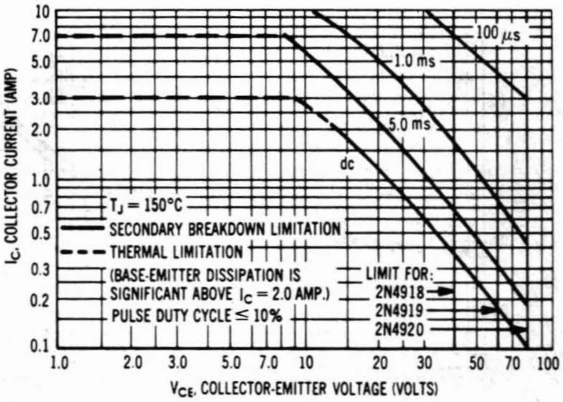


FIGURE 5 — ACTIVE-REGION SAFE OPERATING AREA



The safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor which must be observed for reliable operation. Collector load lines for specific circuits must fall below the limits indicated by the applicable curve.

The data of Figure 5 is based upon $T_{J(pk)} = 150°C$; T_C is variable depending upon conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} \le 150°C$. $T_{J(pk)}$ may be calculated from the data in Figure 4 . At high case temperatures, thermal limitations will reduce the power which can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 — STORAGE TIME

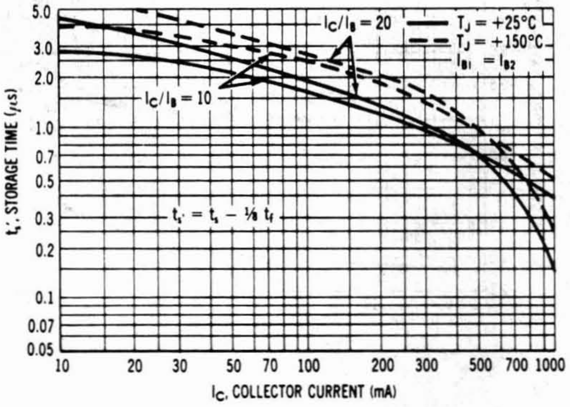
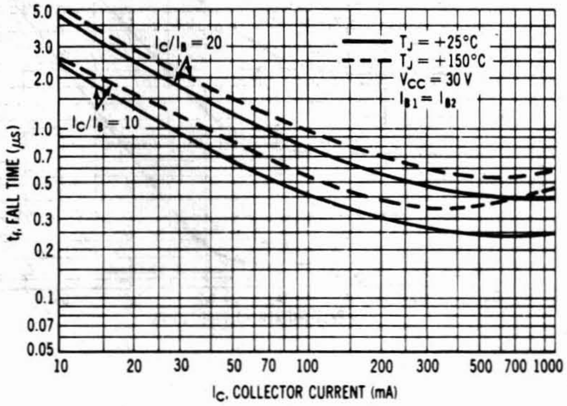


FIGURE 7 — FALL TIME



TYPICAL DC CHARACTERISTICS

FIGURE 8 — CURRENT GAIN

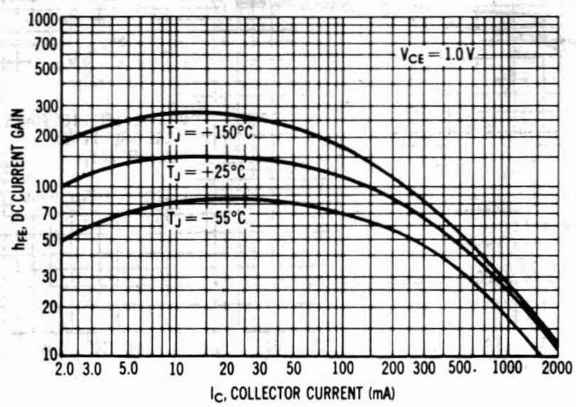


FIGURE 9 — COLLECTOR SATURATION REGION

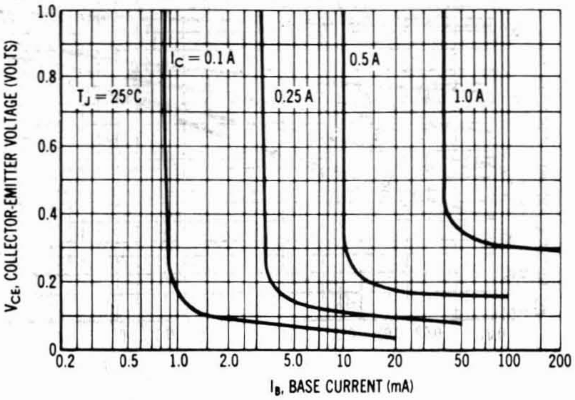


FIGURE 10 — EFFECTS OF BASE-EMITTER RESISTANCE

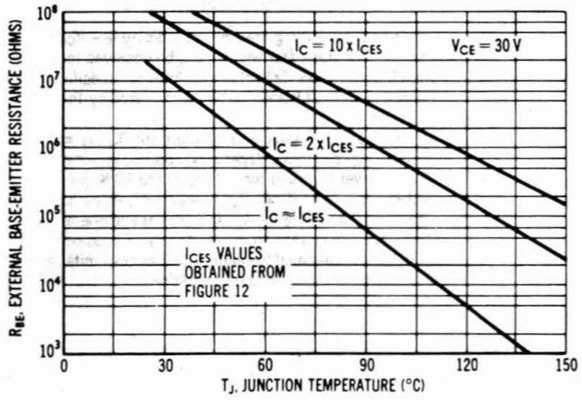


FIGURE 11 — "ON" VOLTAGE

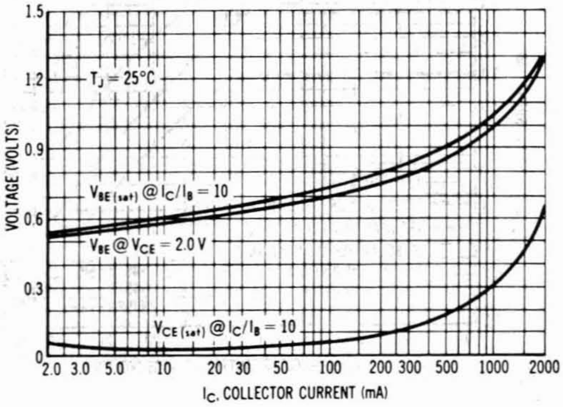


FIGURE 12 — COLLECTOR CUTOFF REGION

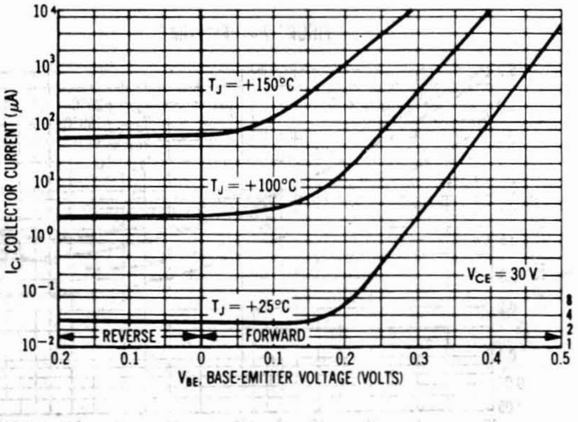
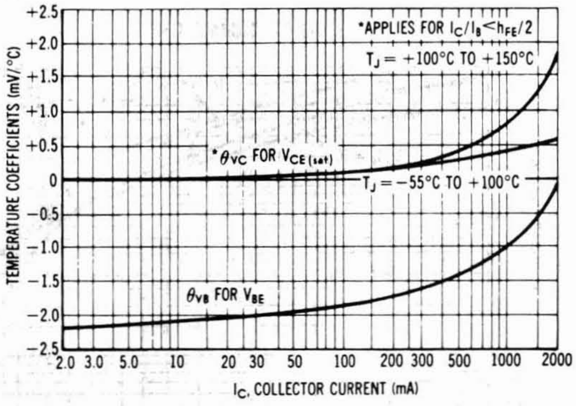
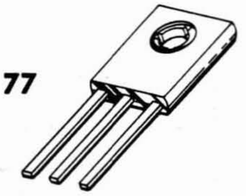


FIGURE 13 — TEMPERATURE COEFFICIENTS



2N4921 thru 2N4923 (SILICON)



CASE 77

Medium-power plastic NPN silicon transistors designed for driver circuits, switching, and amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N4921	2N4922	2N4923	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	5.0			Vdc
Collector Current — Continuous*	I_C*	1.0 3.0			Adc
Base Current — Continuous	I_B	1.0			Adc
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	30 0.24			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150			°C

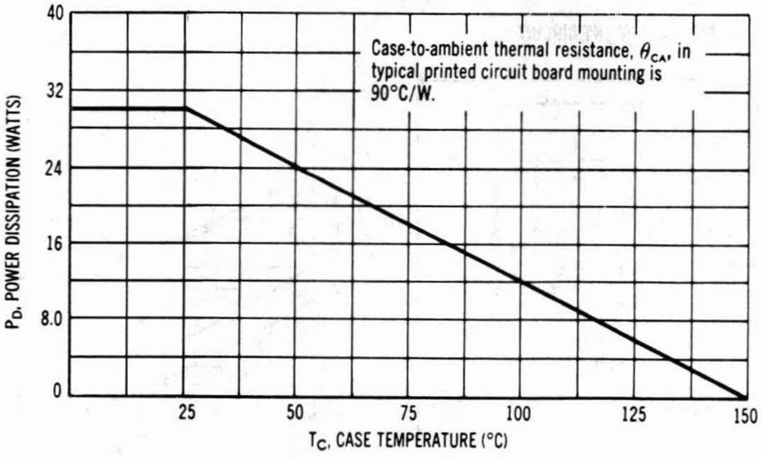
THERMAL CHARACTERISTICS **

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	4.16	°C/W

* The 1.0 Amp maximum I_C value is based upon JEDEC current gain requirements. The 3.0 Amp maximum value is based upon actual current-handling capability of the device (see Figure 5).

** Recommend use of thermal compound for lowest thermal resistance.

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 5. All limits are applicable and must be observed.

2N4921 thru 2N4923 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Figure No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 0.1 Adc, I_B = 0) 2N4921 2N4922 2N4923	-	$BV_{CEO(sus)}$*	40 60 80	- - -	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, I_B = 0) 2N4921 (V_{CE} = 30 Vdc, I_B = 0) 2N4922 (V_{CE} = 40 Vdc, I_B = 0) 2N4923	-	I_{CEO}	- - -	0.5 0.5 0.5	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc) (V_{CE} = Rated V_{CEO}, $V_{EB(off)}$ = 1.5 Vdc, T_C = 125°C)	12	I_{CEX}	- -	0.1 0.5	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)	-	I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)	-	I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 50 mAdc, V_{CE} = 1.0 Vdc) (I_C = 500 mAdc, V_{CE} = 1.0 Vdc) (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	8	h_{FE}*	40 20 10	- 100 -	-
Collector-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	9 11 13	$V_{CE(sat)}$*	-	0.6	Vdc
Base-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	11 13	$V_{BE(sat)}$*	-	1.3	Vdc
Base-Emitter On Voltage* (I_C = 1.0 Adc, V_{CE} = 1.0 Vdc)	11 13	$V_{BE(on)}$*	-	1.3	Vdc
SMALL SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 MHz)	-	f_T	3.0	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	-	C_{ob}	-	100	pF
Small-Signal Current Gain (I_C = 250 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	-	h_{fe}	25	-	-

* Pulse Test: PW ≈ 300 μs, Duty Cycle ≈ 2.0%.

FIGURE 2 — SWITCHING TIME EQUIVALENT CIRCUIT

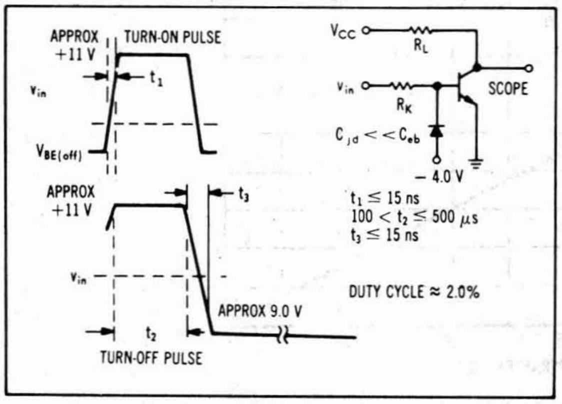

APPROX +11 V
TURN-ON PULSE
t_1
v_{in}
$V_{BE(off)}$
APPROX +11 V
t_3
v_{in}
APPROX 9.0 V
t_2
TURN-OFF PULSE
V_{CC}
R_L
v_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
− 4.0 V
$t_1 \leq 15$ ns
$100 < t_2 \leq 500\ \mu s$
$t_3 \leq 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 3 — TURN-ON TIME

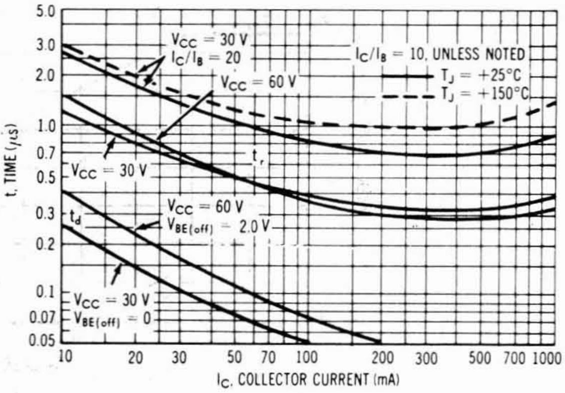


FIGURE 4 — THERMAL RESPONSE

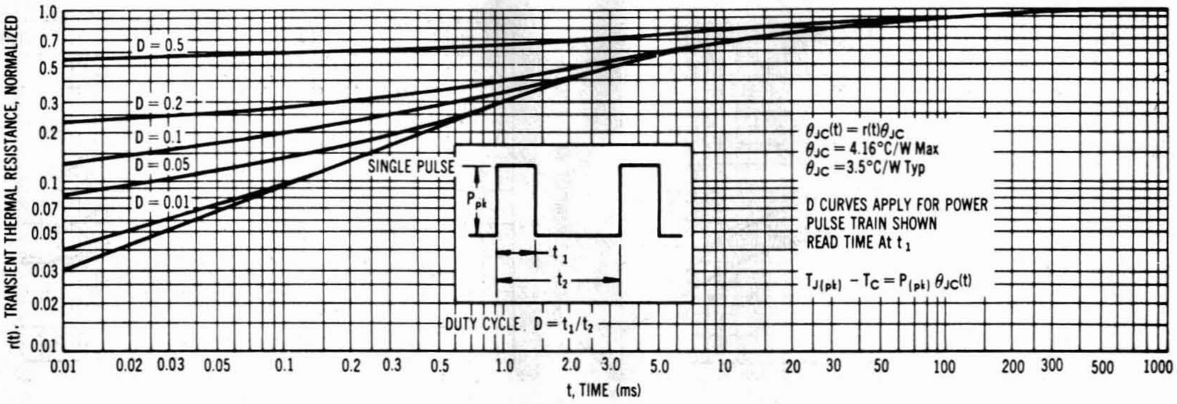
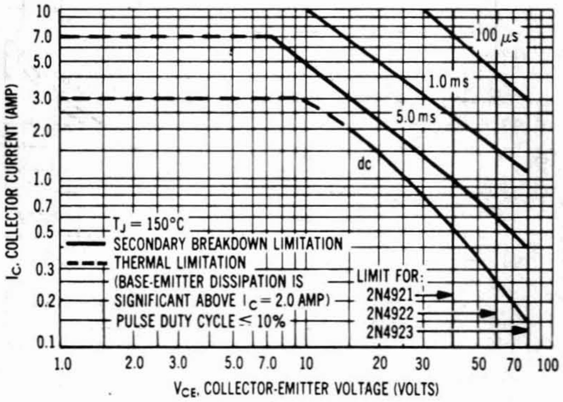


FIGURE 5 — ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)}$ = 150°C; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq 150°C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 — STORAGE TIME

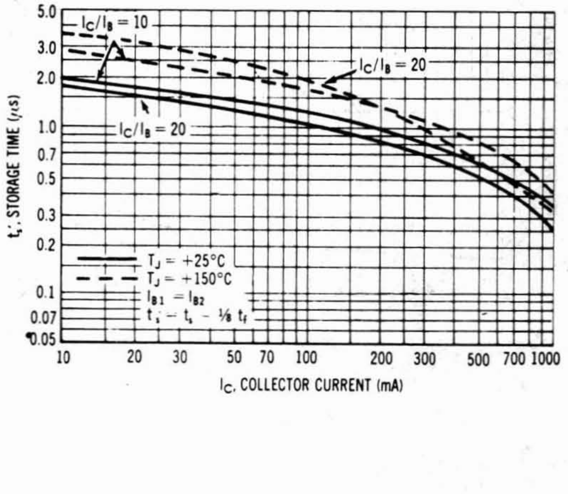
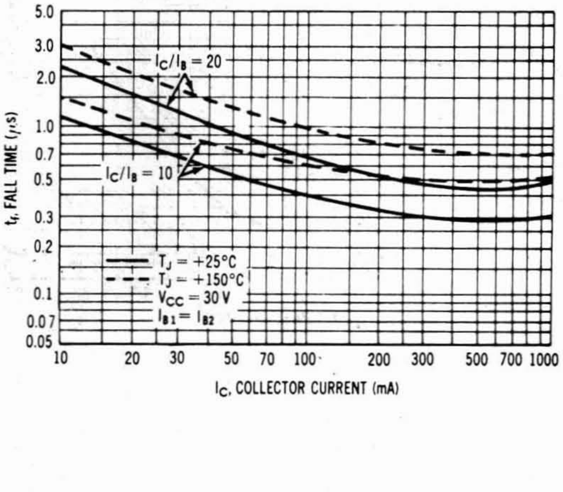


FIGURE 7 — FALL TIME



2N4921 thru 2N4923 (continued)

FIGURE 8 — CURRENT GAIN

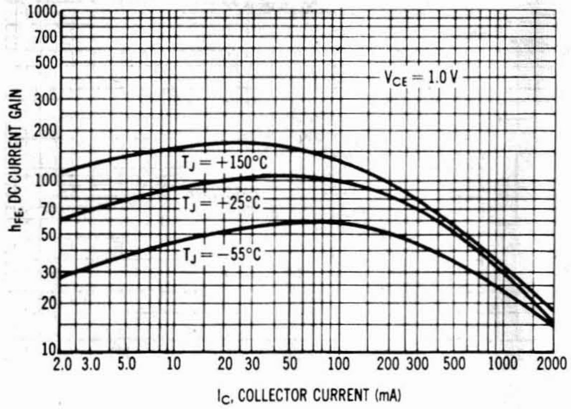


FIGURE 9 — COLLECTOR SATURATION REGION

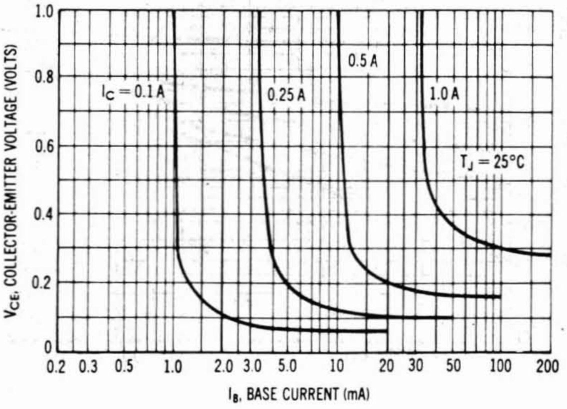


FIGURE 10 — EFFECTS OF BASE-EMITTER RESISTANCE

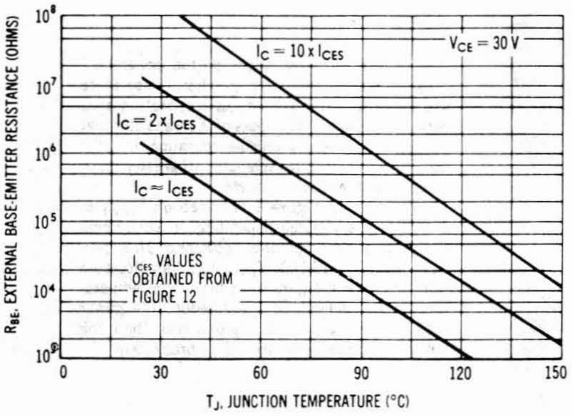


FIGURE 11 — "ON" VOLTAGE

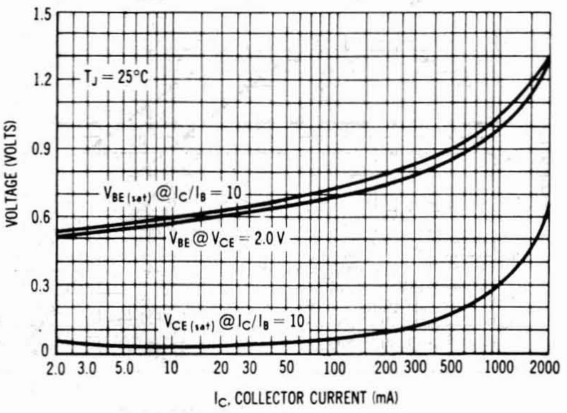


FIGURE 12 — COLLECTOR CUTOFF REGION

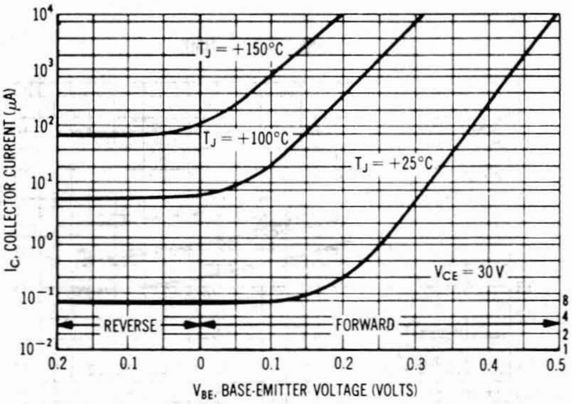
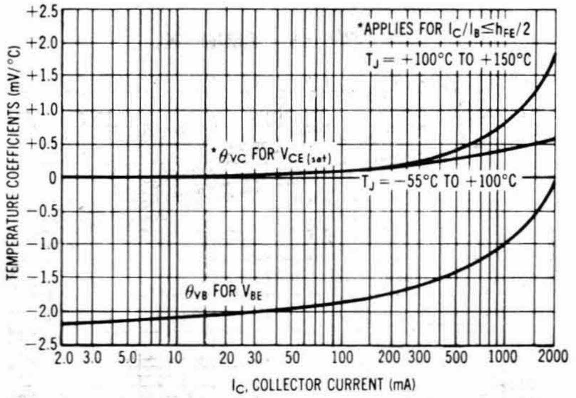


FIGURE 13 — TEMPERATURE COEFFICIENTS



2N4924 (SILICON)
2N4925

. . . NPN silicon annular transistors designed for high-voltage, high-frequency amplifier applications.

Collector connected to case

CASE 79
(TO-39)

MAXIMUM RATINGS

Rating	Symbol	2N4924	2N4925	Unit
Collector-Emitter Voltage	V_{CEO}	100	150	Vdc
Collector-Base Voltage	V_{CB}	100	150	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current - Continuous	I_C	200		mAdc
Total Device Dissipation $T_A = 25°C$ Derate above 25°C	P_D	1.0 5.71		W mW/°C
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	5.0 28.6		W mW/°C
Operating Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to + 200		°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0) 2N4924	$BV_{CEO}{}^*$	100	-	Vdc
2N4925		150	-	
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_C = 0) 2N4924	BV_{CBO}	100	-	Vdc
2N4925		150	-	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 50 Vdc, I_E = 0)		-	0.1	
(V_{CB} = 75 Vdc, I_E = 0)		-	0.1	
ON CHARACTERISTICS				
DC Current Gain*	$h_{FE}{}^*$			-
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)		25	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)		35	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)		40	200	
Collector-Emitter Saturation Voltage*	$V_{CE(sat)}{}^*$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc)		-	0.25	
(I_C = 50 mAdc, I_B = 5.0 mAdc)		-	0.4	
Base-Emitter On Voltage* (I_C = 50 mAdc, V_{CE} = 10 Vdc)	$V_{BE(on)}{}^*$	-	0.95	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain - Bandwidth Product (I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	100	500	MHz
Collector-Base Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	C_{cb}	-	10	pF
Collector-Emitter Capacitance (V_{BE} = 1.0 Vdc, I_C = 0, f = 100 kHz)	C_{eb}	-	80	pF

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N4926 (SILICON)
2N4927

. . . NPN silicon annular transistors designed for high-voltage, high-frequency amplifier applications.

Collector connected to case

CASE 79
(TO-39)

MAXIMUM RATINGS

Rating	Symbol	2N4926	2N4927	Unit
Collector-Emitter Voltage	V_{CEO}	200	250	Vdc
Collector-Base Voltage	V_{CB}	200	250	Vdc
Emitter-Base Voltage	V_{EB}	7.0		Vdc
Collector Current - Continuous	I_C	50		mAdc
Total Device Dissipation $T_A = 25°C$ Derate above 25°C	P_D	1.0 5.71		W mW/°C
Total Device Dissipation $T_C = 25°C$ Derate above 25°C	P_D	5.0 28.6		W mW/°C
Operating Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to + 200		°C

2N4926, 2N4927 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc , I_B = 0) 2N4926	BV_{CEO}*	200	-	Vdc
2N4927		250	-	
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_C = 0) 2N4926	BV_{CBO}	200	-	Vdc
2N4927		250	-	
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	7.0	-	Vdc
Collector Cutoff Current (V_{CB} = 100 Vdc, I_E = 0) 2N4926	I_{CBO}	-	0.1	μAdc
(V_{CB} = 100 Vdc, I_E = 0, T_A = 100°C)		-	10	
(V_{CB} = 150 Vdc, I_E = 0) 2N4927		-	0.1	
(V_{CB} = 150 Vdc, I_E = 0, T_A = 100°C)		-	10	
Emitter Cutoff Current (V_{BE} = 5.0 V	I_{EBO}	-	0.1	μAdc

*Pulse Width ≦ 300 μs, Duty Cycle ≦ 1.0%

ON CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
DC Current Gain** (I_C = 3.0 mAdc, V_{CE} = 10 Vdc)	h_{FE}**	10	-	-
(I_C = 10 mAdc, V_{CE} = 10 Vdc)		15	-	
(I_C = 30 mAdc, V_{CE} = 10 Vdc)		20	200	
(I_C = 50 mAdc, V_{CE} = 20 Vdc)		20	-	
Collector-Emitter Saturation Voltage** (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$**	-	1.0	Vdc
(I_C = 30 mAdc, I_B = 3.0 mAdc)		-	2.0	
Base-Emitter Saturation Voltage** (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$**	-	1.2	Vdc
(I_C = 50 mAdc, I_B = 3.0 mAdc)			1.5	
Base-Emitter On Voltage (I_C = 30 mAdc, V_{CE} = 10 Vdc)	$V_{BE(on)}$	-	1.5	Vdc

SMALL-SIGNAL CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 20 MHz)	f_T	30	300	MHz
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	C_{cb}	-	6.0	pF
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}	75	750	k ohm
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}	0.1	1.0	$X10^{-4}$
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	25	250	-
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	5.0	50	μmhos
Real Part of Input Impedance (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 5.0 MHz)	$Re(h_{ie})$	4	40	ohms

** Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%

2N4928 thru 2N4931

CASE 79
(TO-39)

High-voltage PNP silicon annular transistors for use in general-purpose high-voltage applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	2N4928	2N4929	2N4930	2N4931	Unit
Collector-Emitter Voltage	V_{CEO}	100	150	200	250	Vdc
Collector-Base Voltage	V_{CB}	100	150	200	250	Vdc
Emitter-Base Voltage	V_{EB}	4.0	4.0	4.0	4.0	Vdc
Collector Current — Continuous	I_C	100	500	500	500	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.6 3.4	1.0 5.71	1.0 5.71	1.0 5.71	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	3.0 17.2	5.0 28.6	5.0 28.6	5.0 28.6	Watt mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200				°C

2N4928 thru 2N4931 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage*	BV_{CEO}^{*}			Vdc
(I_C = 10 mAdc, I_B = 0) 2N4928		100	-	
2N4929		150	-	
2N4930		200	-	
2N4931		250	-	
Collector-Base Breakdown Voltage	BV_{CBO}			Vdc
(I_E = 0, I_C = 100 μAdc) 2N4928		100	-	
2N4929		150	-	
2N4930		200	-	
2N4931		250	-	
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4.0	-	Vdc
Collector Cutoff Current	I_{CBO}			μAdc
(V_{CB} = 50 Vdc, I_E = 0) 2N4928		-	0.5	
(V_{CB} = 75 Vdc, I_E = 0) 2N4929		-	0.5	
(V_{CB} = 150 Vdc, I_E = 0) 2N4930, 2N4931		-	1.0	
Emitter Cutoff Current	I_{EBO}			μAdc
(V_{BE} = 3.0 Vdc, I_C = 0) 2N4928, 2N4929		-	0.5	
(V_{BE} = 3.0 Vdc, I_C = 0) 2N4930, 2N4931		-	1.0	
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			-
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc) All Types		20	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)* 2N4928, 2N4929		25	200	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)* 2N4930, 2N4931		20	200	
(I_C = 50 mAdc, V_{CE} = 10 Vdc)* 2N4928, 2N4929		20	-	
(I_C = 30 mAdc, V_{CE} = 10 Vdc)* 2N4930, 2N4931		20	-	
Collector-Emitter Saturation Voltage*	$V_{CE(sat)}^{*}$			Vdc
(I_C = 10 mAdc, I_B = 1.0 mAdc) 2N4928, 2N4929		-	0.5	
2N4930, 2N4931		-	5.0	
Base-Emitter On Voltage (I_C = 10 mAdc, V_{CE} = 10 Vdc)	$V_{BE(on)}$	-	1.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Gandwidth Product	f_T			MHz
(I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz) 2N4928, 2N4929		100	1,000	
(I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 20 MHz) 2N4930, 2N4931		20	200	
Collector-Base Capacitance	C_{cb}			pF
(V_{CB} = 20 Vdc, I_E = 0, f = 140 kHz) 2N4928		-	6.0	
(V_{CB} = 20 Vdc, I_E = 0, f = 140 kHz) 2N4929		-	10	
(V_{CB} = 20 Vdc, I_E = 0, f = 140 kHz) 2N4930, 2N4931		-	20	
Emitter-Base Capacitance	C_{eb}			pF
(V_{BE} = 2.0 Vdc, I_C = 0, f = 140 kHz) 2N4928		-	40	
(V_{BE} = 1.0 Vdc, I_C = 0, f = 140 kHz) 2N4929		-	80	
(V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz) 2N4930, 2N4931		-	400	

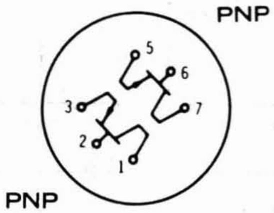
*Pulse Width ≤ 300 μs: Duty Cycle ≤ 2.0%

2N4937 thru 2N4942

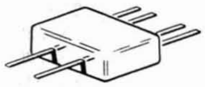
Dual PNP silicon annular transistors especially designed for low-level, differential amplifier applications.

CASE 32

2N4937
2N4938
2N4939

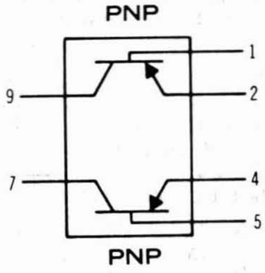


Pins 4 and 8 omitted



CASE 33
(TO-89)

2N4940
2N4941
2N4942



Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	40		Vdc
Collector-Base Voltage	V_{CB}	50		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current - Continuous	I_C	50		mAdc
Base Current	I_B	10		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ $T_A = 25°C$	P_D			
Metal Can		500	600	mW
Derate above 25°C		2.9	3.4	mW/°C
Flat Pack		250	350	mW
Derate above 25°C		1.5	2.0	mW/°C

2N4937 thru 2N4942 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	40		-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	50		-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0		-	Vdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0)	I_{CBO}	-	2.0	20	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	3.0	20	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 100 μAdc, V_{CE} = 10 Vdc) (I_C = 1.0 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc)	h_{FE}	40 50 50	- - -	200 250 250	-
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain-Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	400	900	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz) Emitter Guarded	C_{cb}	-	3.0	5.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz) Collector Guarded	C_{eb}	-	7.0	10	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{ie}	1.0	4.0	10	kΩ
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{re}	-	3.0	10	$X\ 10^{-4}$
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{fe}	50	-	-	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{oe}	5.0	15	50	μmhos
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 kΩ , f = 10 Hz to 15.7 kHz)	NF	-	-	4.0	dB
MATCHING CHARACTERISTICS					
DC Current Gain Ratio* (I_C = 100 μAdc to 1.0 mAdc, V_{CE} = 10 Vdc) 2N4937, 2N4940 2N4938, 2N4941 2N4939, 2N4942 (I_C = 100 μAdc to 1.0 mAdc, V_{CE} = 10 Vdc, T_A = -55°C to +125°C) 2N4937, 2N4940 2N4938, 2N4941 2N4939, 2N4942	h_{FE1}/h_{FE2}*	0.9 0.8 - 0.85 0.7 -	- - 0.7 - - 0.6	1.0 1.0 - 1.0 1.0 -	-
Base Voltage Differential (I_C = 100 μA to 1.0 mAdc, V_{CE} = 10 Vdc) 2N4937, 2N4940 2N4938, 2N4941 2N4939, 2N4942	$\lvert V_{BE1}-V_{BE2}\rvert$	- - -	- - 5.0	3.0 5.0 -	mVdc
Base Voltage Differential Gradient (I_C = 100 μAdc to 1.0 mAdc, V_{CE} = 10 Vdc, T_A = -55°C to +125°C) 2N4937, 2N4940 2N4938, 2N4941 2N4939, 2N4942	$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$	- - -	- - 20	10 20 -	μV/°C

* The lowest h_{FE} reading is taken as h_{FE1} for this ratio

2N4948 (SILICON)
2N4949

CASE 22A
(TO-18 Modified)
(Lead 3 connected to case)

Silicon annular unijunction transistors designed for military and industrial use in pulse, timing, triggering, sensing, and oscillator circuits. The annular process provides low leakage current, fast switching and low peak-point currents as well as outstanding reliability and uniformity.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	P_D	360*	mW
RMS Emitter Current	I_e	50	mA
Peak Pulse Emitter Current**	i_e	1.0**	Amp
Emitter Reverse Voltage	V_{B2E}	30	Volts
Storage Temperature Range	T_{stg}	-65 to +200	°C

* Derate 2.4 mW/°C increase in ambient temperature. Total power dissipation (available power to Emitter and Base-Two) must be limited by external circuitry. Interbase voltage (V_{B2B1}) limited by power dissipation,

$$V_{B2B1} = \sqrt{R_{BB} \cdot P_D}.$$

** Capacitance discharge current must fall to 0.37 Amp within 3.0 ms and PRR ≤ 10 PPS.

2N4948, 2N4949 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Intrinsic Standoff Ratio (V_{B2B1} = 10 V) Note 1	2N4948 2N4949	η	0.55 0.74	- -	0.82 0.86	-
Interbase Resistance (V_{B2B1} = 3.0 V, I_E = 0)	2N4948, 2N4949	R_{BB}	4.0	7.0	12.0	k ohms
Interbase Resistance Temperature Coefficient (V_{B2B1} = 3.0 V, I_E = 0, T_A = -65°C to +100°C)		αR_{BB}	0.1	-	0.9	%/°C
Emitter Saturation Voltage (V_{B2B1} = 10 V, I_E = 50 mA) Note 2		$V_{EB1(sat)}$	-	2.5	3.0	Volts
Modulated Interbase Current (V_{B2B1} = 10 V, I_E = 50 mA)		$I_{B2(mod)}$	12	15	-	mA
Emitter Reverse Current (V_{B2E} = 30 V, I_{B1} = 0) (V_{B2E} = 30 V, I_{B1} = 0, T_A = 125°C)		I_{EB2O}	- -	5.0 -	10 1.0	nA μA
Peak Point Emitter Current (V_{B2B1} = 25 V)	2N4948 2N4949	I_P	- -	0.6 0.6	2.0 1.0	μA
Valley Point Current (V_{B2B1} = 20 V, R_{B2} = 100 ohms) Note 2	2N4948, 2N4949	I_V	2.0	4.0	- -	mA
Base-One Peak Pulse Voltage (Note 3, Figure 3)	2N4949 2N4948	V_{OB1}	3.0 6.0	5.0 8.0	- -	Volts
Maximum Oscillation Frequency (Figure 4)		$f_{(max)}$	-	1.25	-	MHz

NOTES

1. Intrinsic standoff ratio.
   η, is defined by equation:

$$\eta = \frac{V_P - V_{(EB1)}}{V_{B2B1}}$$

Where V_P = Peak Point Emitter Voltage
V_{B2B1} = Interbase Voltage
$V_{(EB1)}$ = Emitter to Base-One Junction Diode Drop
(≈0.5 V @ 10 μA)

2. Use pulse techniques: PW ≈ 300 μs duty cycle ≤2% to avoid internal heating due to interbase modulation which may result in erroneous readings.

3. Base-One Peak Pulse Voltage is measured in circuit of Figure 3. This specification is used to ensure minimum pulse amplitude for applications in SCR firing circuits and other types of pulse circuits.

FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

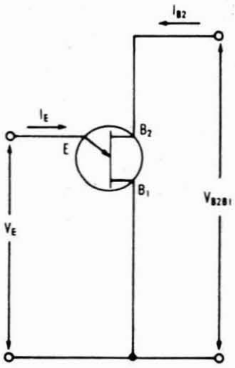


FIGURE 2 — STATIC EMITTER CHARACTERISTICS CURVES

(Exaggerated to Show Details)

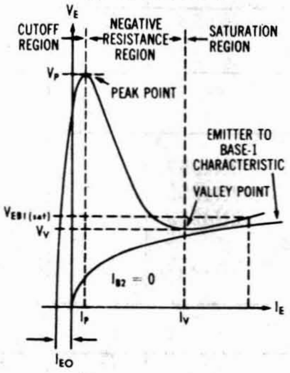


FIGURE 3 — V_{OB1} TEST CIRCUIT
(Typical Relaxation Oscillator)

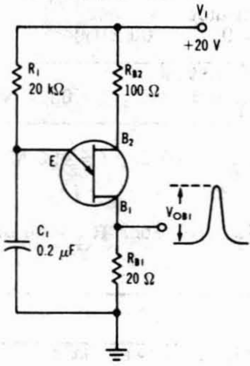
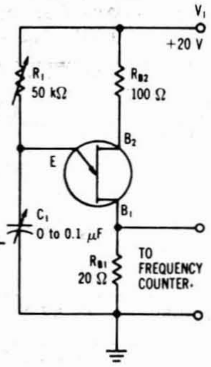


FIGURE 4 — F(max) MAXIMUM FREQUENCY TEST CIRCUIT



2N4957 (SILICON)
2N4958
2N4959

PNP silicon annular small-signal RF transistor designed for high-gain, low-noise amplifier, oscillator, and mixer applications.

CASE 20
(TO-72)

Active elements isolated from case

MAXIMUM RATINGS

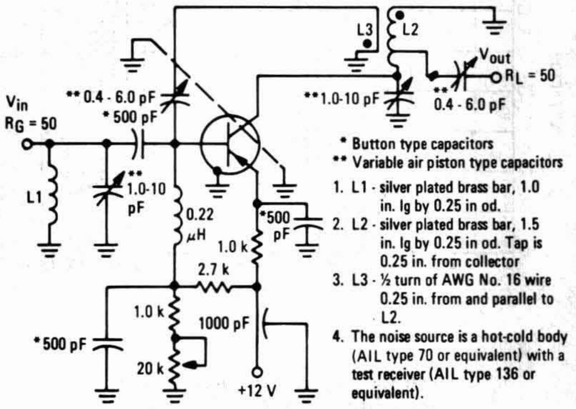
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current — Continuous	I_C	30	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	200 1.14	mWatt mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage ($I_C = 1.0$ mAdc, $I_B = 0$)	BV_{CEO}	30	—	—	Vdc
Collector-Base Breakdown Voltage ($I_C = 100\ \mu$Adc, $I_E = 0$)	BV_{CBO}	30	—	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu$Adc, $I_C = 0$)	BV_{EBO}	3.0	—	—	Vdc
Collector Cutoff Current ($V_{CB} = 20$ Vdc, $I_E = 0$)	I_{CBO}	—	—	0.1	μAdc
($V_{CB} = 20$ Vdc, 0, $T_A = 150°C$)		—	—	100	
ON CHARACTERISTICS					
DC Current Gain ($I_C = 2.0$ mAdc, $V_{CE} = 10$ Vdc)	h_{FE}	20	40	—	—
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product ($I_E = 2.0$ mAdc, $V_{CE} = 10$ Vdc, f = 100 MHz) 2N4957	f_T	1200	1600	—	MHz
2N4958, 2N4959		1000	1500	—	
Collector-Base Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 100 kHz)	C_{cb}	—	0.4	0.8	pF
Collector-Base Time Constant ($I_E = 2.0$ mAdc, $V_{CB} = 10$ Vdc, f = 63.6 MHz)	$r_b'C_C$	—	—	8.0	ps
Noise Figure ($I_C = 2.0$ mAdc, $V_{CE} = 10$ Vdc, f = 450 MHz) 2N4957	NF	—	2.6	3.0	dB
Fig. 1 2N4958		—	2.9	3.3	
2N4959		—	3.2	3.8	
($I_C = 2.0$ mAdc, $V_{CE} = 10$ Vdc, $R_G = 50$ ohms, f = 1.0 GHz) 2N4957		—	5.0	—	
FUNCTIONAL TESTS					
Common-Emitter Amplifier Power Gain ($V_{CE} = 10$ Vdc, $I_C = 2.0$ mAdc, f = 450 MHz) 2N4957	G_{pe}	17	—	—	dB
2N4958		16	—	—	
2N4959		15	—	—	
($V_{CE} = 10$ Vdc, $I_C = 2.0$ mAdc, $R_G = 50$ ohms, f = 1.0 GHz) 2N4957		—	13	—	

RF PERFORMANCE DATA

FIGURE 1 – NOISE FIGURE AND POWER GAIN TEST CIRCUIT


V_{in}
RG = 50
** 0.4 - 6.0 pF
* 500 pF
** 1.0-10 pF
L1
0.22 μH
1.0 k
2.7 k
1.0 k
*500 pF
20 k
1000 pF
*500 pF
*500 pF
+12 V
L3
L2
Vout
RL = 50
**1.0-10 pF
** 0.4 - 6.0 pF

* Button type capacitors
** Variable air piston type capacitors

1. L1 - silver plated brass bar, 1.0 in. lg by 0.25 in od.
2. L2 - silver plated brass bar, 1.5 in. lg by 0.25 in od. Tap is 0.25 in. from collector
3. L3 - ½ turn of AWG No. 16 wire 0.25 in. from and parallel to L2.
4. The noise source is a hot-cold body (AIL type 70 or equivalent) with a test receiver (AIL type 136 or equivalent).

FIGURE 2 – UNILATERALIZED POWER GAIN versus FREQUENCY

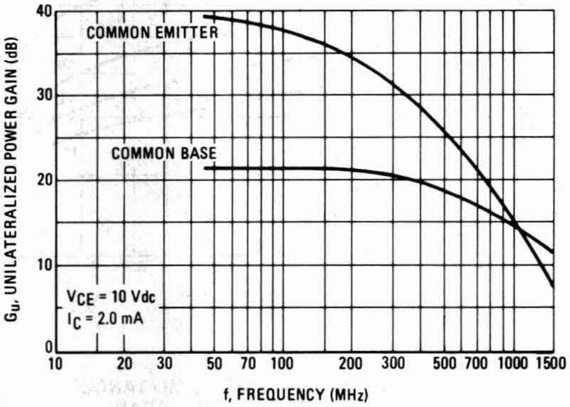


FIGURE 3 – NOISE FIGURE versus FREQUENCY

(RS & IC OPTIMIZED FOR BROAD BAND PERFORMANCE)

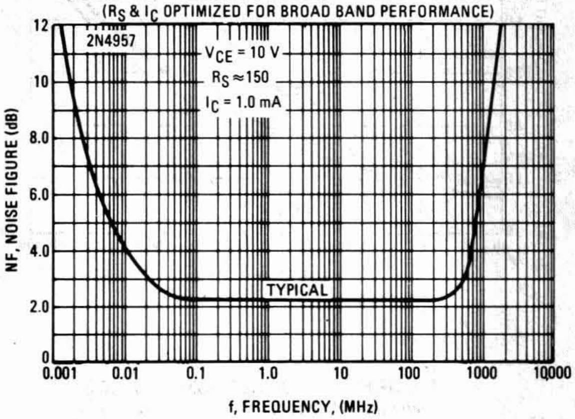


FIGURE 4 – NOISE FIGURE AND POWER GAIN versus COLLECTOR CURRENT

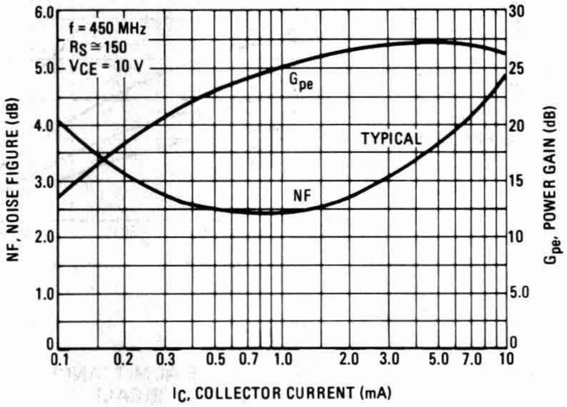


FIGURE 5 – CONTOURS OF NOISE FIGURE versus SOURCE RESISTANCE AND COLLECTOR CURRENT

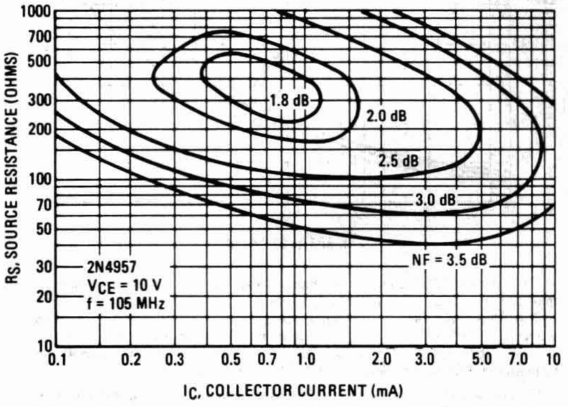
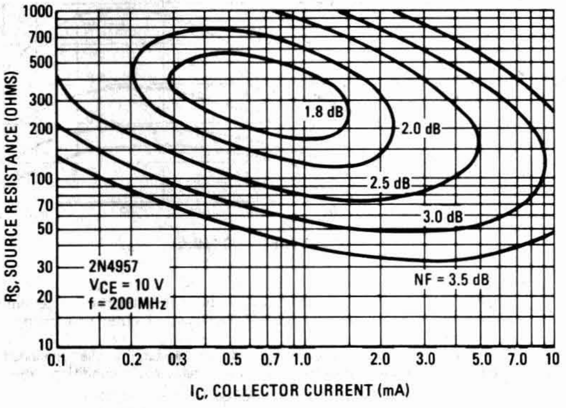


FIGURE 6 – CONTOURS OF NOISE FIGURE versus SOURCE RESISTANCE AND COLLECTOR CURRENT



COMMON EMITTER CIRCUIT DESIGN DATA

(V_{CE} = 10 Vdc, I_C = 2.0 mA)

FIGURE 7 – TRANSDUCER GAIN versus FREQUENCY

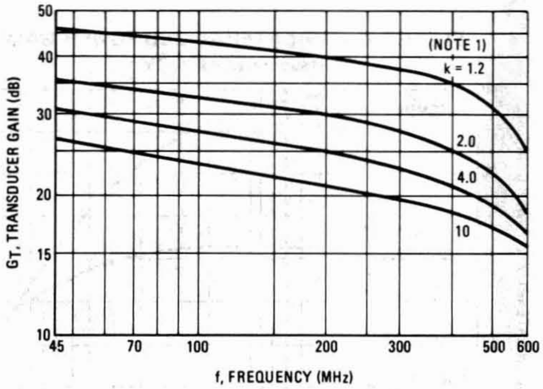


FIGURE 8 – LINVILL STABILITY FACTOR versus FREQUENCY

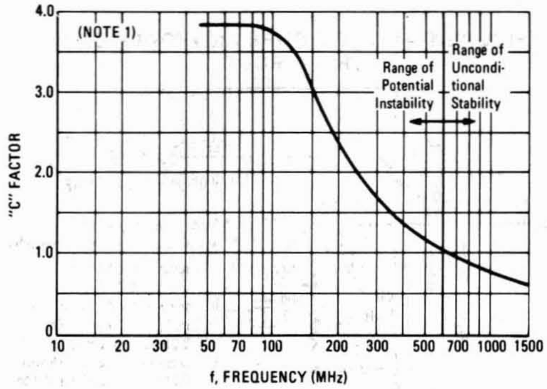


FIGURE 9 – LOAD ADMITTANCE versus FREQUENCY (REAL)

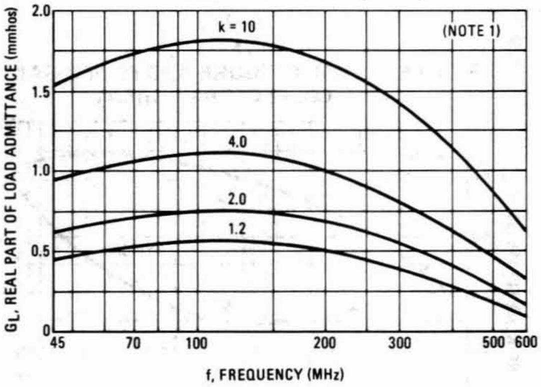


FIGURE 10 – LOAD ADMITTANCE versus FREQUENCY (IMAGINARY)

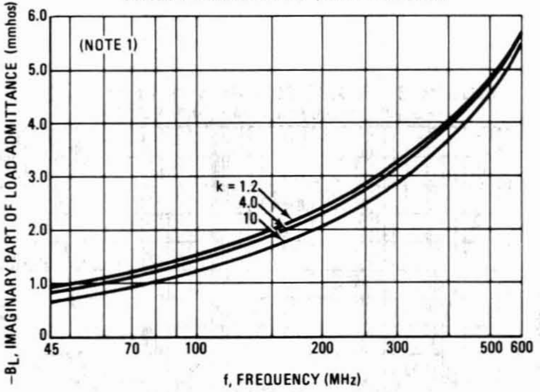


FIGURE 11 – SOURCE ADMITTANCE versus FREQUENCY (REAL)

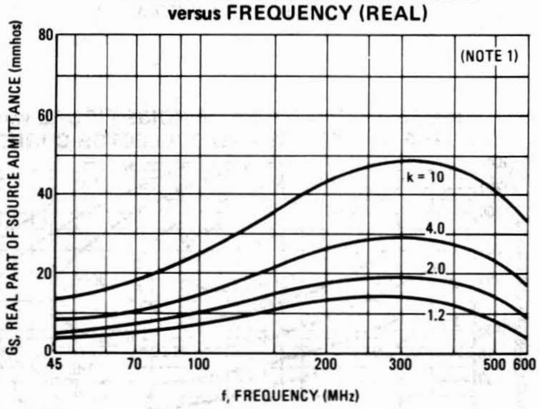
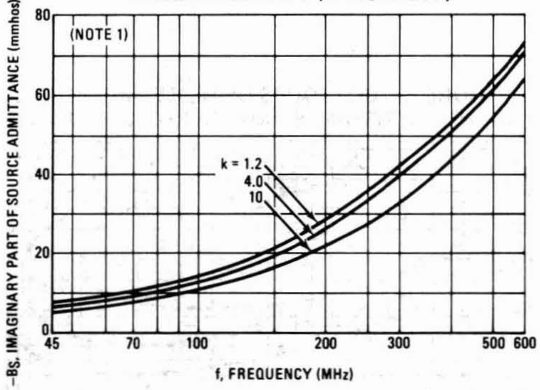


FIGURE 12 – SOURCE ADMITTANCE versus FREQUENCY (IMAGINARY)



NOTE 1

Figures 7 through 18 are included to assist the circuit designer in determining the stability of his particular circuit. Two stability criteria are given in these figures.

The Linvill "C" factor* is a measure of transistor stability when the input and output are terminated in the worst-case (open circuit) condition. When "C" is less than 1.0, the circuit is unconditionally stable. When "C" is greater than 1.0, the circuit is potentially unstable.

The Stern "K" factor† has been defined to determine the stability of a practical amplifier terminated in finite load and source admittances. If "K" is greater than 1.0, the circuit will be stable. If less than 1.0, the circuit will be unstable. For further details, see Application Note AN-215.

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* "Transistors and Active Circuits," Linvill and Gibbons, McGraw-Hill, 1961.

† "Stability and Power Gain of Tuned Transistor Amplifiers," Arthur P. Stern, Proc. I.R.E., March 1967.

COMMON BASE CIRCUIT DESIGN DATA

(V_{CB} = 10 Vdc, I_C = 2.0 mA)

FIGURE 13 – TRANSDUCER GAIN versus FREQUENCY

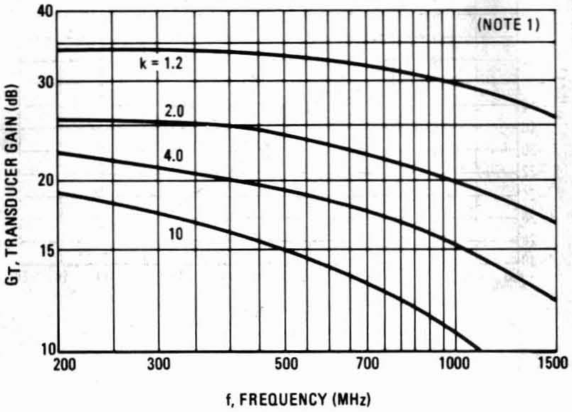


FIGURE 14 – LINVILL STABILITY FACTOR versus FREQUENCY

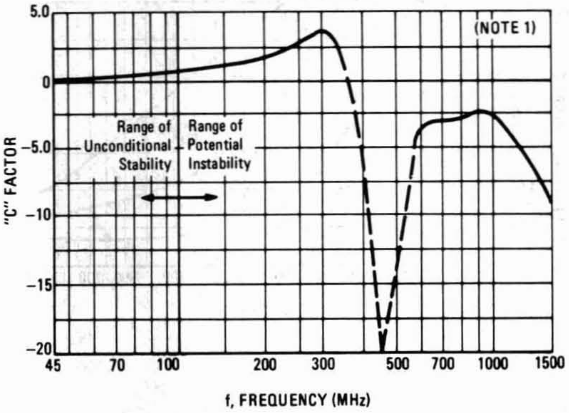


FIGURE 15 – LOAD ADMITTANCE versus FREQUENCY (REAL)

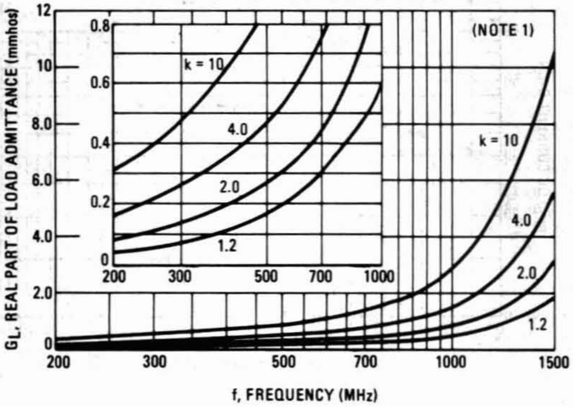


FIGURE 16 – LOAD ADMITTANCE versus FREQUENCY (IMAGINARY)

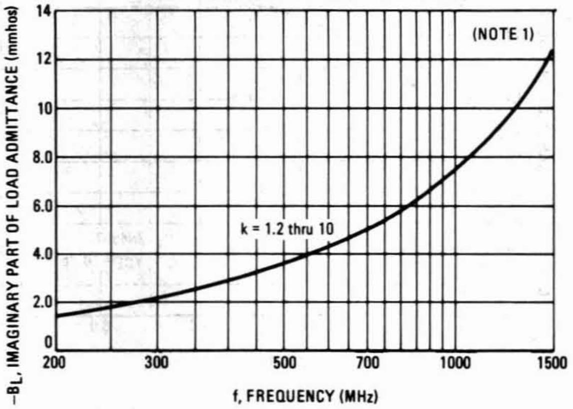


FIGURE 17 – SOURCE ADMITTANCE versus FREQUENCY (REAL)

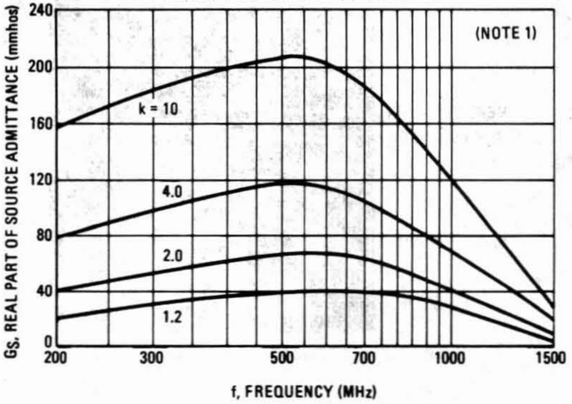


FIGURE 18 – SOURCE ADMITTANCE versus FREQUENCY (IMAGINARY)

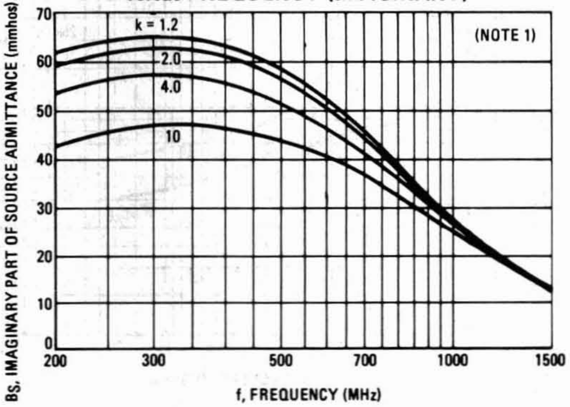


FIGURE 19 – SMALL-SIGNAL CURRENT GAIN versus FREQUENCY

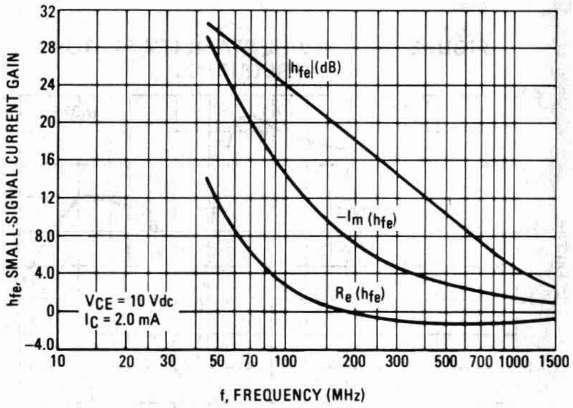


FIGURE 20 – POLAR h_fe

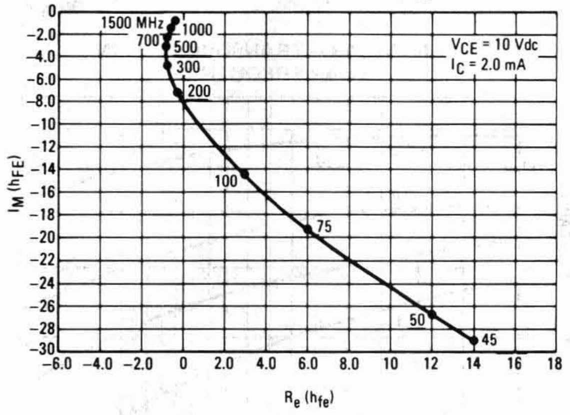


FIGURE 21 – f_T versus COLLECTOR CURRENT

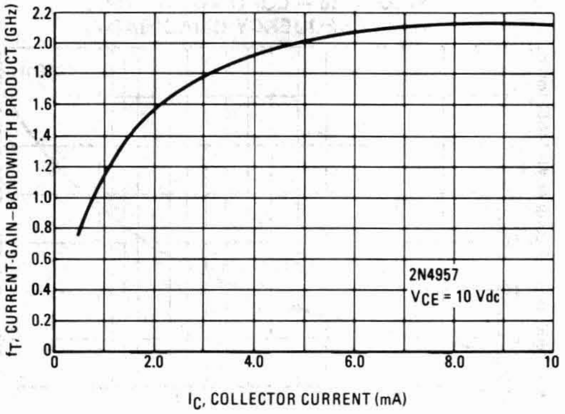


FIGURE 22 – DC CURRENT GAIN

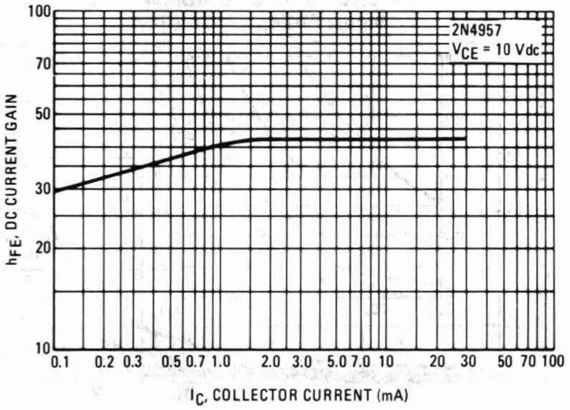


FIGURE 23 – CAPACITANCE

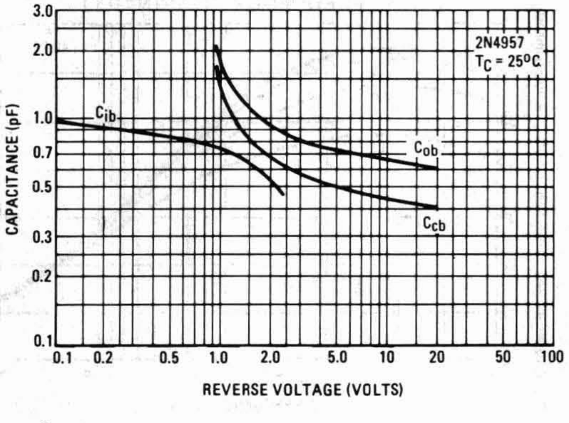
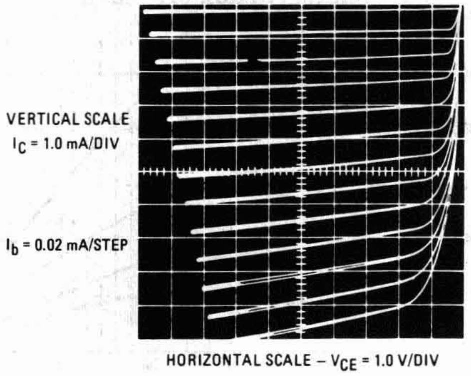
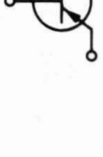
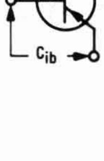


FIGURE 24 – COLLECTOR CHARACTERISTICS

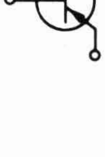




Apply reverse bias between collector and base and measure capacitance between these terminals. Emitter is open.



Apply reverse bias between emitter and base and measure capacitance between these terminals. Collector is open.



Apply reverse bias between collector and base and measure capacitance between these terminals. Emitter is guarded.

Y PARAMETERS versus CURRENT

f = 450 MHz

COMMON BASE

V_{CB} = 10 Vdc ——— V_{CB} = 15 Vdc — — —

COMMON EMITTER

V_{CE} = 10 Vdc ——— V_{CE} = 15 Vdc — — —

FIGURE 25 – INPUT ADMITTANCE

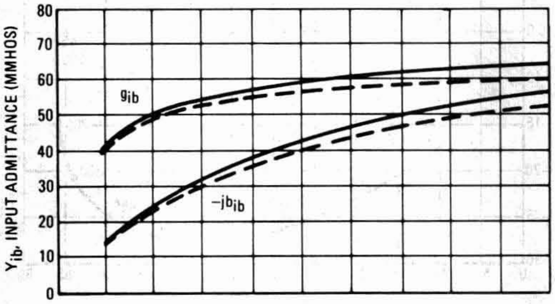


FIGURE 26 – INPUT ADMITTANCE

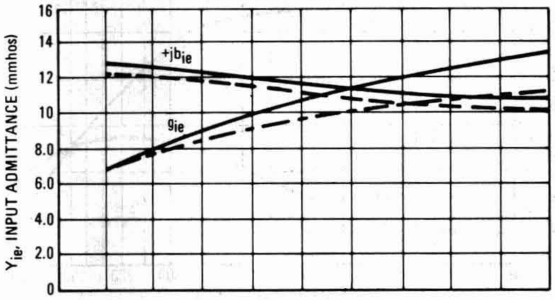


FIGURE 27 – FORWARD TRANSFER ADMITTANCE

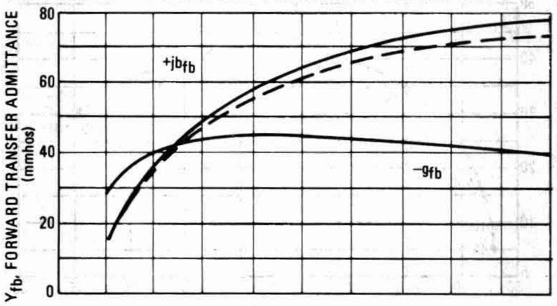


FIGURE 28 – FORWARD TRANSFER ADMITTANCE

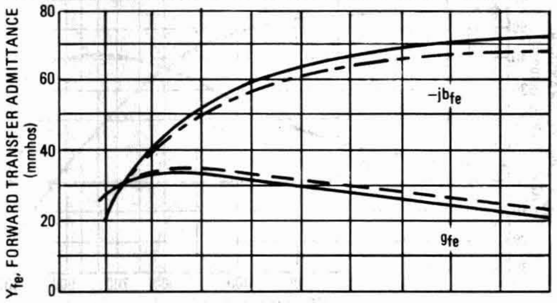


FIGURE 29 – OUTPUT ADMITTANCE

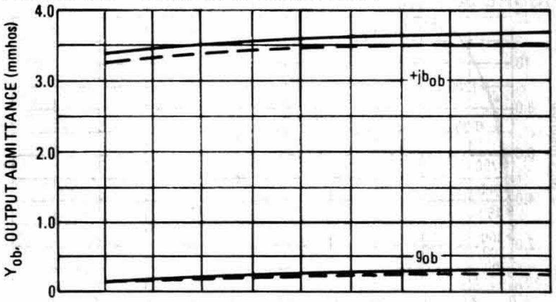


FIGURE 30 – OUTPUT ADMITTANCE

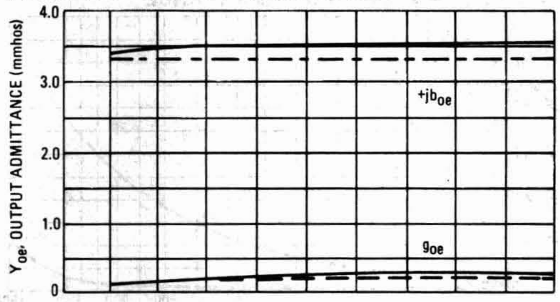


FIGURE 31 – REVERSE TRANSFER ADMITTANCE

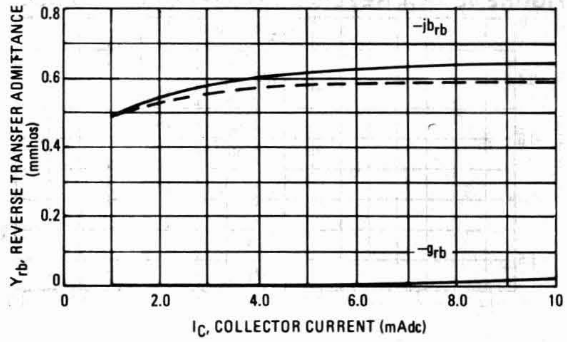
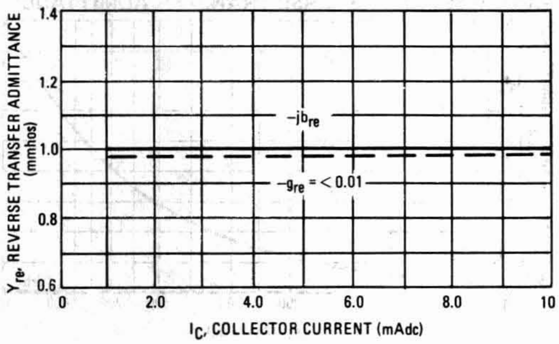


FIGURE 32 – REVERSE TRANSFER ADMITTANCE



COMMON BASE Y PARAMETER VARIATIONS

(V_{CB} = 10 Vdc, I_C = 2.0 mAdc)

Y PARAMETERS versus FREQUENCY

POLAR Y PARAMETERS versus FREQUENCY

FIGURE 33 – y_{ib} INPUT ADMITTANCE

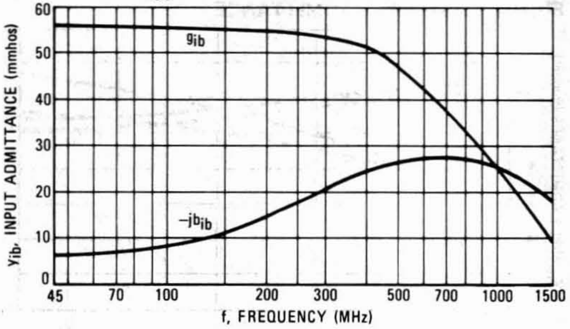


FIGURE 34 – y_{ib} INPUT ADMITTANCE

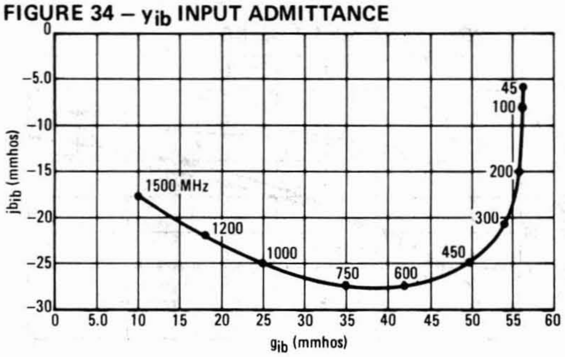


FIGURE 35 – y_{fb} FORWARD TRANSFER ADMITTANCE

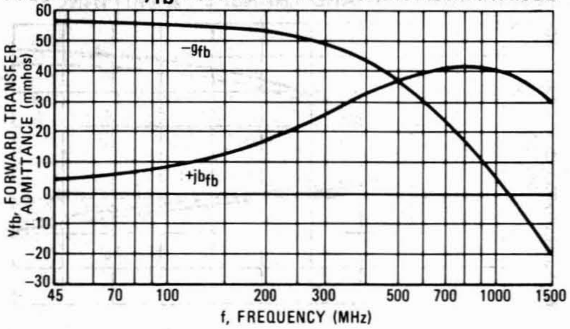


FIGURE 36 – y_{fb} FORWARD TRANSFER ADMITTANCE

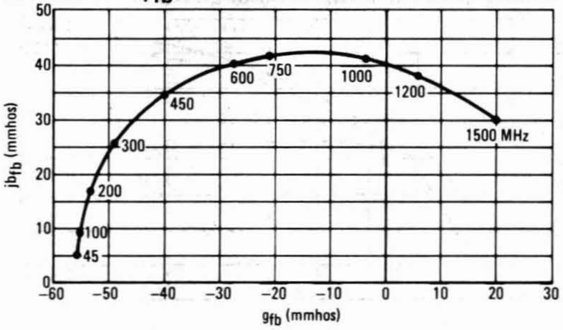


FIGURE 37 – y_{ob} OUTPUT ADMITTANCE

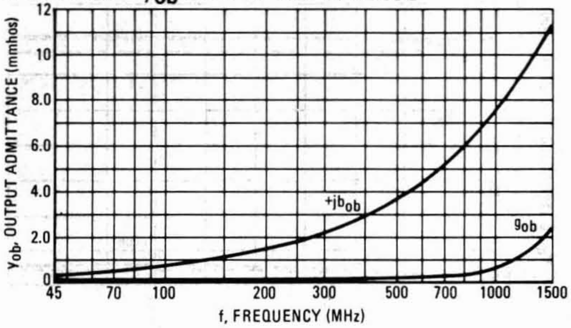


FIGURE 38 – y_{ob} OUTPUT ADMITTANCE

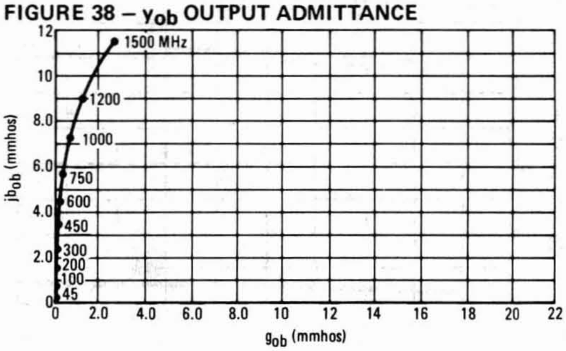


FIGURE 39 – y_{rb} REVERSE TRANSFER ADMITTANCE

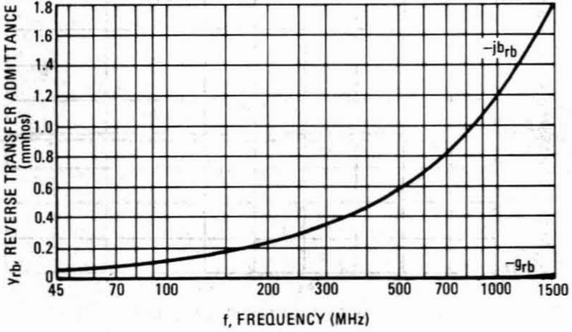
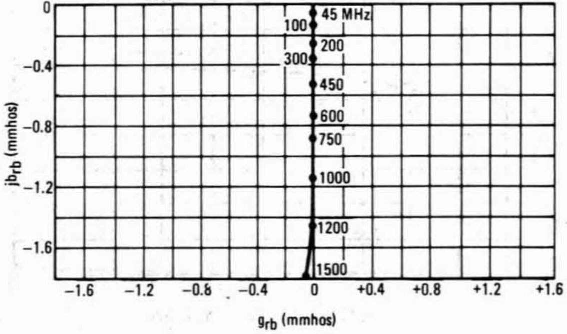


FIGURE 40 – y_{rb} REVERSE TRANSFER ADMITTANCE



COMMON EMITTER Y PARAMETER VARIATIONS

(V_{CE} = 10 Vdc, I_C = 2.0 mA)

Y PARAMETERS versus FREQUENCY

FIGURE 41 – y_{ie} INPUT ADMITTANCE

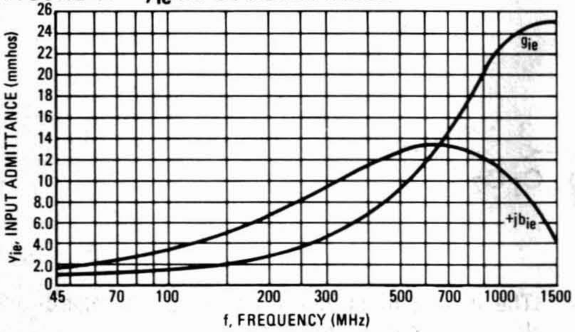


FIGURE 43 – y_{fe} FORWARD TRANSFER ADMITTANCE

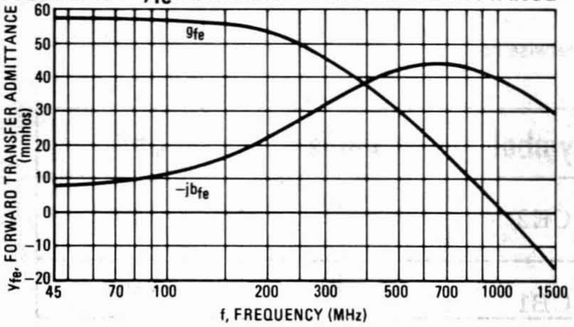


FIGURE 45 – y_{oe} OUTPUT ADMITTANCE

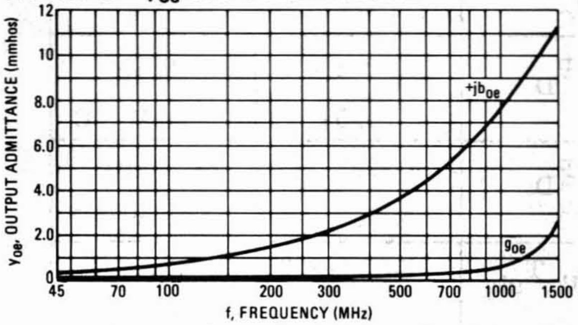
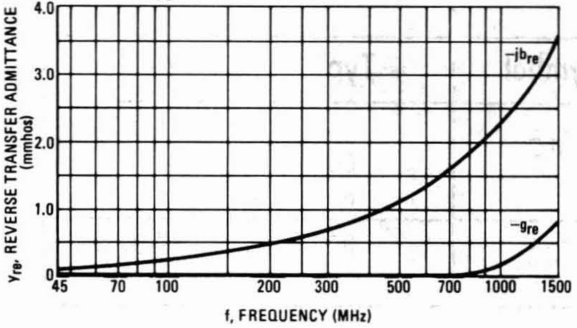


FIGURE 47 – y_{re} REVERSE TRANSFER ADMITTANCE



POLAR Y PARAMETERS versus FREQUENCY

FIGURE 42 – y_{ie} INPUT ADMITTANCE

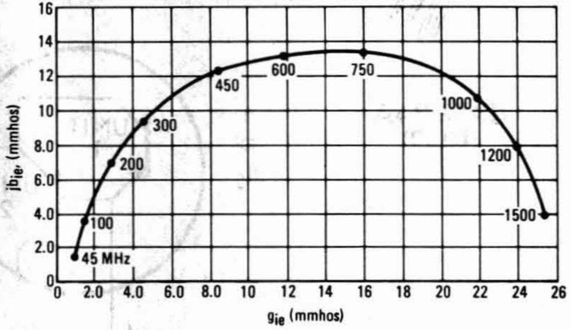


FIGURE 44 – y_{fe} FORWARD TRANSFER ADMITTANCE

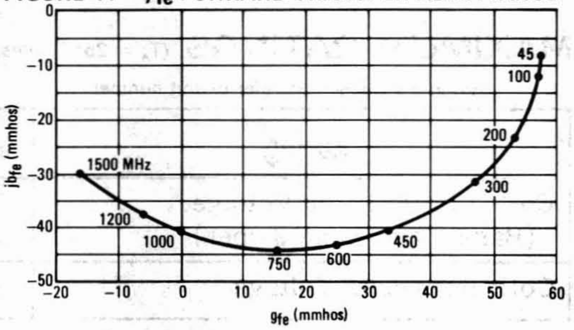


FIGURE 46 – y_{oe} OUTPUT ADMITTANCE

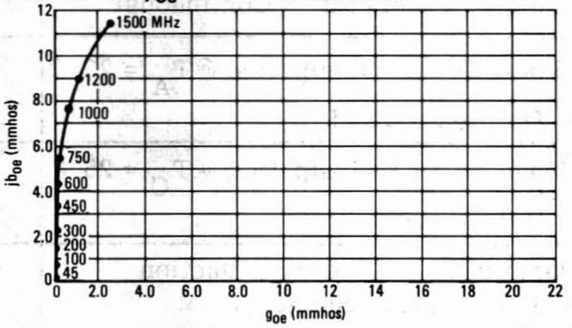
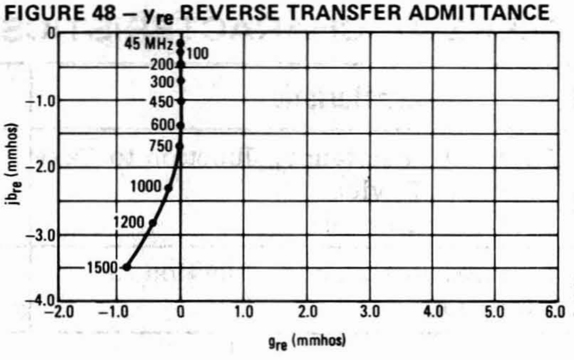


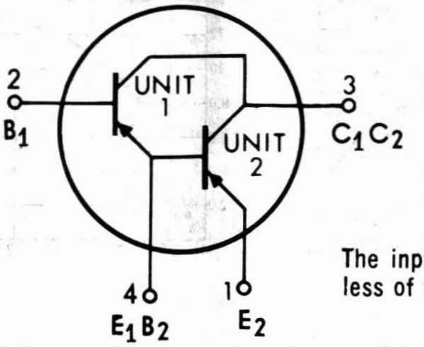
FIGURE 48 – y_{re} REVERSE TRANSFER ADMITTANCE



2N4974 (SILICON)
2N4975

CASE 34A
(TO-12)

PNP silicon annular darlington amplifiers contain two PNP silicon annular transistors connected as a darlington amplifier.



The input unit is identified as Unit 1 regardless of terminal numbering.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Numerical subscripts refer to unit number

Rating	Symbol	Value	Unit
Collector-Emitter Voltage (Base 1 and Base 2 open)	V_{CE2}	30	Vdc
Collector-Base Voltage	V_{CB1}	40	Vdc
Emitter-Base Voltage	V_{E2B1}	10	Vdc
Collector Current – Continuous	I_C	1.0	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	0.8 4.57	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	2.5 14.3	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Typ	Unit
Thermal Resistance, Junction to Case Output Device Driver Device	θ_{JC}	 60 85	°C/W
Thermal Resistance, Junction to Junction	θ_{JJ}	30	°C/W

2N4974, 2N4975 (continued)

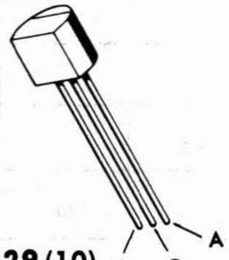
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Numerical subscripts refer to unit number, lead 4 open unless otherwise noted.

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage * (I_C = 10 mAdc, E_2B_1 termination open)	BV_{CE2} *	30	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc)	BV_{CB1O}	40	50	-	Vdc
Emitter-Base Breakdown Voltage (I_{B1} = 10 µAdc)	BV_{E2B1O}	10	12.5	-	Vdc
Collector Cutoff Current (V_{CB1} = 30 Vdc)	I_{CB1O}	-	0.5	10	nAdc
Emitter Cutoff Current (V_{E2B1} = 5.0 Vdc)	I_{E2B1O}	-	0.15	10	nAdc
ON CHARACTERISTICS					
DC Current Gain	h_{FE}				-
(I_C = 1.0 µAdc, V_{CE2} = 5.0 Vdc) 2N4974		5,000	9,000	-	
2N4975		1,000	4,000	-	
(I_C = 1.0 µAdc, V_{CE2} = 5.0 Vdc, T_A = -55°C) 2N4974		-	2,000	-	
2N4975		-	1,000	-	
(I_C = 10 µAdc, V_{CE2} = 5.0 Vdc) 2N4974		10,000	15,000	-	
2N4975		5,000	9,000		
(I_C = 10 µAdc, V_{CE2} = 5.0 Vdc, T_A = -55°C) 2N4974		-	3,500	-	
2N4975		-	2,000	-	
(I_C = 100 µAdc, V_{CE2} = 5.0 Vdc) 2N4974		20,000	30,000	-	
2N4975		10,000	20,000	-	
(I_C = 1.0 mAdc, V_{CE2} = 5.0 Vdc) 2N4974		25,000	50,000	-	
2N4975		15,000	30,000		
(I_C = 10 mAdc, V_{CE2} = 5.0 Vdc)* 2N4974		30,000	60,000	150,000	
2N4975		15,000	30,000	75,000	
(I_C = 10 mAdc, V_{CE2} = 5.0 Vdc, T_A = -55°C)* 2N4974		-	15,000	-	
2N4975		-	10,000	-	
(I_C = 100 mAdc, V_{CE2} = 5.0 Vdc)* 2N4974		25,000	50,000	-	
2N4975		15,000	30,000	-	
(I_C = 500 mAdc, V_{CE2} = 5.0 Vdc)* 2N4974		15,000	25,000	-	
2N4975		5,000	10,000	-	
(I_C = 1.0 Adc, V_{CE2} = 5.0 Vdc)* 2N4974		2,000	4,000	-	
2N4975		1,000	2,000	-	
Collector-Emitter Saturation Voltage * (I_C = 500 mAdc, I_{B1} = 1.0 mAdc)	$V_{CE2(sat)}$*	-	1.4	2.0	Vdc
Base-Emitter Voltage * (I_C = 500 mAdc, I_{B1} = 1.0 mAdc)	V_{B1E2}*	-	2.0	2.7	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE2} = 5.0 Vdc, f = 100 MHz)	f_T	175	275	-	MHz
Output Capacitance (V_{CB1} = 10 Vdc, I_{E2} = 0, f = 140 kHz)	C_{ob1}	-	4.0	8.0	pF
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	h_{fe}				-
2N4974		25,000	-	-	
2N4975		15,000	-	-	
Noise Figure (I_C = 1.0 mAdc, V_{CB1} = 10 Vdc, R_S = 10 k ohms, BW = 15.7 kHz)	NF	-	3.0	6.0	dB

* Pulse Test: Pulse width ≦ 300 µs, duty cycle ≦ 2%

2N5060 thru 2N5064 (SILICON)



CASE 29 (10)
(TO- 92)

PNPN plastic thyristors (silicon controlled rectifiers) designed for operation in low voltage mA/μA switching and detection circuits.

MAXIMUM RATINGS (T_J = 125°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage (Note 1)	$V_{RXM(rep)}$		Volt
2N5060		30	
2N5061		60	
2N5062		100	
2N5063		150	
2N5064		200	
Forward Current RMS	I_f	0.8	Amp
Peak Surge Current (One Cycle, 60 Hz) No Repetition until Thermal Equilibrium is Restored	$I_{FM(surge)}$	6.0	Amp
Peak Gate Power - Forward	P_{GFM}	0.1	Watt
Average Gate Power - Forward	$P_{GF(AV)}$	0.01	Watt
Peak Gate Current - Forward (300 μs, 120 PPS)	I_{GFM}	1.0	Amp
Peak Gate Voltage - Forward	V_{GFM}	5.0	Volt
Reverse	V_{GRM}	5.0	
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C
Lead Solder Temperature (>1/16" from case, 10 sec. max)		+230	°C

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted, R_{GK} = 1000 ohms)

Characteristic	Symbol	Min	Max	Unit
Peak Forward Blocking Voltage (Note 1) 2N5060 2N5061 2N5062 2N5063 2N5064	V_{FXM}	30* 60* 100* 150* 200*	 - - - -	Volt
Peak Reverse Blocking Current (Rated V_{RXM}, T_J = 125°C)	I_{RXM}	-	50*	μA
Peak Forward Blocking Current (Rated V_{FXM}, T_J = 125°C)	I_{FXM}	-	50*	μA
Forward "On" Voltage (I_F = 1.0 A Peak)	V_F	-	1.7*	Volt
Gate Trigger Current (Note 2) (Anode Voltage = 7.0 V, R_L = 100 ohms) (T_C = 25° C) (T_C = -65°C)	I_{GT}	 -	 200 350*	μAdc
Gate Trigger Voltage (Anode Voltage = 7.0 V, R_L = 100 ohms, T_C = 25°C) (Anode Voltage = 7.0 V, R_L = 100 ohms, T_C = -65°C) (Anode Voltage = Rated V_{FXM}, R_L = 100 ohms, T_J = 125°C)	V_{GT}	 - - 0.1*	 0.8 1.2* -	Volt
Holding Current (Anode Voltage = 7.0 V) T_C = 25°C T_C = -65°C	I_{HX}		5.0 10*	mA
Turn-On Time	t_{on}	Circuit dependent, consult manufacturer		
Turn-Off Time	t_{off}			

*JEDEC Registered Values

Notes: 1. V_{RXM} and V_{FXM} can be applied for all types on a continuous dc basis without incurring damage.

2. R_{GK} current is not included in measurement.

Thyristor devices shall not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

Thyristor devices shall not have a positive bias applied to the gate concurrently with a negative potential applied to the anode.

FIGURE 1 — CURRENT DERATING

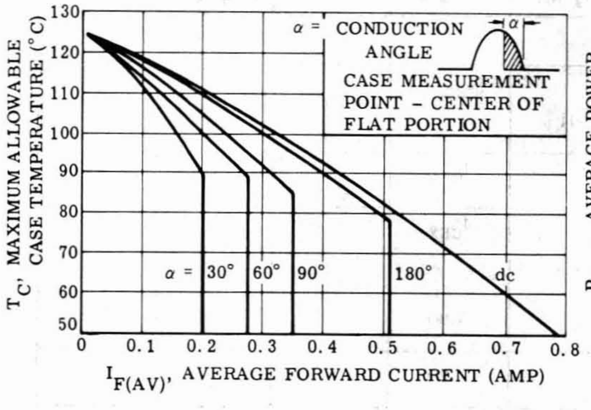
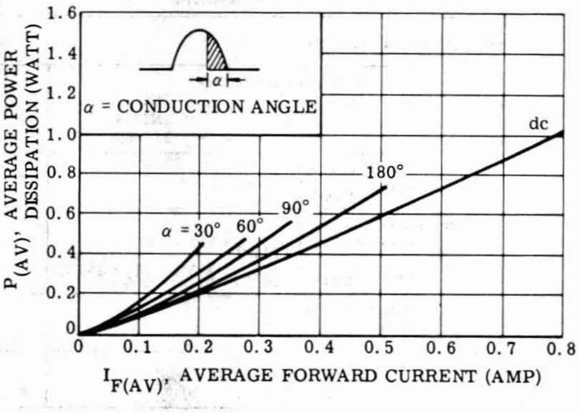
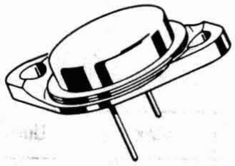


FIGURE 2 — POWER DISSIPATION



2N5067 (SILICON)
2N5068
2N5069



CASE 11
(TO-3)

NPN power transistors for use in power amplifier and switching circuits. Complement to PNP 2N4901 thru 2N4903.

MAXIMUM RATINGS

Rating	Symbol	2N5067	2N5068	2N5069	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	5.0			Vdc
Collector Current — Continuous	I_C	5.0			Adc
Base Current - Continuous	I_B	1.0			Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	87.5 0.5			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	2.0	°C/W

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* ($I_C = 0.2$ Adc, $I_B = 0$) 2N5067 2N5068 2N5069	11	$BV_{CEO(sus)}$*	40 60 80	- - -	Vdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $I_B = 0$)		I_{CEO}	-	1.0	mAdc
Collector Cutoff Current (V_{CE} = Rated V_{CEO}, $V_{EB(off)} = 1.5$ Vdc) (V_{CE} = Rated V_{CEO}, $V_{EB(off)} = 1.5$ Vdc, $T_C = 150°C$)	5, 6	I_{CEX}	- -	1.0 2.0	mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, $I_E = 0$)	5, 6	I_{CBO}	-	1.0	mAdc
Emitter Cutoff Current ($V_{EB} = 5.0$ Vdc, $I_C = 0$)		I_{EBO}	-	1.0	mAdc

* Pulse Test, PW ≈ 300 μs, Duty Cycle ≈ 2.0%

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
ON CHARACTERISTICS					
DC Current Gain*	1	h_{FE}*			-
(I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)			20	80	
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)			7.0	-	
Collector-Emitter Saturation Voltage*	2, 3, 4	$V_{CE(sat)}$*			Vdc
(I_C = 1.0 Adc, I_B = 0.1 Adc)			-	0.4	
(I_C = 5.0 Adc, I_B = 1.0 Adc)			-	1.5	
Base-Emitter On Voltage* (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)	3, 4	$V_{BE(on)}$*	-	1.2	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz)		f_T	4.0	-	MHz
Small-Signal Current Gain (I_C = 500 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{fe}	20	-	-

* Pulse Test, PW ≈ 300 μs, Duty Cycle ≈ 2.0%

FIGURE 1 — NORMALIZED DC CURRENT GAIN

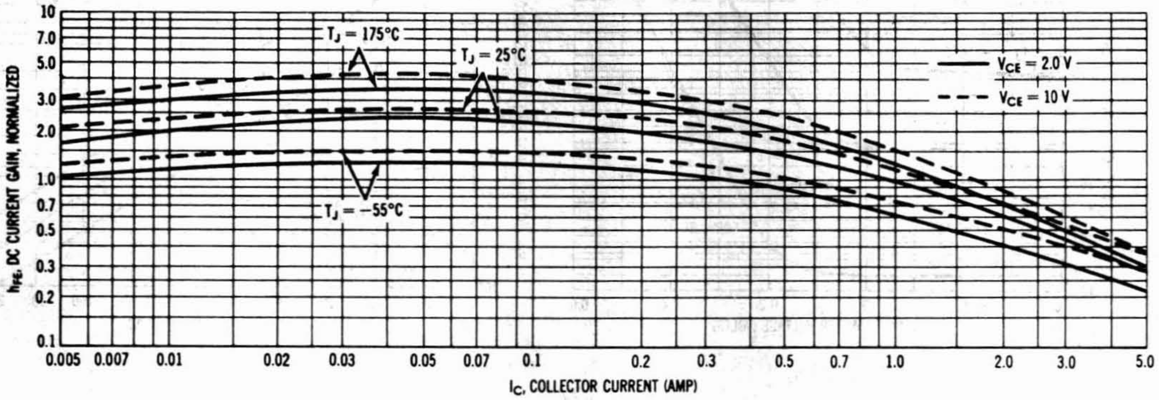


FIGURE 2 — COLLECTOR SATURATION REGION

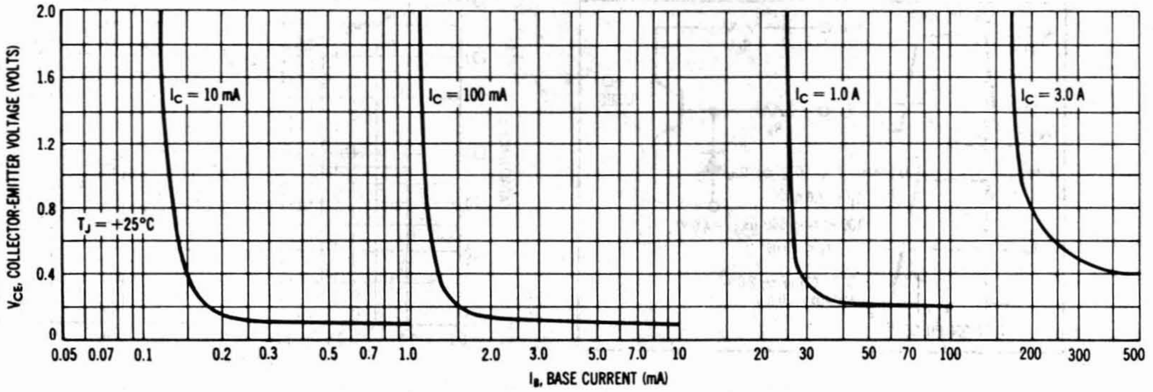


FIGURE 3 — "ON" VOLTAGES

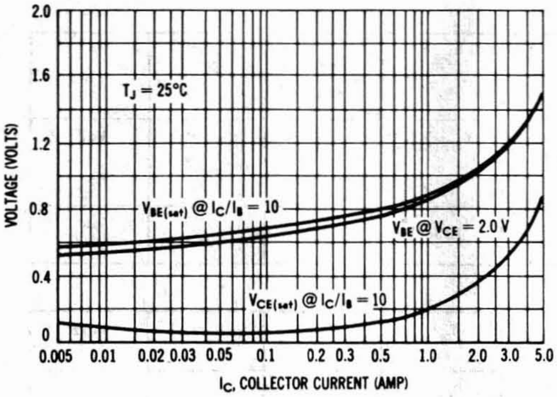
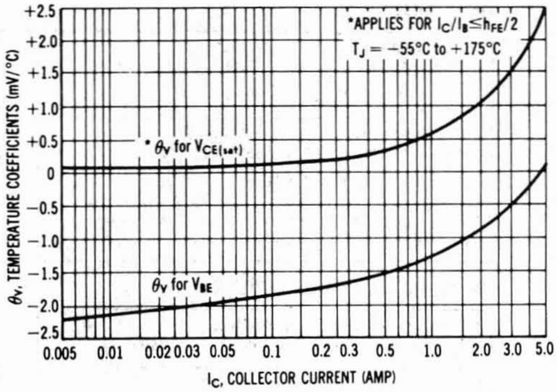


FIGURE 4 — TEMPERATURE COEFFICIENTS



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 5 — CUT-OFF REGION

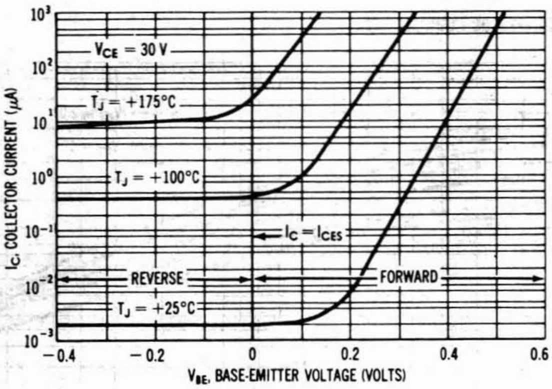


FIGURE 6 — EFFECTS OF BASE-EMITTER RESISTANCE

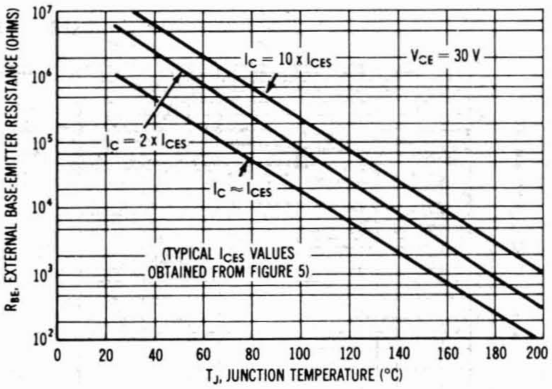


FIGURE 7 — SWITCHING TIME EQUIVALENT CIRCUIT

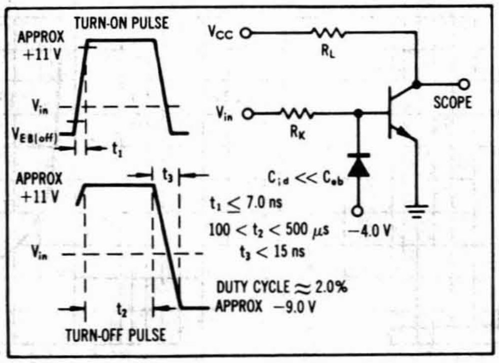

TURN-ON PULSE
APPROX
+11 V
V_{in}
$V_{EB(off)}$
t_1
APPROX
+11 V
t_3
V_{in}
t_2
TURN-OFF PULSE
V_{CC}
R_L
V_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
−4.0 V
$t_1 \leq 7.0$ ns
$100 < t_2 < 500$ μs
$t_3 < 15$ ns
DUTY CYCLE ≈ 2.0%
APPROX −9.0 V

FIGURE 8 — CAPACITANCE

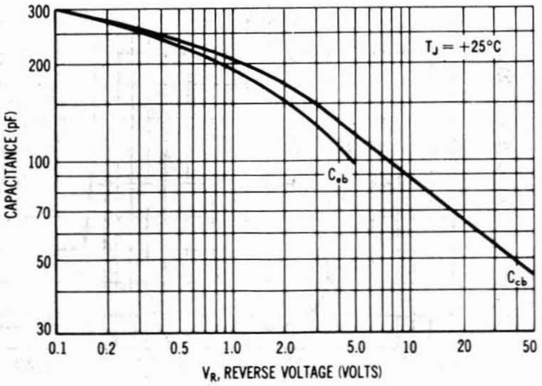


FIGURE 9 — TURN-ON TIME

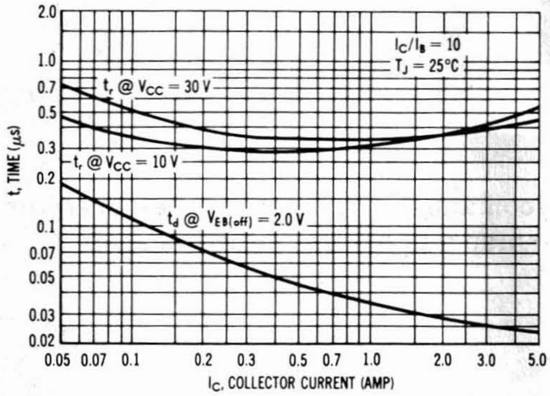
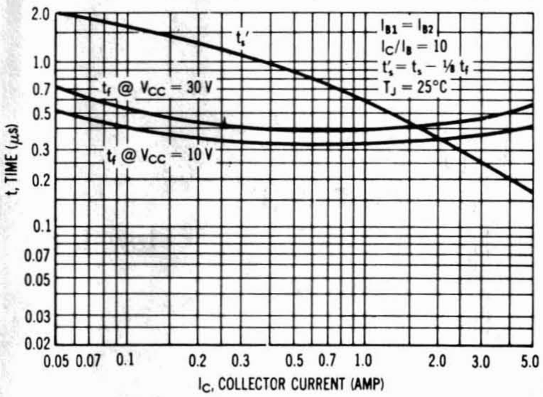
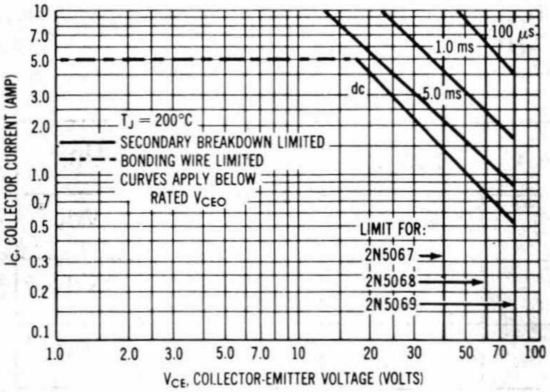


FIGURE 10 — TURN-OFF TIME



RATING AND THERMAL DATA

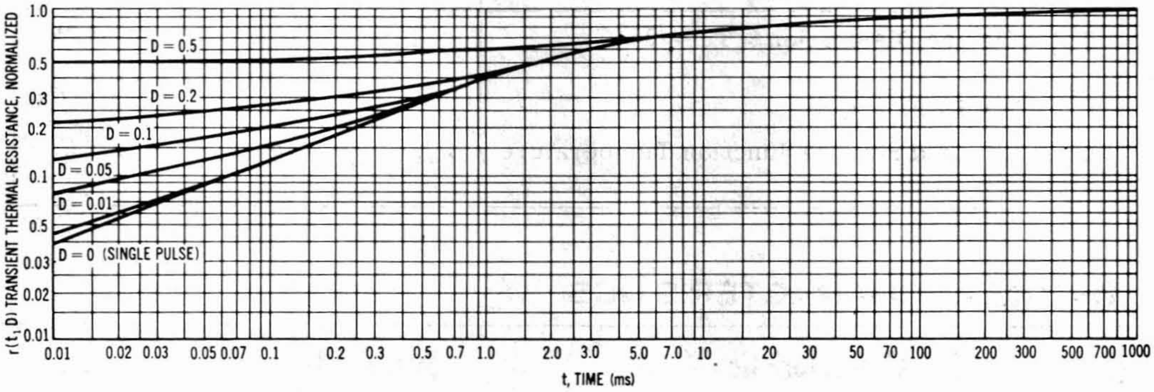
FIGURE 11 — ACTIVE-REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

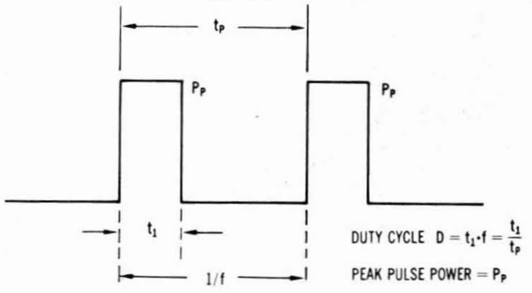
The data of Figure 11 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 12. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 12 — TRANSIENT THERMAL RESISTANCE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



A train of periodical power pulses can be represented by the model as shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 12 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 12 by the steady state value θ_{JC}.

Example:

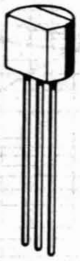
The 2N5067 is dissipating 100 watts under the following conditions: $t_1 = 0.1$ ms, $t_P = 0.5$ ms. $(D = 0.2)$

Using Figure 12, at a pulse width of 0.1 ms and D = 0.2, the reading of r (t_1, D) is 0.28.

The peak rise in junction temperature is therefore

$$\triangle T = r(t) \times P_P \times \theta_{JC} = 0.28 \times 100 \times 2.0 = 56°C$$

2N5086 (SILICON)
2N5087



CASE 29 (1)
(TO-92)

PNP silicon annular transistors designed for low-level, low-noise amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Vdc
Collector-Base Voltage	V_{CB}	50	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current – Continuous Peak	I_C	50 100	mAdc
Total Device Dissipation @ T_A = 25° C Derate above 25° C	P_D	310 2.81	mW mW/° C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	° C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	° C/mW

2N5086, 2N5087 (continued)

ELECTRICAL CHARACTERISTICS T_A = 25°C unless otherwise noted

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)	BV_{CEO}	50	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	50	-	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	-	10	nAdc
(V_{CB} = 35 Vdc, I_E = 0)		-	-	50	
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	-	50	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) 2N5086	h_{FE}	150	-	500	-
2N5087		250	-	800	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) 2N5086		150	-	-	
2N5087		250	-	-	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc) 2N5086		150	-	-	
2N5087		250	-	-	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	-	-	0.3	Vdc
Base-Emitter On Voltage (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc	$V_{BE(on)}$	-	-	0.85	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain – Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 20 MHz) 2N5086	f_T	40	120	-	MHz
2N5087		40	150	-	
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	-	4.0	pF
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz) 2N5086	h_{fe}	150	-	600	-
2N5087		250	-	900	
Noise Figure (I_C = 20 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 10 Hz to 15.7 kHz) 2N5086	NF	-	-	3.0	dB
2N5087		-	-	2.0	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc, R_S = 3.0 k ohms, f = 1.0 kHz) 2N5086		-	1.2	3.0	
2N5087		-	1.0	2.0	

NOISE FIGURE

V_{CE} = 5.0 Vdc, T_A = 25

FIGURE 1 — FREQUENCY EFFECTS

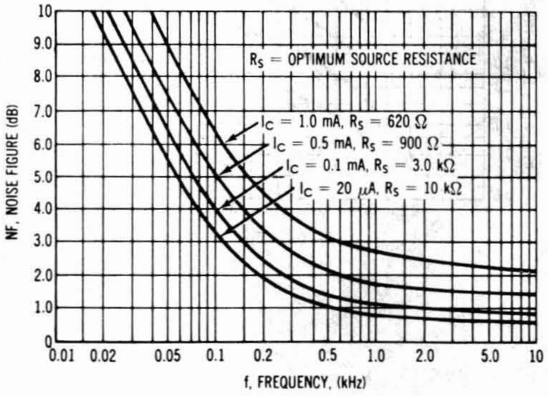
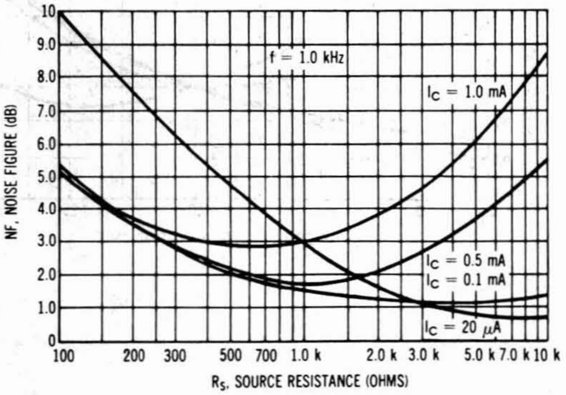


FIGURE 2 — SOURCE RESISTANCE EFFECTS



h PARAMETERS

V_{CE} = 10 Vdc, f = 1.0 kHz, T_A = 25°C
(For Figures 3, 4, 5, 6, 8)

This group of graphs illustrates the relationship of the "h" parameters for this series of transistors. To obtain these curves, 4 units were selected and identified by number — the same units were used to develop curves on each graph.

FIGURE 3 — INPUT IMPEDANCE

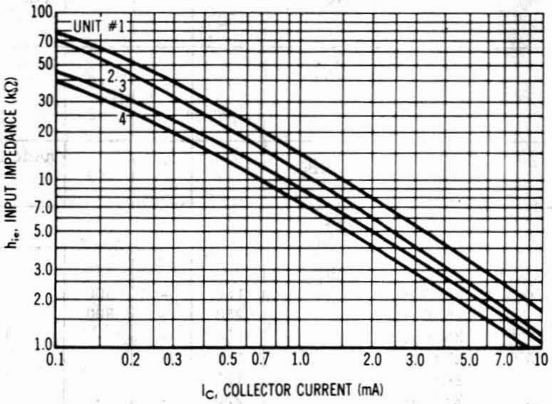


FIGURE 4 — VOLTAGE FEEDBACK RATIO

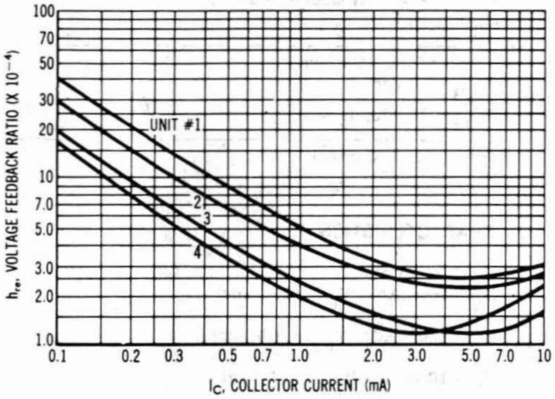


FIGURE 5 — CURRENT GAIN

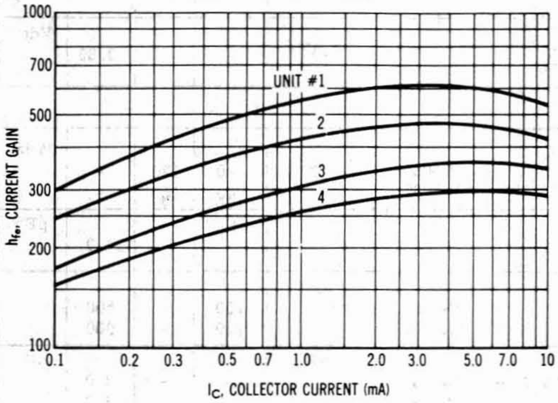


FIGURE 6 — OUTPUT ADMITTANCE

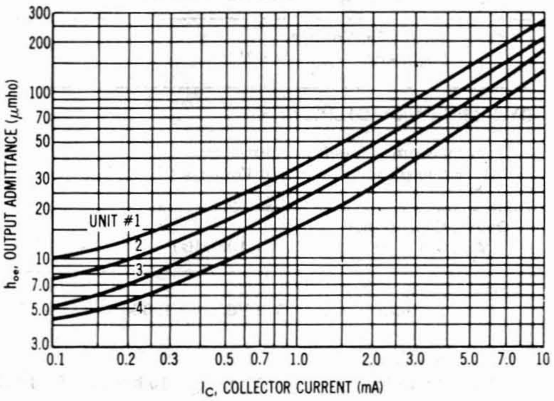


FIGURE 7 — EFFECT OF VOLTAGE

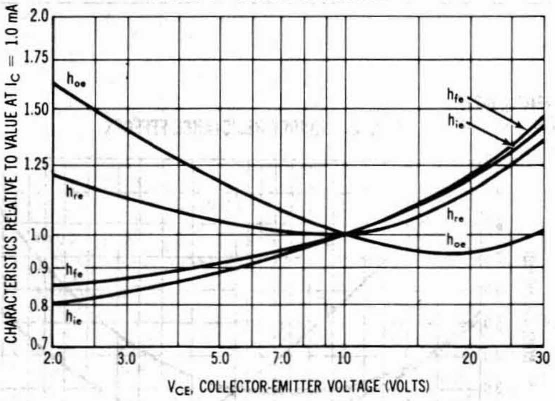


FIGURE 8 — DETERMINANT

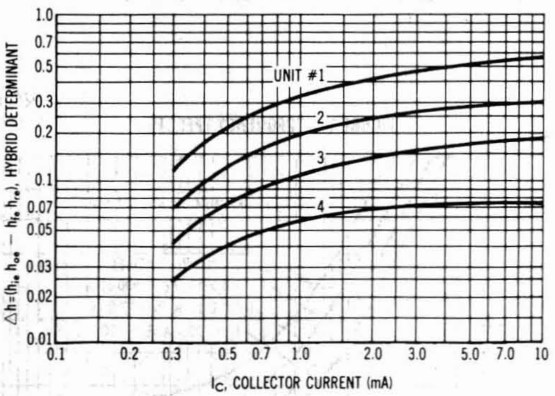


FIGURE 9 — DC CURRENT-GAIN

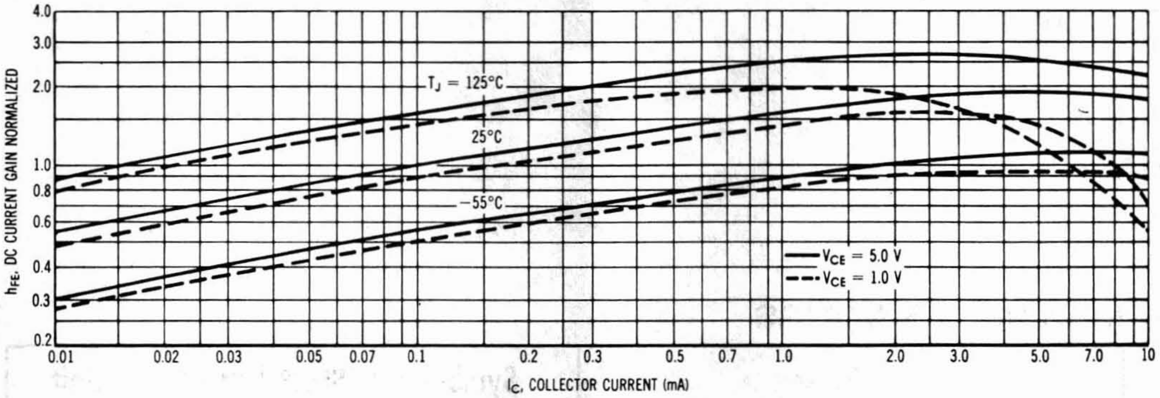


FIGURE 10 — COLLECTOR SATURATION REGION

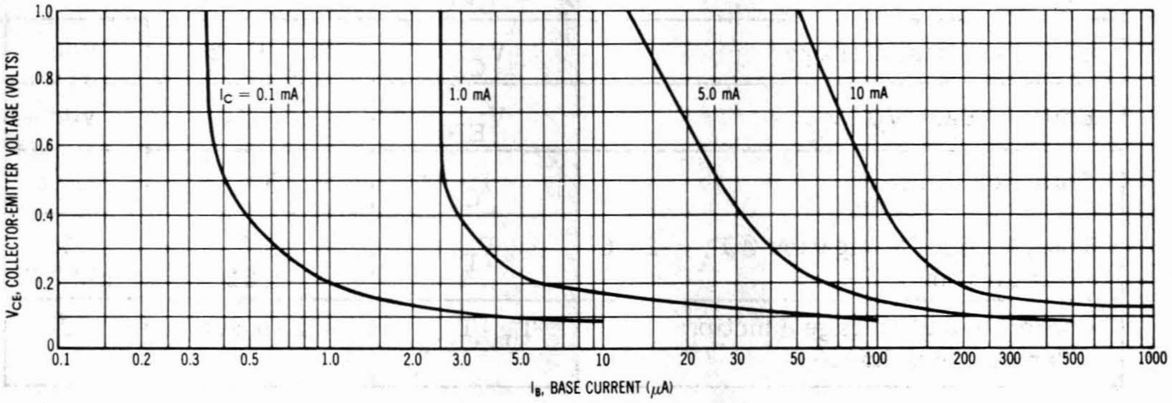


FIGURE 11 — CURRENT-GAIN — BANDWIDTH PRODUCT

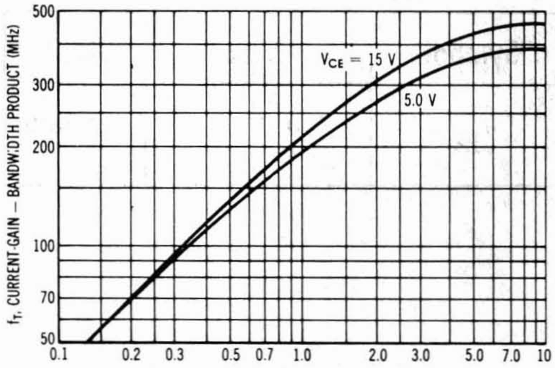
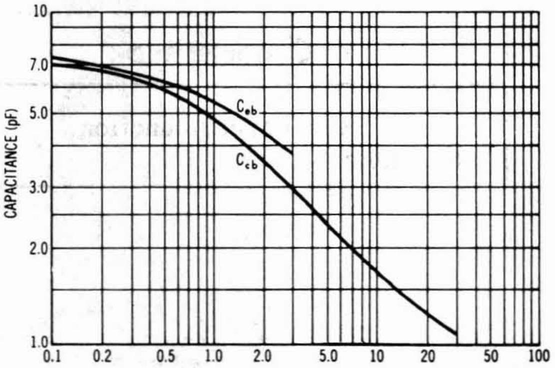


FIGURE 12 — CAPACITANCES



2N5088 (SILICON)
2N5089

CASE 29 (1)
(TO-92)

NPN silicon annular transistors designed for low-level, low-noise amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	2N5088	2N5089	Unit
Collector-Emitter Voltage	V_{CEO}	30	25	Vdc
Collector-Base Voltage	V_{CB}	35	30	Vdc
Emitter-Base Voltage	V_{EB}	4.5		Vdc
Collector Current	I_C	50		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)	2N5088	BV_{CEO}	30	-	-	Vdc
	2N5089		25	-	-	
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	2N5088	BV_{CBO}	35	-	-	Vdc
	2N5089		30	-	-	
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	2N5088	I_{CBO}	-	-	50	nAdc
(V_{CB} = 15 Vdc, I_E = 0)	2N5089		-	-	50	
Emitter Cutoff Current ($V_{EB(off)}$ = 3.0 Vdc, I_C = 0)		I_{EBO}	-	-	50	nAdc
($V_{EB(off)}$ = 4.5 Vdc, I_C = 0)			-	-	100	
ON CHARACTERISTICS						
DC Current Gain (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	2N5088	h_{FE}	300	-	900	
	2N5089		400	-	1200	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	2N5088		350	-	-	
	2N5089		450	-	-	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc)	2N5088		300	-	-	
	2N5089		400	-	-	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{CE(sat)}$	-	-	0.5	Vdc
Base-Emitter On Voltage (I_C = 10 mAdc, V_{CE} = 5.0 Vdc)		$V_{BE(on)}$	-	-	0.8	Vdc
DYNAMIC CHARACTERISTICS						
Current-Gain – Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 20 MHz		f_T	50	175	-	MHz
Collector-Base Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz, emitter guarded)		C_{cb}	-	1.8	4.0	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz, collector guarded)		C_{eb}	-	4.0	10	pF
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N5088	h_{fe}	350	-	1400	-
	2N5089		450	-	1800	
Noise Figure (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 10 Hz to 15.7 kHz	2N5088	NF	-	-	3.0	dB
	2N5089		-	-	2.0	

NOISE FIGURE

V_{CE} = 5.0 Vdc, T_A = 25 °C

FIGURE 1 — FREQUENCY EFFECTS

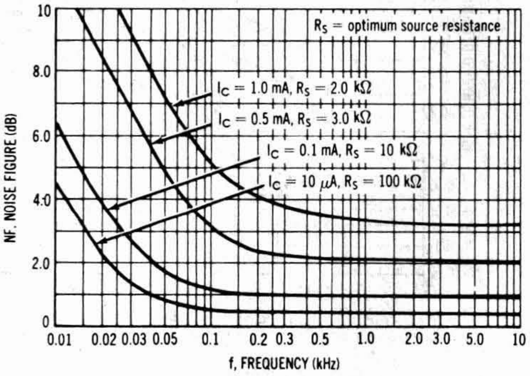
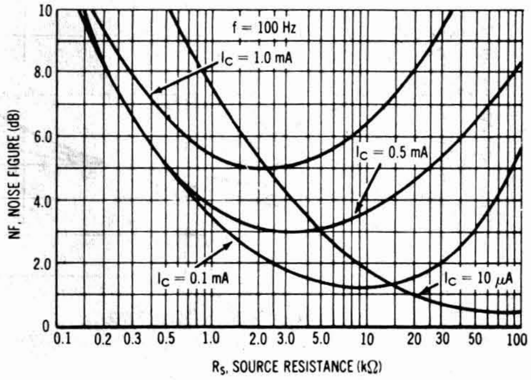


FIGURE 2 — SOURCE RESISTANCE EFFECTS



h PARAMETERS

V_{CE} = 10 Vdc, f = 1.0 kHz, T_A = 25°C
(For Figures 3, 4, 5, 6, 8)

This group of graphs illustrates the relationship of the "h" parameters for this series of transistors. To obtain these curves, 4 units were selected and identified by number — the same units were used to develop curves on each graph.

FIGURE 3 — INPUT IMPEDANCE

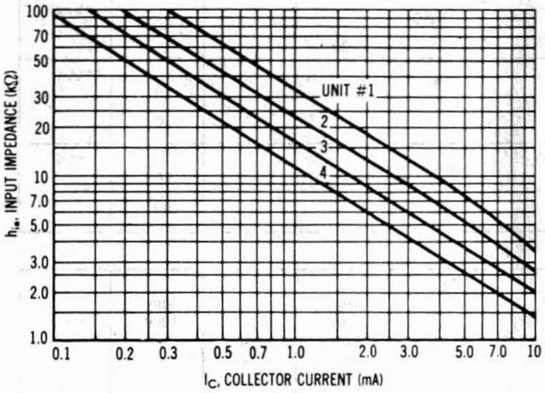


FIGURE 4 — VOLTAGE FEEDBACK RATIO

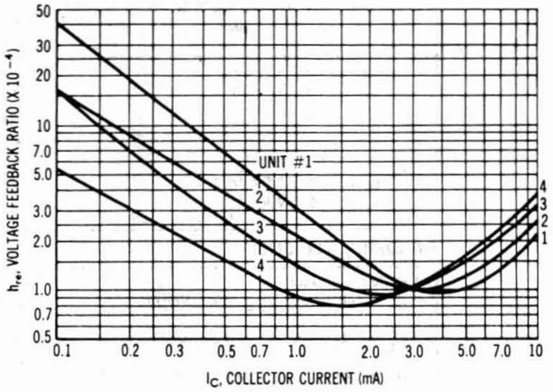


FIGURE 5 — CURRENT GAIN

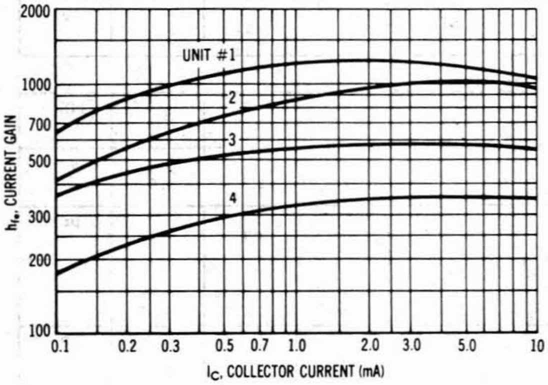


FIGURE 6 — OUTPUT ADMITTANCE

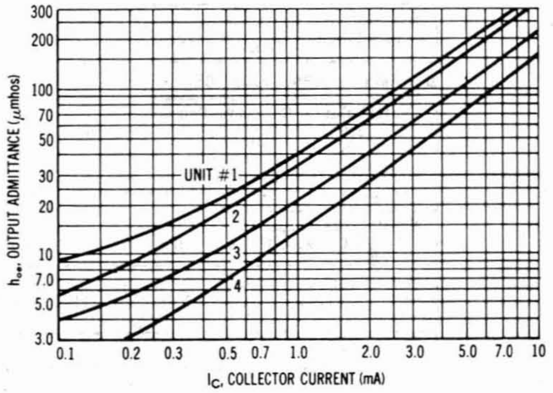


FIGURE 7 — EFFECT OF VOLTAGE

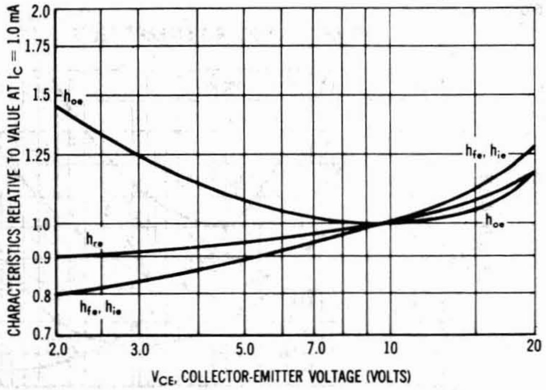


FIGURE 8 — DETERMINANT

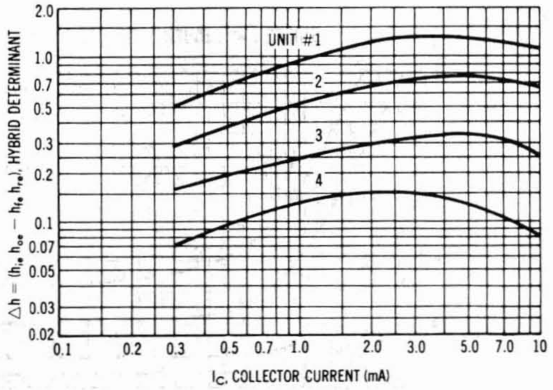


FIGURE 9 — DC CURRENT GAIN

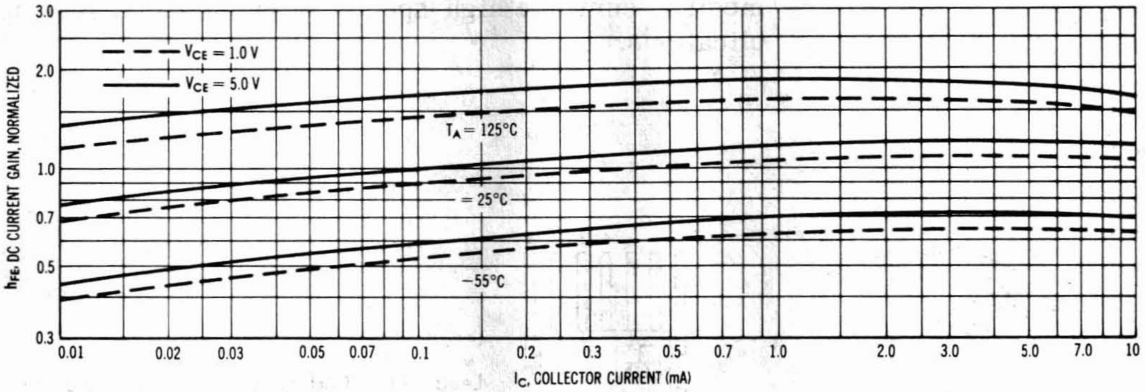


FIGURE 10 — COLLECTOR SATURATION REGION

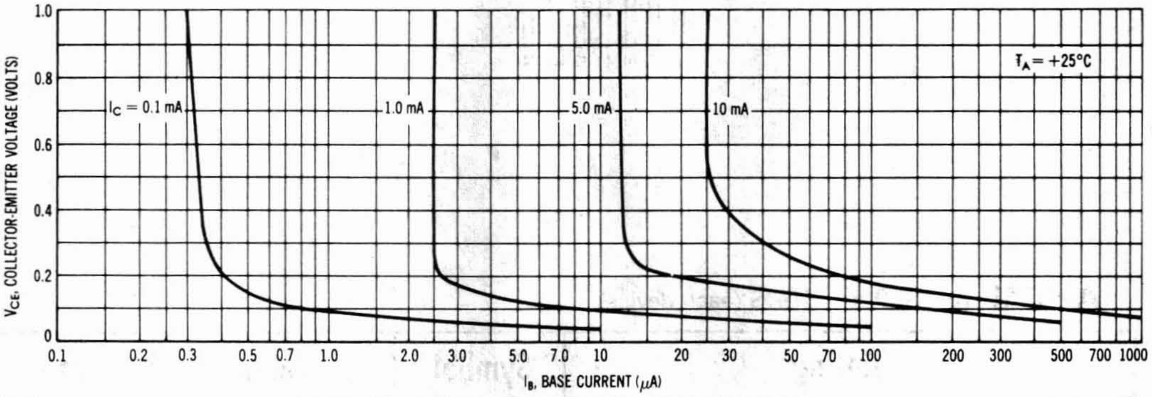


FIGURE 11 — CURRENT GAIN — BANDWIDTH PRODUCT

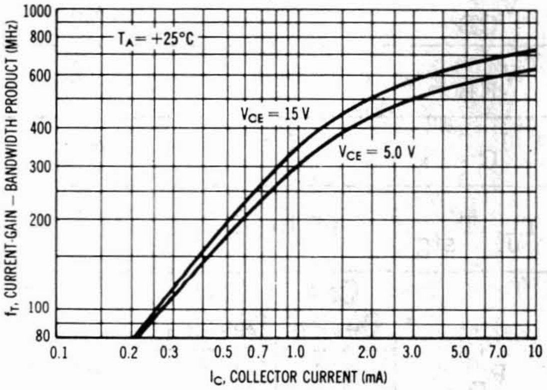
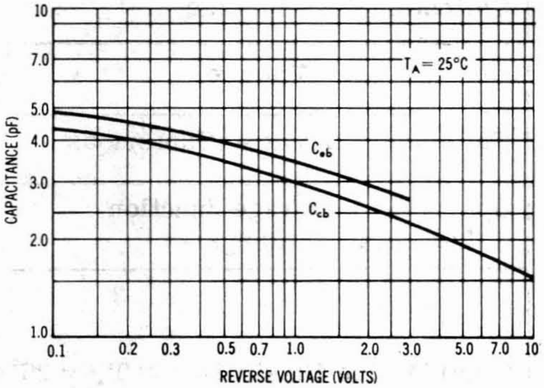
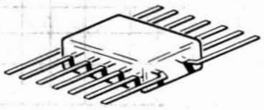


FIGURE 12 — CAPACITANCE

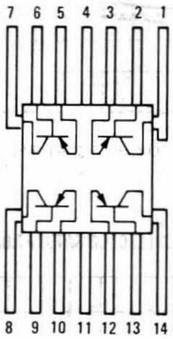


2N5146 (SILICON)

Quad PNP silicon annular transistor designed for medium-current, high-speed switching and driver applications.



CASE 83
(TO-86)



Lead 1 identified by color dot or by elbow on lead. All leads electrically isolated from package.

MAXIMUM RATINGS (each device)

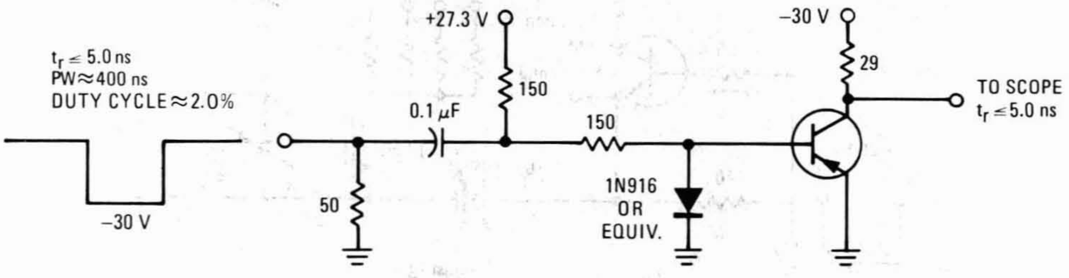
Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	40		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current — Continuous	I_C	1.5		Adc
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Device	Four Devices	
Total Device Dissipation @ T_A = 25°C	P_D	400	500	mW
Derate above 25°C		2.28	2.86	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	1.25	5.0	Watts
Derate above 25°C		7.15	28.6	mW/°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

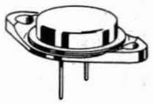
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	40		-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40		-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0		-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, $V_{BE(off)}$ = 2.0 Vdc)	I_{CEX}	-	30	100	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	30	100	nAdc
Base Cutoff Current (V_{CE} = 30 Vdc, $V_{BE(off)}$ = 2.0 Vdc)	I_{BL}	-	-	200	nAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}*	20	40	-	-
Collector-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	$V_{CE(sat)}$*	-	0.7	1.0	Vdc
Base-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	$V_{BE(sat)}$*	-	1.1	1.4	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	150	250	-	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{cb}	-	11	20	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{eb}	-	60	80	pF
SWITCHING CHARACTERISTICS					
Delay Time (I_C = 1.0 Adc, I_{B1} = 0.1 Adc)	t_d	-	7.0	10	ns
Rise Time (I_C = 1.0 Adc, I_{B1} = 0.1 Adc)	t_r	-	15	30	ns
Storage Time (I_C = 1.0 Adc, I_{B1} = I_{B2} = 0.1 Adc)	t_s	-	30	80	ns
Fall Time (I_C = 1.0 Adc, I_{B1} = I_{B2} = 0.1 Adc)	t_f	-	16	30	ns

* Pulse test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%

FIGURE 1 – SWITCHING TIME TEST CIRCUIT



2N5155 (GERMANIUM)



Collector Connected to Case
CASE 11A
(TO-3 modified)

PNP Germanium power transistor designed for high-current switching applications requiring low saturation voltages, fast switching times and above average Collector-Emitter Sustaining Voltage capability.

- Alloy Diffused Epitaxial Construction
- Low Saturation Voltages –
  $V_{CE(sat)} = 0.9$ Vdc (Max) @ $I_C = 25$ Adc
  $V_{BE(sat)} = 1.4$ Vdc (Max) @ $I_C = 25$ Adc
- DC Current Gain –
  $h_{FE} = 25$ (Min) @ $I_C = 8.0$ Adc

MAXIMUM RATINGS

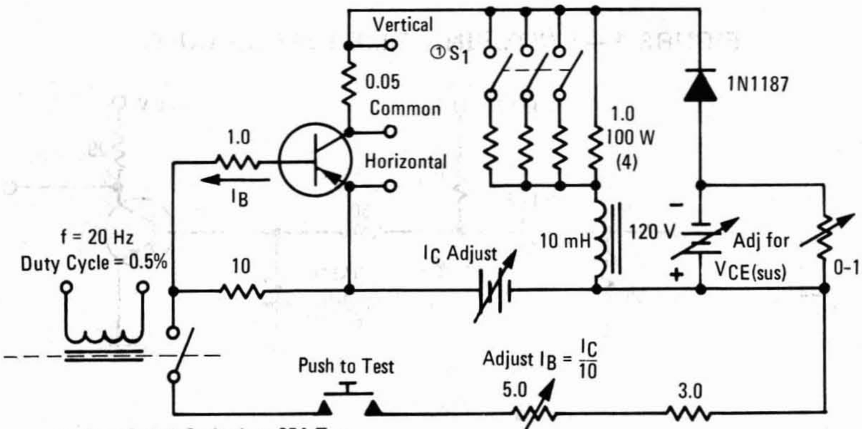
Rating	Symbol	Value	Unit
*Collector-Emitter Voltage	V_{CEO}	120	Vdc
*Collector-Base Voltage	V_{CB}	140	Vdc
*Emitter-Base Voltage	V_{EB}	1.5	Vdc
*Collector Current - Continuous ** - Continuous * - Peak	I_C	15 25 25	Adc
*Base Current - Continuous	I_B	5.0	Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	106 1.25	Watts W/°C
*Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	°C/W

*Indicates JEDEC Registered Data.
**Motorola guarantees this data in addition to the JEDEC Registered data shown.

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT


Vertical
①S1
0.05
Common
1.0
Horizontal
I_B
1N1187
1.0
100 W
(4)
f = 20 Hz
Duty Cycle = 0.5%
10
I_C Adjust
10 mH
120 V
–
+
Adj for
V_CE(sus)
0-150
Push to Test
Adjust I_B = I_C/10
5.0
3.0

① Close Switch S_1 for $I_C = 25A$ Test.

2N5155 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
*Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	BV_{CEO}	120	-	Vdc
*Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 8.0 Adc, R_{EB} = 10 Ohms) (I_C = 25 Adc, R_{EB} = 10 Ohms)	$V_{CE(sus)}$	120 80	- -	Vdc
*Collector Cutoff Current (V_{CE} = 140 Vdc, $V_{BE(off)}$ = 0.2 Vdc) (V_{CE} = 140 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C)	I_{CEX}	- -	10 25	mAdc
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)	I_{CBO}	-	200	μAdc
*Emitter Cutoff Current (V_{EB} = 1.5 Vdc, I_C = 0)	I_{EBO}	-	500	mAdc
ON CHARACTERISTICS				
*DC Current Gain (I_C = 8.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	25	100	-
*Collector-Emitter Saturation Voltage (I_C = 25 Adc, I_B = 2.5 Adc)	$V_{CE(sat)}$	-	0.9	Vdc
*Base-Emitter Saturation Voltage (I_C = 25 Adc, I_B = 2.5 Adc)	$V_{BE(sat)}$	-	1.4	Vdc
Pulse Energy Test (Note 1) (See Figure 2) (I_C = 4.2 Adc, V_{CE} = 30 Vdc)	PET	1.26	-	Joule
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc, f = 50 kHz)	f_T	100	-	kHz

SWITCHING CHARACTERISTICS

Characteristic	Conditions	Symbol	Min	Max	Unit
Rise Time	(V_{CC} = -12 Vdc, I_C = 10 Adc, I_{B1} = 1.0 Adc, I_{B2} = 1.0 Adc) (See Figure 3)	t_r	-	18	μs
Storage Time		t_s	-	12	μs
Fall Time		t_f	-	18	μs

*Indicates JEDEC Registered Data.

Note 1: Pulse Test: Pulse Width = 10 ms, Duty Cycle = 2.5%.

FIGURE 2 – PULSE ENERGY TEST CIRCUIT

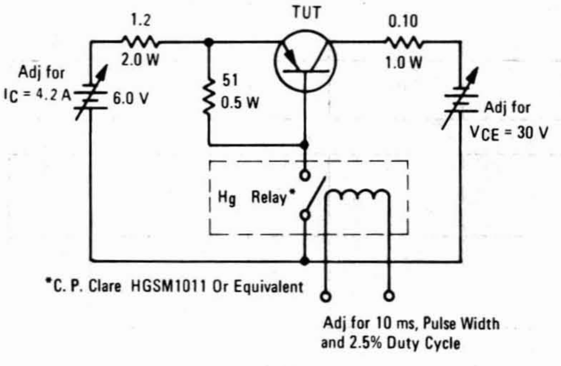
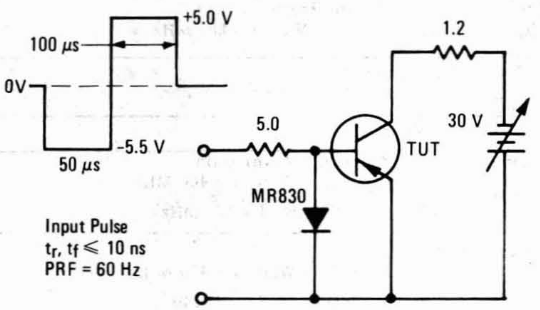

1.2
2.0 W
TUT
0.10
1.0 W
Adj for
IC = 4.2 A
6.0 V
51
0.5 W
Adj for
VCE = 30 V
Hg Relay*
*C. P. Clare HGSM1011 Or Equivalent
Adj for 10 ms, Pulse Width
and 2.5% Duty Cycle

FIGURE 3 – SWITCHING TIME TEST CIRCUIT


+5.0 V
100 μs
0V
-5.5 V
50 μs
1.2
30 V
5.0
TUT
MR830
Input Pulse
tr, tf ≤ 10 ns
PRF = 60 Hz

2N5160 (SILICON)

PNP silicon RF power transistors designed for amplifier, frequency multiplier or oscillator applications in military and industrial equipment. Suitable for use as Class A, B, or C output driver, or pre-driver stages in VHF and UHF.

CASE 79
(TO-39)

Collector connected to case

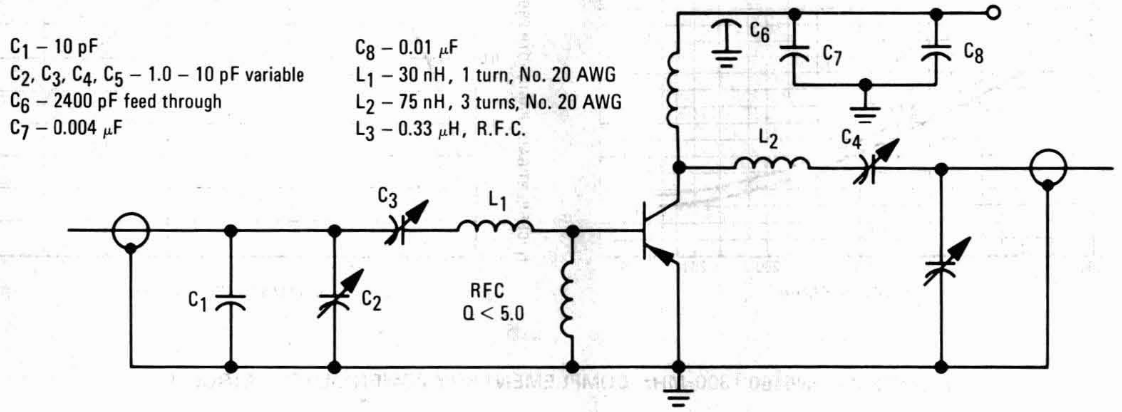
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	0.4	Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	5.0 28.6	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage ($I_C = 5.0$ mAdc, $I_B = 0$)	$BV_{CEO(sus)}$	40	-	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 0.1$ mAdc, $I_C = 0$)	BV_{EBO}	4.0	-	-	Vdc
Collector Cutoff Current ($V_{CE} = 28$ Vdc, $I_B = 0$)	I_{CEO}	-	-	20	µAdc
Collector Cutoff Current ($V_{CE} = 60$ Vdc, $V_{BE} = 0$)	I_{CES}	-	-	0.1	mAdc
Collector Cutoff Current ($V_{CB} = 28$ Vdc, $I_E = 0$)	I_{CBO}	-	-	1.0	µAdc
ON CHARACTERISTICS					
DC Current Gain ($I_C = 50$ mAdc, $V_{CE} = 5.0$ Vdc)	h_{FE}	10	-	-	-
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product ($I_C = 50$ mAdc, $V_{CE} = 15$ Vdc, f = 200 MHz)	f_T	500	900	-	MHz
Collector-Base Capacitance ($V_{CB} = 28$ Vdc, $I_E = 0$, f = 0.1 to 1.0 MHz)	C_{cb}	-	2.5	4.0	pF
FUNCTIONAL TESTS					
Common-Emitter Amplifier Power Gain ($V_{CE} = 28$ Vdc, $P_{in} = 0.16$ Watt, f = 400 MHz) ($V_{CE} = 28$ Vdc, $P_{in} = 50$ mW, f = 175 MHz)	G_{PE}	8.0 -	8.8 14.5	- -	dB
Power Output ($V_{CE} = 28$ Vdc, $P_{in} = 0.16$ Watt, f = 400 MHz) ($V_{CE} = 28$ Vdc, $P_{in} = 50$ mW, f = 175 MHz)	P_{out}	1.0 -	1.2 1.4	- -	Watt
Collector Efficiency ($V_{CE} = 28$ Vdc, $P_{in} = 0.16$ Watt, f = 400 MHz)	η	45	55	-	%

FIGURE 1 – 400-MHz TEST CIRCUIT



C_1 – 10 pF
C_2, C_3, C_4, C_5 – 1.0 – 10 pF variable
C_6 – 2400 pF feed through
C_7 – 0.004 μF
C_8 – 0.01 μF
L_1 – 30 nH, 1 turn, No. 20 AWG
L_2 – 75 nH, 3 turns, No. 20 AWG
L_3 – 0.33 μH, R.F.C.

FIGURE 2 – POWER OUTPUT versus FREQUENCY

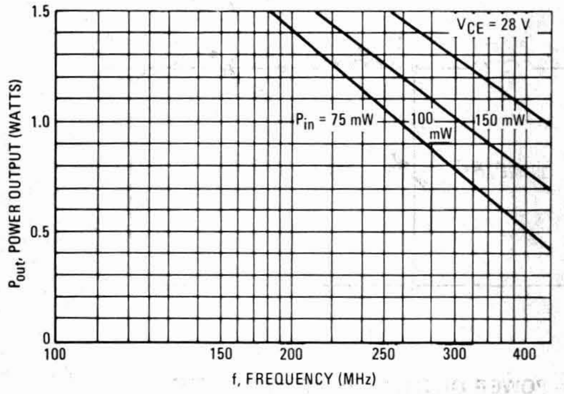


FIGURE 3 – POWER OUTPUT versus POWER INPUT

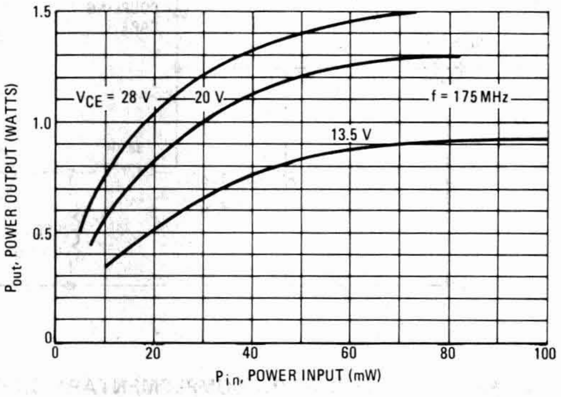


FIGURE 4 – PARALLEL INPUT IMPEDANCE versus FREQUENCY

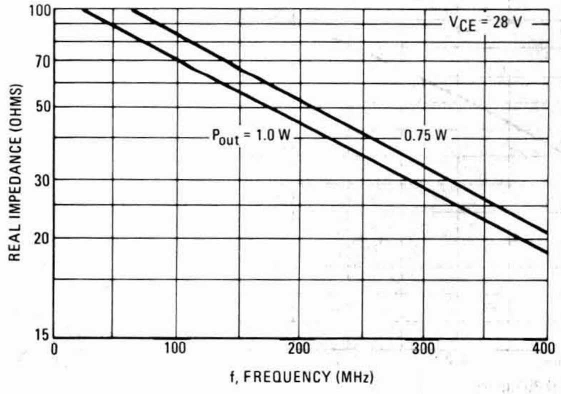


FIGURE 5 – PARALLEL INPUT IMPEDANCE versus FREQUENCY

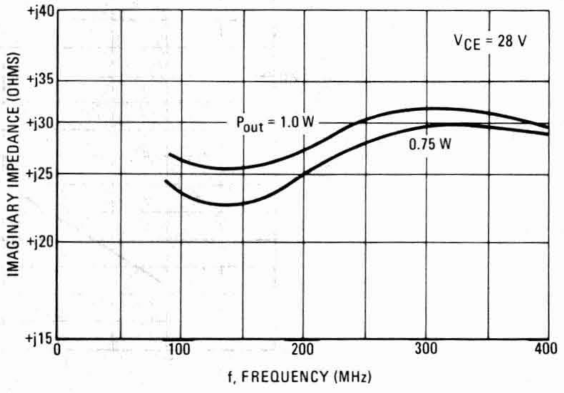


FIGURE 6 – PARALLEL OUTPUT CAPACITANCE versus FREQUENCY

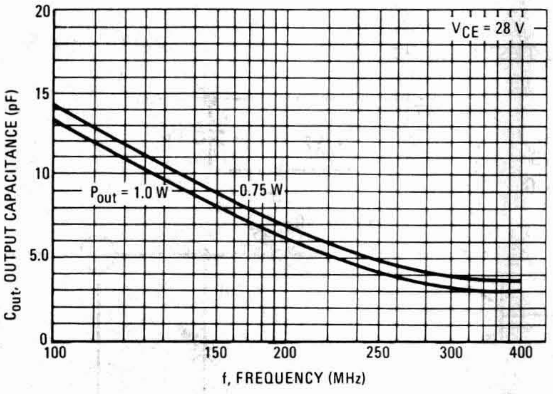


FIGURE 7 – CURRENT-GAIN–BANDWIDTH PRODUCT versus COLLECTOR CURRENT

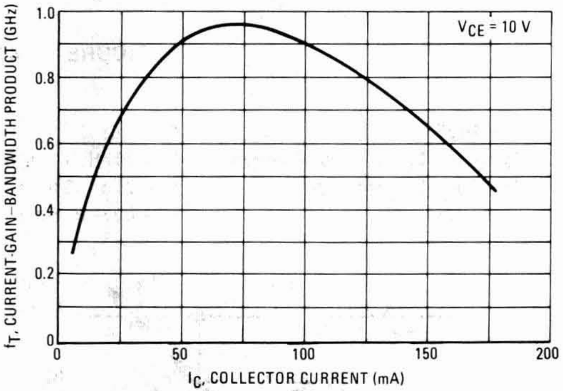
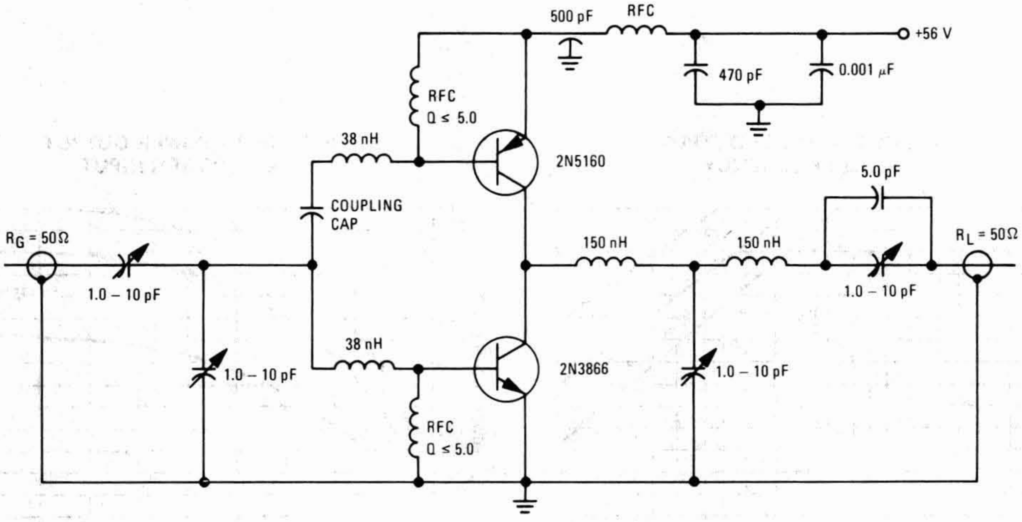
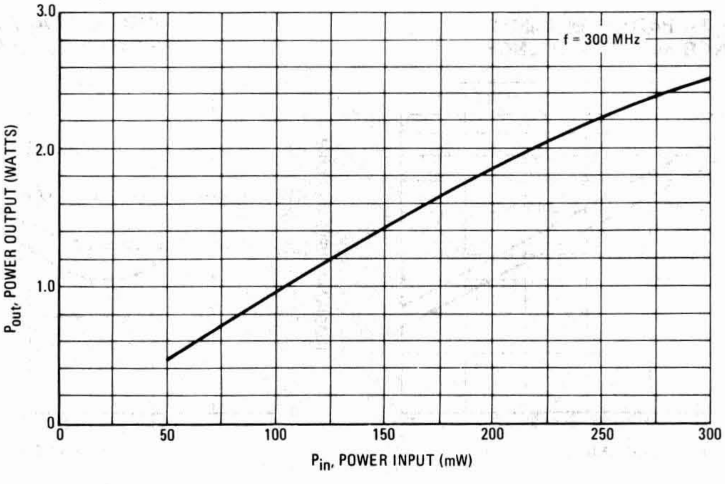


FIGURE 8 – 2N5160 300-MHz COMPLEMENTARY POWER OUTPUT CIRCUIT



500 pF
RFC
+56 V
470 pF
0.001 μF
RFC
Q ≤ 5.0
38 nH
2N5160
5.0 pF
COUPLING
CAP
R_G = 50Ω
150 nH
150 nH
R_L = 50Ω
1.0 – 10 pF
1.0 – 10 pF
38 nH
2N3866
1.0 – 10 pF
1.0 – 10 pF
RFC
Q ≤ 5.0

FIGURE 9 – COMPLEMENTARY CIRCUIT – POWER OUTPUT versus POWER INPUT



2N5161 (SILICON)
2N5162

CASE 36
(TO-60)

Case common to emitter

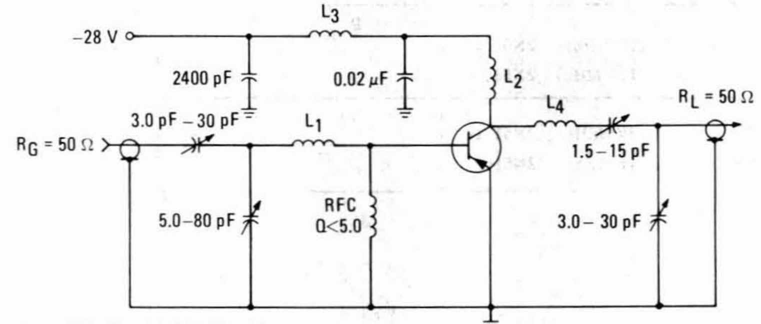
PNP silicon RF power transistors designed for amplifier or oscillator applications in military and industrial equipment. Suitable for use as Class B or C output or power oscillator in VHF applications.

MAXIMUM RATINGS

Rating	Symbol	2N5161	2N5162	Unit
Collector-Emitter Voltage	V_{CEO}	40		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	4.0		Vdc
Collector Current	I_C	1.5	5.0	Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	20 0.114	50 0.286	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

FIGURE 1 — 175 MHz TEST CIRCUITS

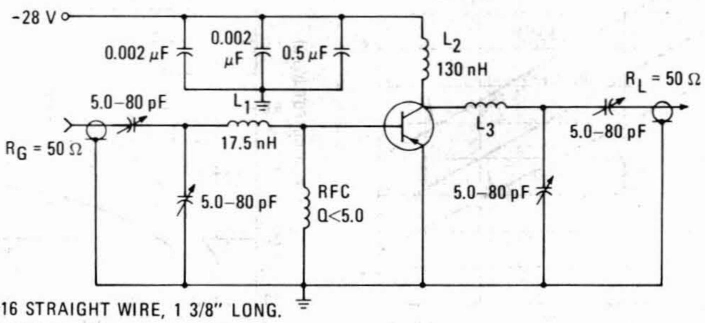
1a – 2N5161



–28 V
L3
2400 pF
0.02 μF
L2
3.0 pF – 30 pF
L1
L4
RL = 50 Ω
RG = 50 Ω
1.5–15 pF
5.0–80 pF
RFC
Q<5.0
3.0– 30 pF

L_1 – 1 TURN, #18 AWG (21 nH)
L_2, L_3 – 0.33 μH RFC
L_4 – 4 TURNS, #16 AWG, ½" I.D. (200 nH)

1b – 2N5162



–28 V
0.002 μF
0.002 μF
0.5 μF
L2
130 nH
RL = 50 Ω
5.0–80 pF
L1
RG = 50 Ω
17.5 nH
L3
5.0–80 pF
5.0–80 pF
RFC
Q<5.0
5.0–80 pF

L_1 – #16 STRAIGHT WIRE, 1 3/8" LONG.
L_2 – 5 TURNS #20 AWG, 1/2" LONG.
L_3 – 1 TURN #18 AWG WIRE.

2N5161, 2N5162 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage* (I_C = 200 mAdc, I_B = 0)		$BV_{CEO(sus)}$*	40	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 1.0 mAdc, I_C = 0) (I_E = 5.0 mAdc, I_C = 0)	2N5161 2N5162	BV_{EBO}	4.0 4.0	- -	- -	Vdc
Collector Cutoff Current (V_{CE} = 60 Vdc, V_{BE} = 0) (V_{CE} = 28 Vdc, V_{BE} = 0, T_C = 200°C)	2N5161 2N5162 2N5161 2N5162	I_{CES}	- - - -	- - - -	0.5 1.0 5.0 10	mAdc
Collector Cutoff Current (V_{CB} = 28 Vdc, I_E = 0)	2N5161 2N5162	I_{CBO}	- -	- -	0.1 0.2	mAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 250 mAdc, V_{CE} = 5.0 Vdc) (I_C = 2.0 Adc, V_{CE} = 5.0 Vdc)	2N5161 2N5162	h_{FE}	10 10	- -	- -	-
DYNAMIC CHARACTERISTICS						
Current-Gain–Bandwidth Product (I_C = 200 mAdc, V_{CE} = 20 Vdc, f = 100 MHz) (I_C = 500 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	2N5161 2N5162	f_T	- -	500 500	- -	MHz
Output Capacitance (V_{CB} = 28 Vdc, I_E = 0, f = 0.1 to 1.0 MHz)	2N5161 2N5162	C_{ob}	- -	10 45	15 60	pF
FUNCTIONAL TEST						
Common-Emitter Amplifier Power Gain (V_{CC} = 28 Vdc, P_{out} = 7.5 Watts, f = 175 MHz) (V_{CC} = 28 Vdc, P_{out} = 30 Watts, f = 175 MHz)	2N5161 2N5162	G_{PE}	8.75 6.0	10.3 7.0	- -	dB
Power Output (V_{CC} = 28 Vdc, P_{in} = 1.0 Watt, f = 175 MHz) (V_{CC} = 28 Vdc, P_{in} = 7.5 Watts, f = 175 MHz)	2N5161 2N5162	P_{out}	7.5 30	8.5 35	- -	Watts
Collector Efficiency (V_{CC} = 28 Vdc, P_{out} = 7.5 Watts, f = 175 MHz) (V_{CC} = 28 Vdc, P_{out} = 30 Watts, f = 175 MHz)	2N5161 2N5162	η	45 55	- -	- -	%

* Pulsed through 25 mH inductor

2N5161 DESIGN DATA

FIGURE 2 – POWER OUTPUT versus FREQUENCY

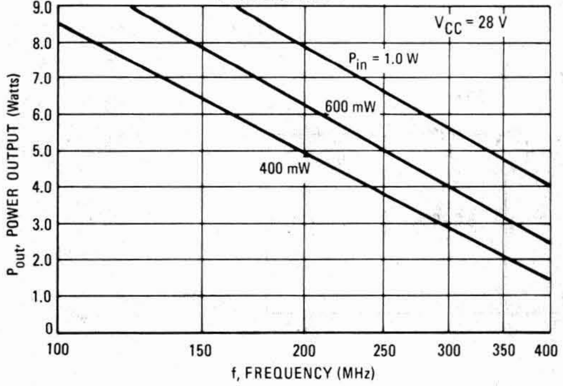
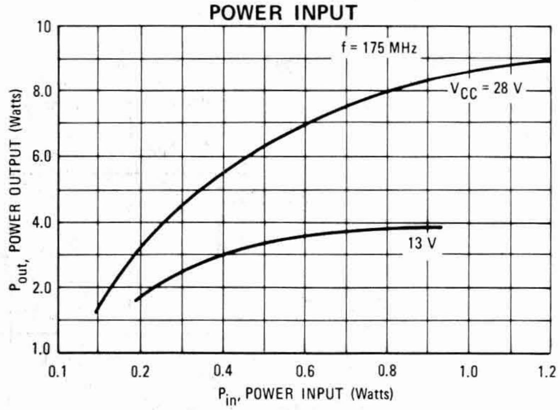


FIGURE 3 – POWER OUTPUT versus POWER INPUT



LARGE SIGNAL IMPEDANCE DATA

FIGURE 4 – REAL SERIES INPUT RESISTANCE versus FREQUENCY

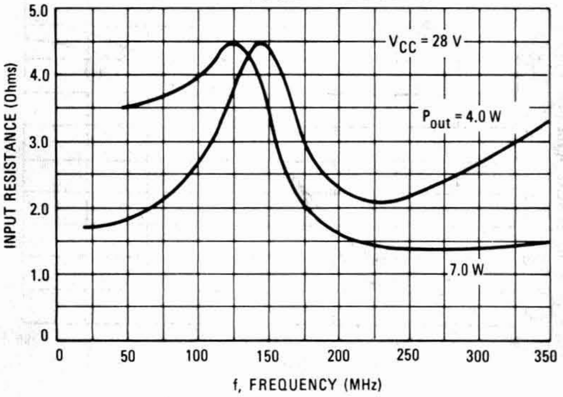


FIGURE 5 – IMAGINARY SERIES INPUT REACTANCE versus FREQUENCY

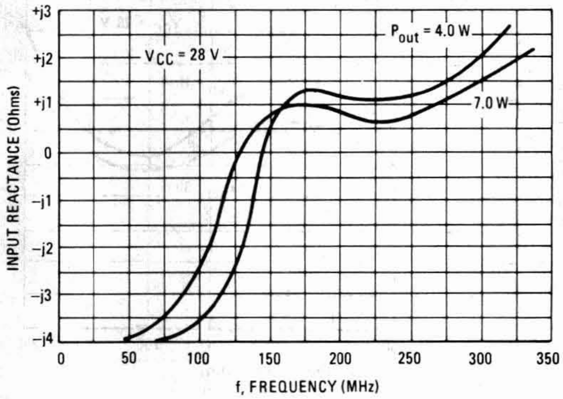
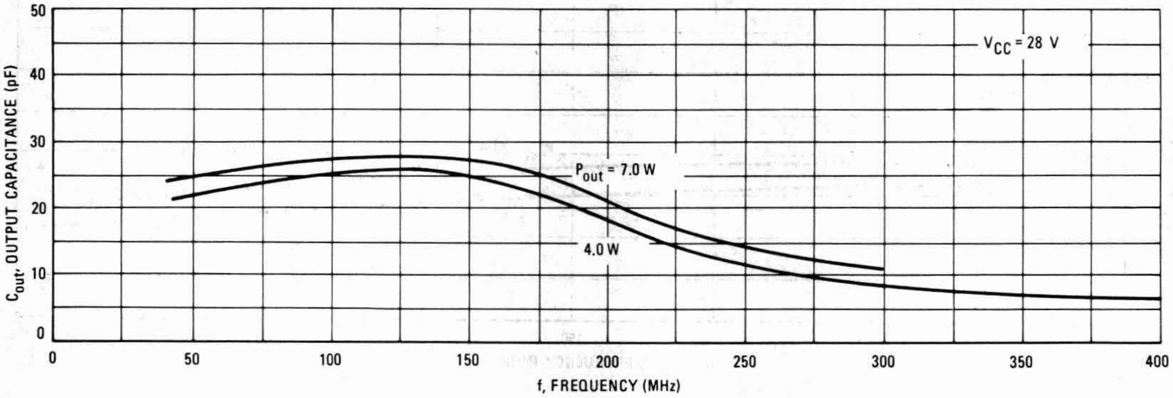


FIGURE 6 – OUTPUT CAPACITANCE versus FREQUENCY



2N5162 DESIGN DATA

FIGURE 7 – POWER OUTPUT versus FREQUENCY

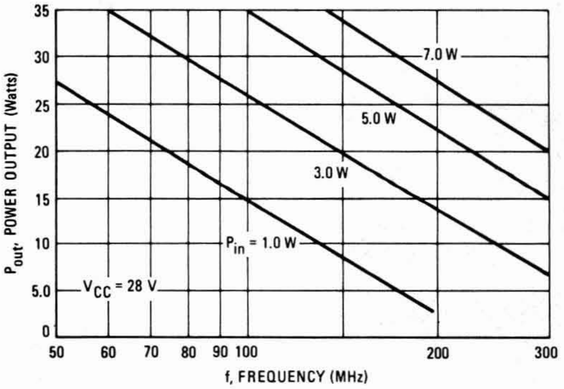
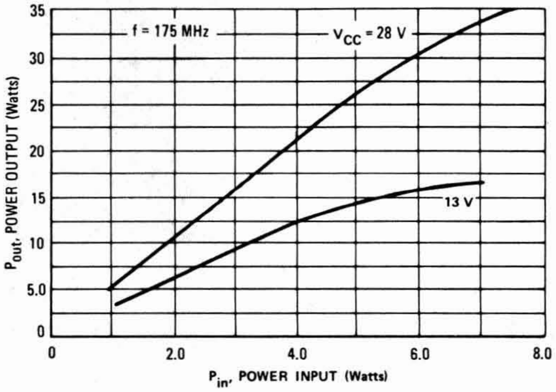


FIGURE 8 – POWER OUTPUT versus POWER INPUT



LARGE SIGNAL IMPEDANCE DATA

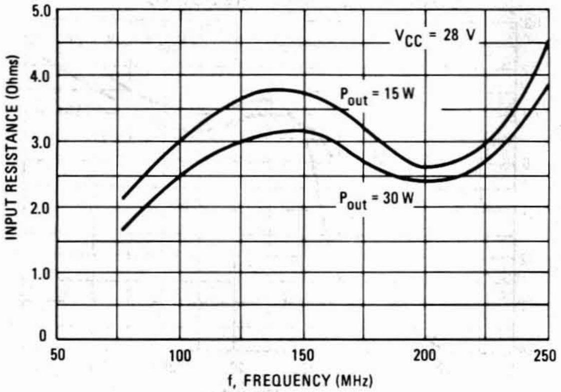


FIGURE 9 – REAL SERIES INPUT RESISTANCE versus FREQUENCY

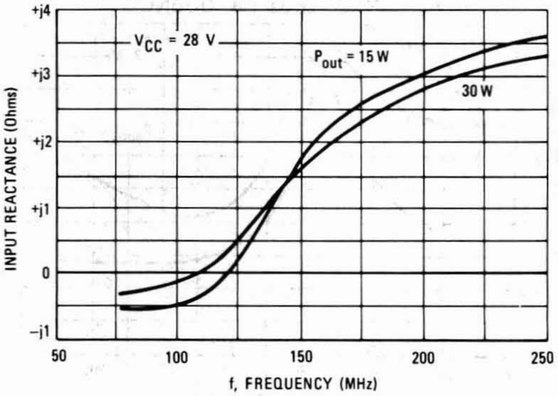
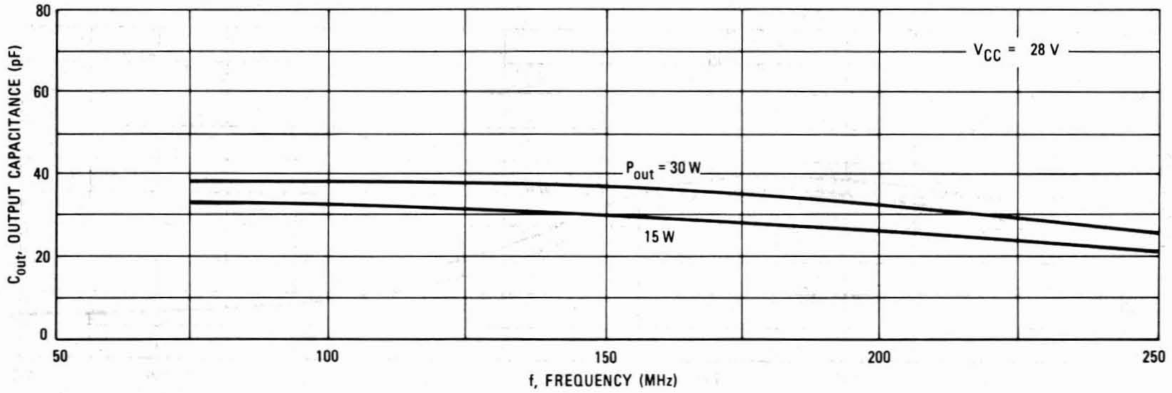
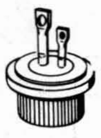


FIGURE 10 – IMAGINARY SERIES INPUT REACTANCE versus FREQUENCY

FIGURE 11 – OUTPUT CAPACITANCE versus FREQUENCY



2N5164 thru 2N5171 (SILICON)
2N5164R thru 2N5171R


2N5164
thru
2N5167

CASE 91

2N5168
thru
2N5171

CASE 92

Cathode and anode terminals reversed for "R" suffix units: i.e., 2N5164R.

Pressfit and pressfit-stud thyristors well suited for industrial and consumer applications such as power supplies, battery chargers, temperature, motor, light, and welder controls, and protective devices.

MAXIMUM RATINGS (T_J = 100°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*†	$V_{ROM(rep)}$*†		Volts
2N5164, 68		50	
2N5165, 69		200	
2N5166, 70		400	
2N5167, 71		600	
Non-repetitive Peak Reverse Blocking Voltage†	$V_{ROM(non-rep)}$†		Volts
2N5164, 68		75	
2N5165, 69		300	
2N5166, 70		500	
2N5167, 71		700	
Forward Current RMS	I_f	20	Amp
Circuit Fusing Considerations (T_J = -40 to +100°C, t ≤ 8.3 ms)	I^2t	235	A^2s
Peak Forward Surge Current † (one cycle, 60 Hz, T_J = -40 to +100°C)	$I_{FM(surge)}$†	240	Amp
Peak Forward Gate Power †	P_{GFM}†	5.0	Watt
Average Forward Gate Power †	$P_{GF(AV)}$†	0.5	Watt
Peak Forward Gate Current †	I_{GFM}†	2.0	Amp
Peak Gate Voltage - Forward** Reverse	V_{GFM}** V_{GRM}	10 10	Volts
Operating Junction Temperature Range†	T_J†	-40 to +100	°C
Storage Temperature Range †	T_{stg}†	-40 to +150	°C
Stud Torque††		30††	in. lb.

THERMAL CHARACTERISTICS

Characteristic	Symbol	Typ	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}			°C/W
2N5164, 65, 66, 67		1.0	1.5†	
2N5168, 69, 70, 71		1.1	1.6†	

*$V_{ROM(rep)}$ for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for zero or negative gate voltage. Devices should not be tested for blocking capability in a manner such that the voltage applied exceeds the rated blocking voltage.

**Devices should not be operated with a positive bias applied to the gate concurrently with a negative potential applied to the anode.

†JEDEC Registered Values

††Reliable operation can be impaired if torque rating is exceeded or if terminal tubes are bent or glass seal broken.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Peak Forward Blocking Voltage*† (T_J = 100°C)	V_{FOM}*†			Volts
2N5164, 2N5168		50	-	
2N5165, 2N5169		200	-	
2N5166, 2N5170		400	-	
2N5167, 2N5171		600	-	
Peak Forward Blocking Current † (Rated V_{FOM} @ T_J = 100°C, gate open)	I_{FOM}†	-	5.0	mA
Peak Reverse Blocking Current † (Rated V_{ROM} @ T_J = 100°C, gate open)	I_{ROM}†	-	5.0	mA
Gate Trigger Current (Continuous dc)**	I_{GT}**			mA
(Anode Voltage = 7.0 Vdc, R_L = 100 Ω)		-	40	
(Anode Voltage = 7.0 Vdc, R_L = 100 Ω, T_C = -40°C)†		-	75†	
Gate Trigger Voltage (Continuous dc)	V_{GT}			Volts
(Anode Voltage = 7.0 Vdc, R_L = 100 Ω)		-	1.5	
(Anode Voltage = 7.0 Vdc, R_L = 100Ω, T_C = -40°C)†		-	2.5†	
(Anode Voltage = Rated V_{FOM}, R_L = 100Ω, T_J = 100°C)†		0.2†	-	
Forward "On" Voltage (pulsed, 1.0 ms max, duty cycle ≤ 1%)	V_F			Volts
(I_F = 20 A)		-	1.5	
(I_F = 41 A) †		-	1.7†	
Holding Current	I_{HO}			mA
(Anode Voltage = 7.0 Vdc, gate open)		-	50	
(Anode Voltage = 7.0 Vdc, gate open, T_C = -40°C) †		-	90†	
		TYPICAL		
Turn-On Time (t_d + t_r) (I_G = 40 mAdc, I_F = 20 Adc)	t_{on}	1.0		μs
Turn-Off Time	t_{off}			μs
(I_F = 10 Adc, I_R = 10 Adc)		20		
(I_F = 10 Adc, I_R = 10 Adc, T_J = 100°C)		30		
(V_{FXM} = rated voltage) (dv/dt = 30 V/μs)				
Forward Voltage Application Rate (Gate open, T_J = 100°C)	dv/dt	50		V/μs

*V_{FOM} for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for zero or negative gate voltage. These devices should not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

** For optimum operation, i.e. faster turn-on, lower switching losses, best di/dt capability, recommended I_{GT} = 200 mA.

† JEDEC Registered Values

EFFECT OF TEMPERATURE UPON TYPICAL TRIGGER CHARACTERISTICS

FIGURE 1 — NORMALIZED GATE TRIGGER CURRENT

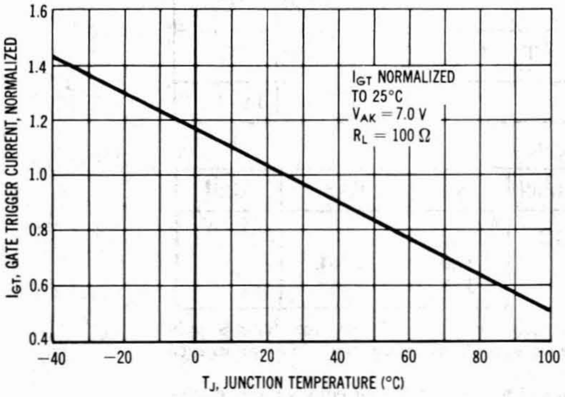
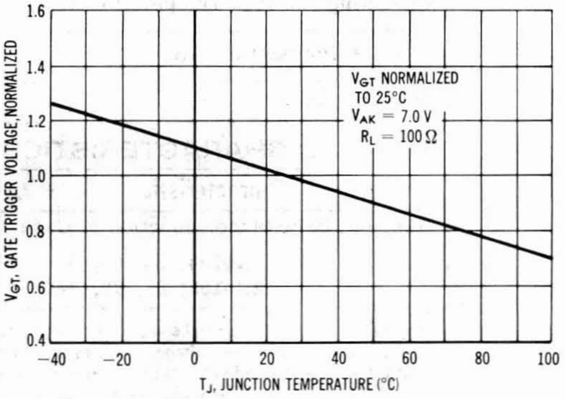


FIGURE 2 — NORMALIZED GATE TRIGGER VOLTAGE



MAXIMUM ALLOWABLE NON-RECURRENT SURGE CURRENT

FIGURE 3 — 60 Hz SURGES

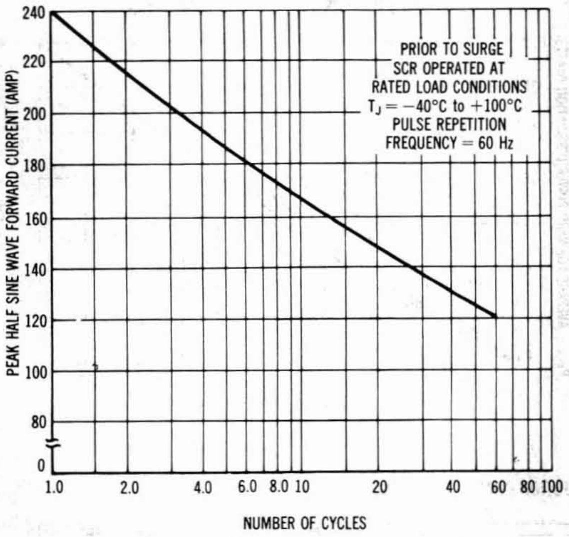


FIGURE 4 — SUB-CYCLE SURGES

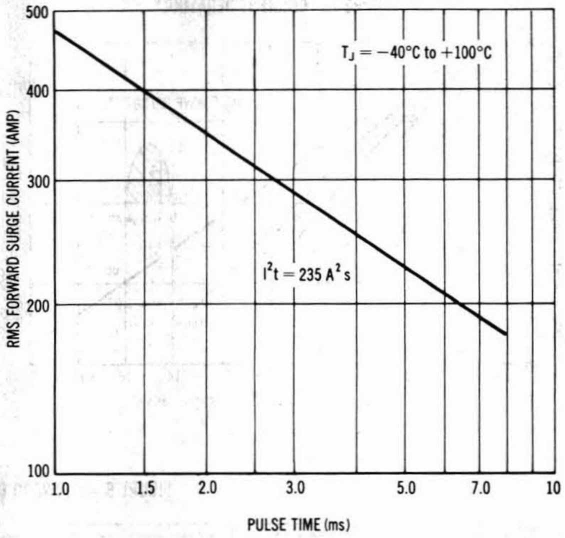


FIGURE 5 — GATE TRIGGER CHARACTERISTICS

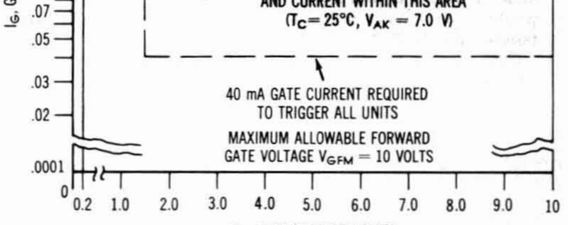
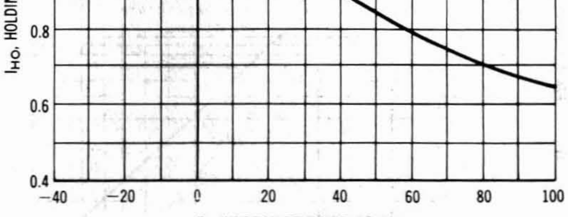


FIGURE 6 — EFFECT OF TEMPERATURE ON TYPICAL HOLDING CURRENT



DERATING AND DISSIPATION FOR RESISTIVE AND INDUCTIVE LOADS (f = 60 to 400 Hz, SINE WAVE)

FIGURE 7 — CURRENT DERATING*

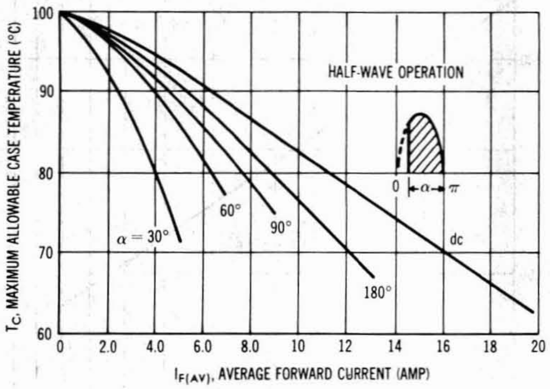


FIGURE 8 — FORWARD POWER DISSIPATION

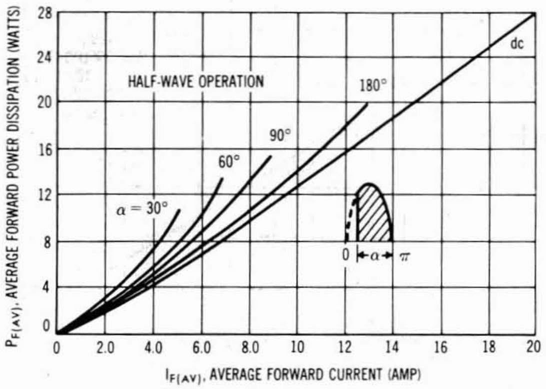


FIGURE 9 — FORWARD CONDUCTION CHARACTERISTICS

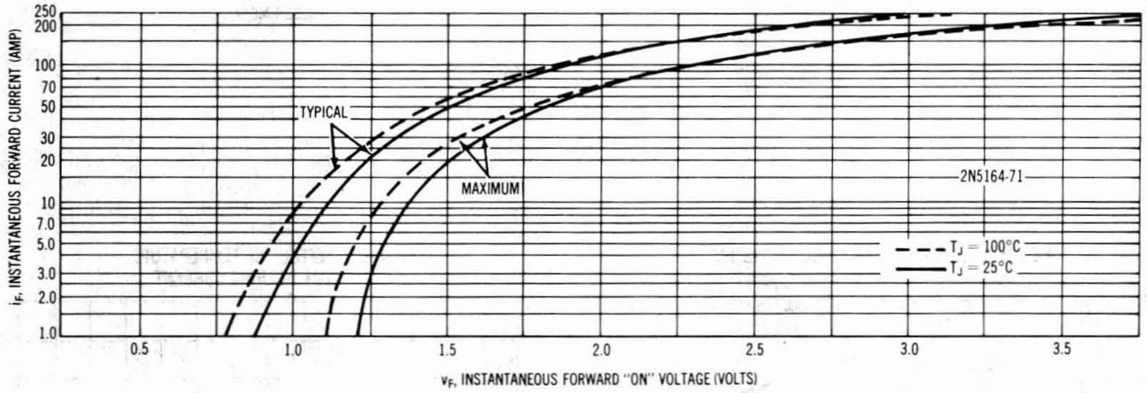
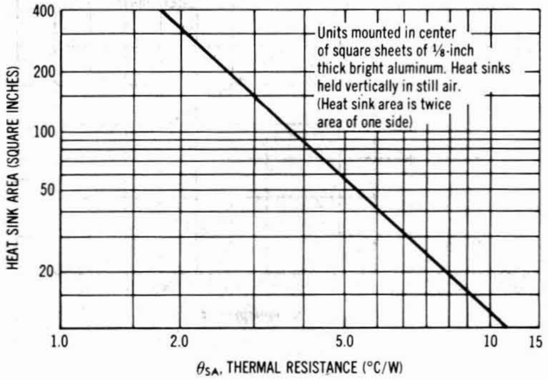


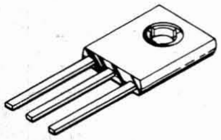
FIGURE 10 — TYPICAL THERMAL RESISTANCE OF PLATES



*Reverse polarity units must be derated an additional 10%; i.e., in Figure 7 the maximum allowable case temperature of the 2N5164 at 16 Adc is 70°C, a derating of 30°C below the maximum junction temperature. For the 2N5164R the derating would be an additional 10% or 3°C, making the allowable case temperature 67°C.

2N5190 (SILICON)
thru
2N5192

Silicon NPN power transistors for use in power amplifier and switching circuits, – excellent safe area limits. Complement to PNP 2N5193, 2N5194, 2N5195.



CASE 77(1)

MAXIMUM RATINGS

Rating	Symbol	2N5190	2N5191	2N5192	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Collector Current	I_C	4.0			Adc
Base Current	I_B	1.0			Adc
Total Device Dissipation @ $T_C = 25^\circ C$ Derate above 25°C	P_D	40 320			Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150			°C

THERMAL CHARACTERISTICS

	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	3.12	°C/W

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage*		$BV_{CEO(sus)}$*			Vdc
($I_C = 0.1$ Adc, $I_B = 0$)	2N5190		40	-	
	2N5191		60	-	
	2N5192		80	-	
Collector Cutoff Current		I_{CEO}			mAdc
($V_{CE} = 40$ Vdc, $I_B = 0$)	2N5190		-	1.0	
($V_{CE} = 60$ Vdc, $I_B = 0$)	2N5191		-	1.0	
($V_{CE} = 80$ Vdc, $I_B = 0$)	2N5192		-	1.0	
Collector Cutoff Current		I_{CEX}			mAdc
($V_{CE} = 40$ Vdc, $V_{EB(off)} = 1.5$ Vdc)	2N5190		-	0.1	
($V_{CE} = 60$ Vdc, $V_{EB(off)} = 1.5$ Vdc)	2N5191		-	0.1	
($V_{CE} = 80$ Vdc, $V_{EB(off)} = 1.5$ Vdc)	2N5192		-	0.1	
($V_{CE} = 40$ Vdc, $V_{EB(off)} = 1.5$ Vdc, $T_C = 125°C$)	2N5190		-	2.0	
($V_{CE} = 60$ Vdc, $V_{EB(off)} = 1.5$ Vdc, $T_C = 125°C$)	2N5191		-	2.0	
($V_{CE} = 80$ Vdc, $V_{EB(off)} = 1.5$ Vdc, $T_C = 125°C$)	2N5192		-	2.0	
Collector Cutoff Current		I_{CBO}			mAdc
($V_{CB} = 40$ Vdc, $I_E = 0$)	2N5190		-	0.1	
($V_{CB} = 60$ Vdc, $I_E = 0$)	2N5191		-	0.1	
($V_{CB} = 80$ Vdc, $I_E = 0$)	2N5192		-	0.1	
Emitter Cutoff Current		I_{EBO}			mAdc
($V_{BE} = 5.0$ Vdc, $I_C = 0$)			-	1.0	

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

(continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
ON CHARACTERISTICS					
DC Current Gain*		h_{FE}*			-
(I_C = 1.5 Adc, V_{CE} = 2.0 Vdc)	2N5190, 2N5191,		25	100	
	2N5192		20	80	
(I_C = 4.0 Adc, V_{CE} = 2.0 Vdc)	2N5190, 2N5191,		10	-	
	2N5192		7.0	-	
Collector-Emitter Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 1.5 Adc, I_B = 0.15 Adc)			-	0.6	
(I_C = 4.0 Adc, I_B = 1.0 Adc)			-	1.4	
Base-Emitter On Voltage*		$V_{BE(on)}$*			Vdc
(I_C = 1.5 Adc, V_{CE} = 2.0 Vdc)			-	1.2	
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product		f_T			MHz
(I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz)			2.0	-	

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 1 – NORMALIZED DC CURRENT GAIN

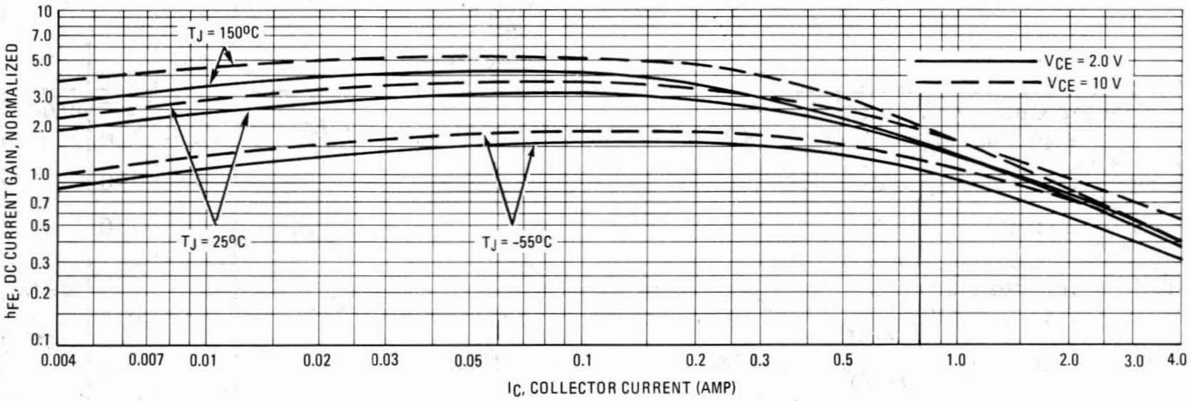


FIGURE 2 – COLLECTOR SATURATION REGION

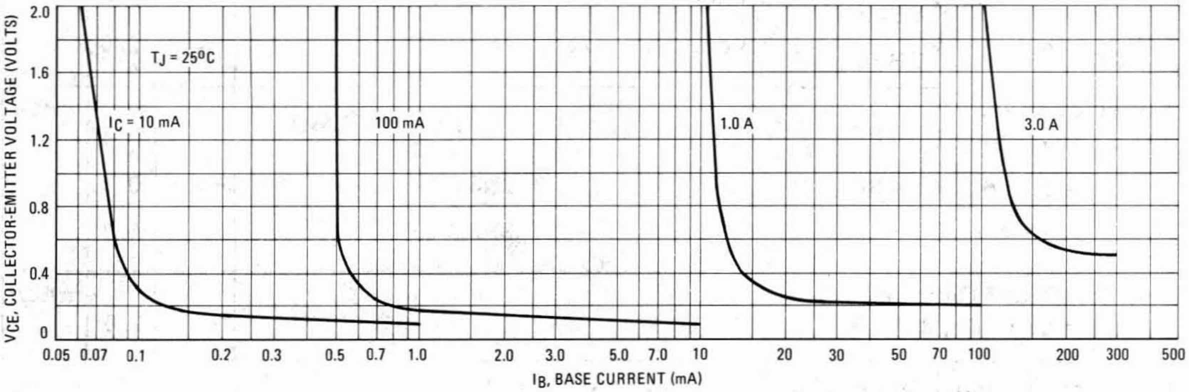


FIGURE 3 – "ON" VOLTAGES

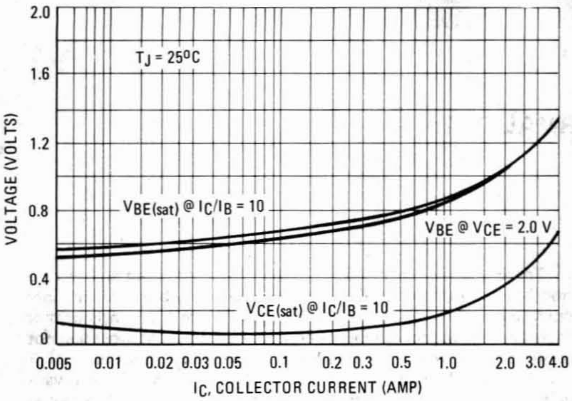
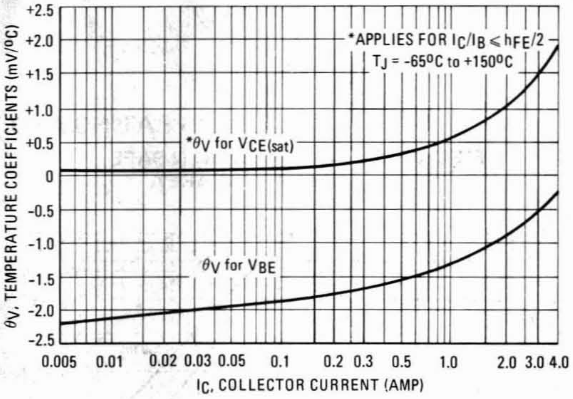


FIGURE 4 – TEMPERATURE COEFFICIENTS



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 5 – COLLECTOR CUT-OFF REGION

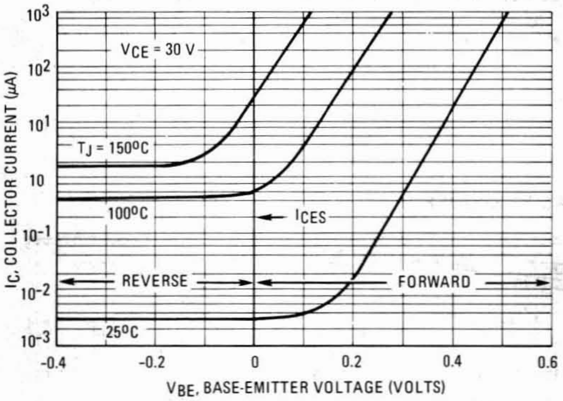


FIGURE 6 – EFFECTS OF BASE-EMITTER RESISTANCE

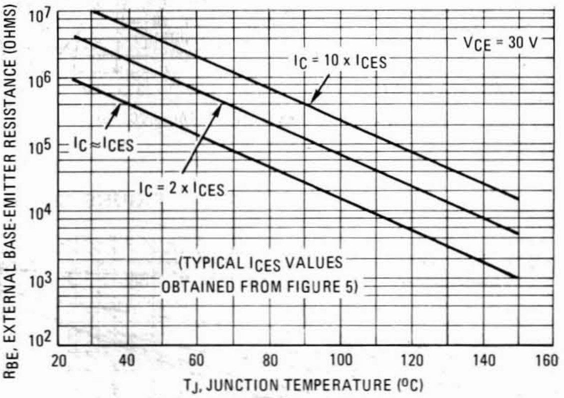
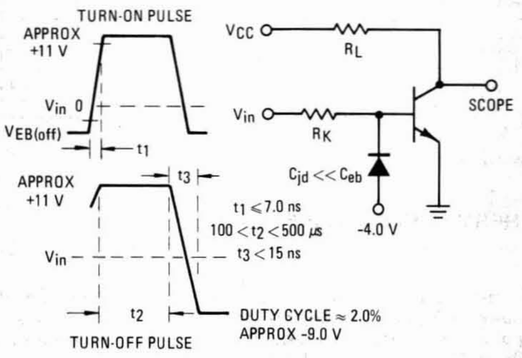


FIGURE 7 – SWITCHING TIME EQUIVALENT CIRCUIT



TURN-ON PULSE
APPROX +11 V
Vin 0
VEB(off)
t1
APPROX +11 V
t3
Vin
t2
TURN-OFF PULSE
VCC
RL
Vin
RK
SCOPE
Cjd << Ceb
-4.0 V
t1 ≤ 7.0 ns
100 < t2 < 500 μs
t3 < 15 ns
DUTY CYCLE ≈ 2.0%
APPROX -9.0 V

FIGURE 8 – CAPACITANCE

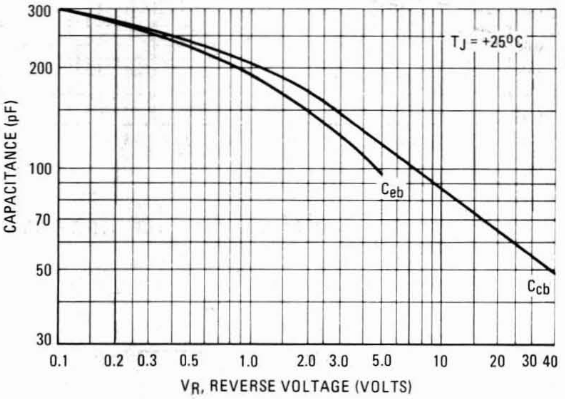


FIGURE 9 – TURN-ON TIME

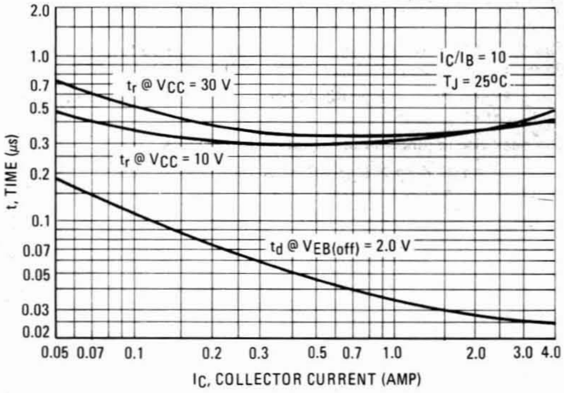
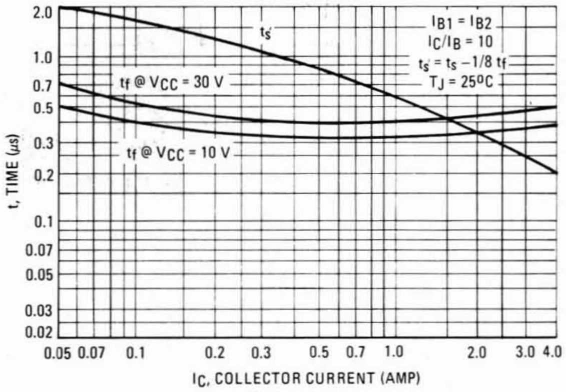
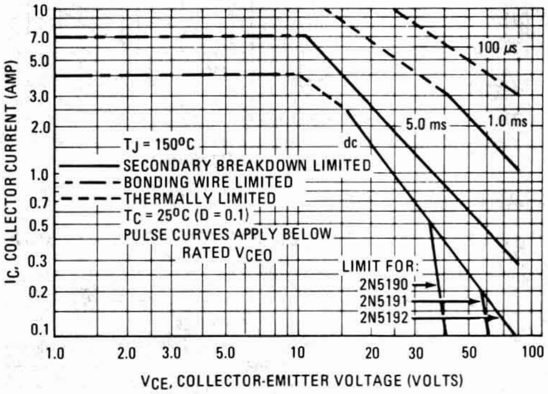


FIGURE 10 – TURN-OFF TIME



RATING AND THERMAL DATA

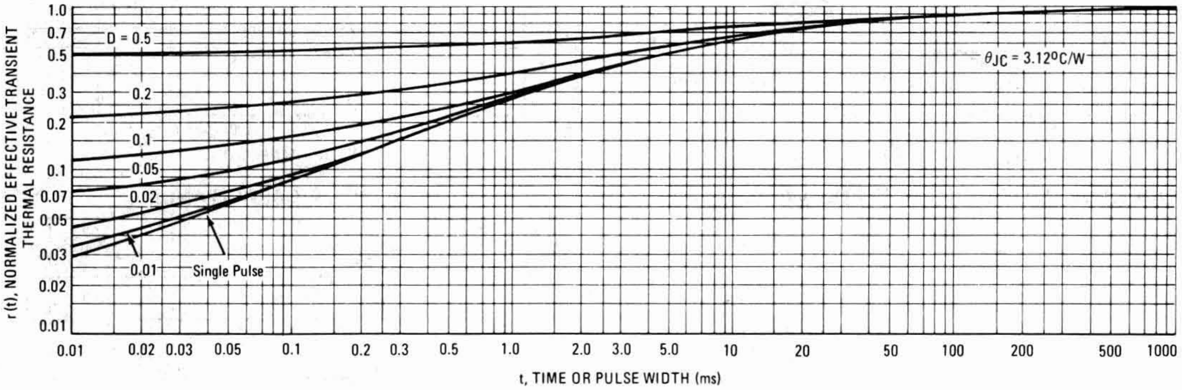
FIGURE 11 – ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate I_C-V_{CE} limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

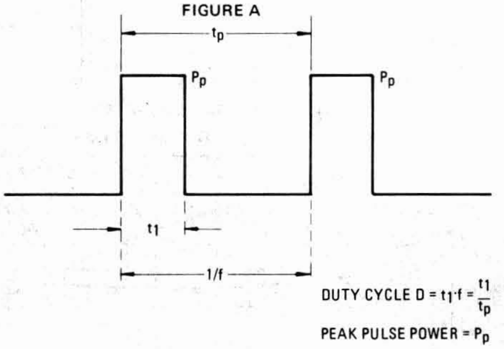
The data of Figure 11 is based on $T_{J(pk)}$ = 150°C; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 150°C$. $T_{J(pk)}$ may be calculated from the data in Figure 12. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 12 – THERMAL RESPONSE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



A train of periodical power pulses can be represented by the model shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 12 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 12 by the steady state value θ_{JC}.

Example:

The 2N5190 is dissipating 50 watts under the following conditions: t_1 = 0.1 ms, tp = 0.5 ms. (D = 0.2).

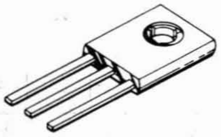
Using Figure 12, at a pulse width of 0.1 ms and D = 0.2, the reading of $r(t_1, D)$ is 0.27.

The peak rise in junction temperature is therefore:

$$\Delta T = r(t) \times P_P \times \theta_{JC} = 0.27 \times 50 \times 3.12 = 42.2^\circ C$$

2N5193 (SILICON)
thru
2N5195

Silicon PNP power transistors for use in power amplifier and switching circuits, – excellent safe area limits. Complement to NPN 2N5190, 2N5191, 2N5192.



CASE 77(1)

MAXIMUM RATINGS

Rating	Symbol	2N5193	2N5194	2N5195	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Collector Current	I_C	4.0			Adc
Base Current	I_B	1.0			Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	40 320			Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150			°C

THERMAL CHARACTERISTICS

	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	3.12	°C/W

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage*		$BV_{CEO(sus)}$*			Vdc
($I_C = 0.1$ Adc, $I_B = 0$)	2N5193		40	-	
	2N5194		60	-	
	2N5195		80	-	
Collector Cutoff Current		I_{CEO}			mAdc
($V_{CE} = 40$ Vdc, $I_B = 0$)	2N5193		-	1.0	
($V_{CE} = 60$ Vdc, $I_B = 0$)	2N5194		-	1.0	
($V_{CE} = 80$ Vdc, $I_B = 0$)	2N5195		-	1.0	
Collector Cutoff Current		I_{CEX}			mAdc
($V_{CE} = 40$ Vdc, $V_{BE(off)} = 1.5$ Vdc)	2N5193		-	0.1	
($V_{CE} = 60$ Vdc, $V_{BE(off)} = 1.5$ Vdc)	2N5194		-	0.1	
($V_{CE} = 80$ Vdc, $V_{BE(off)} = 1.5$ Vdc)	2N5195		-	0.1	
($V_{CE} = 40$ Vdc, $V_{BE(off)} = 1.5$ Vdc, $T_C = 125°C$)	2N5193		-	2.0	
($V_{CE} = 60$ Vdc, $V_{BE(off)} = 1.5$ Vdc, $T_C = 125°C$)	2N5194		-	2.0	
($V_{CE} = 80$ Vdc, $V_{BE(off)} = 1.5$ Vdc, $T_C = 125°C$)	2N5195		-	2.0	
Collector Cutoff Current		I_{CBO}			mAdc
($V_{CB} = 40$ Vdc, $I_E = 0$)	2N5193		-	0.1	
($V_{CB} = 60$ Vdc, $I_E = 0$)	2N5194		-	0.1	
($V_{CB} = 80$ Vdc, $I_E = 0$)	2N5195		-	0.1	
Emitter Cutoff Current		I_{EBO}			mAdc
($V_{BE} = 5.0$ Vdc, $I_C = 0$)			-	1.0	

*Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤ 2.0%.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

ON CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
DC Current Gain*		h_{FE}*			-
(I_C = 1.5 Adc, V_{CE} = 2.0 Vdc)	2N5193, 2N5194,		25	100	
	2N5195		20	80	
(I_C = 4.0 Adc, V_{CE} = 2.0 Vdc)	2N5193, 2N5194,		10	-	
	2N5195		7.0	-	
Collector-Emitter Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 1.5 Adc, I_B = 0.15 Adc)			-	0.6	
(I_C = 4.0 Adc, I_B = 1.0 Adc)			-	1.4	
Base-Emitter On Voltage*		$V_{BE(on)}$*			Vdc
(I_C = 1.5 Adc, V_{CE} = 2.0 Vdc)			-	1.2	

DYNAMIC CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Current-Gain–Bandwidth Product (I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz)	f_T	2.0	-	MHz

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 1 – NORMALIZED DC CURRENT GAIN

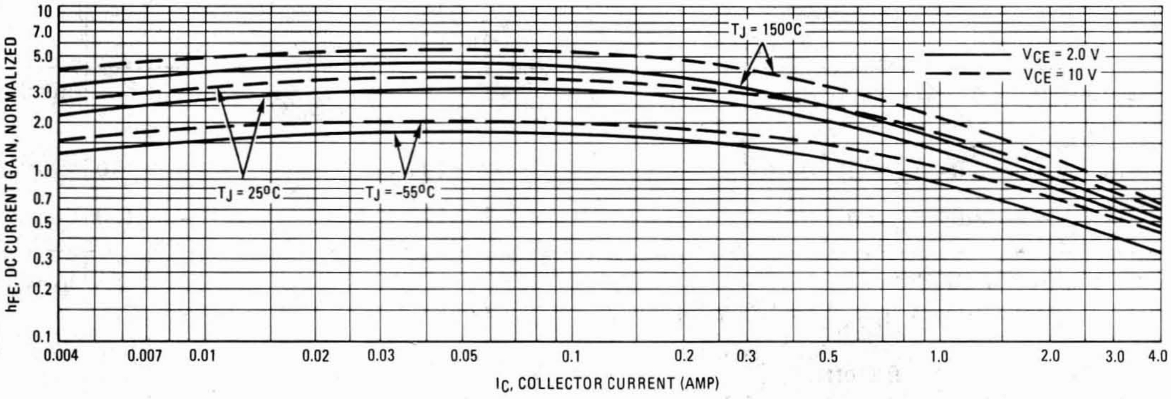


FIGURE 2 – COLLECTOR SATURATION REGION

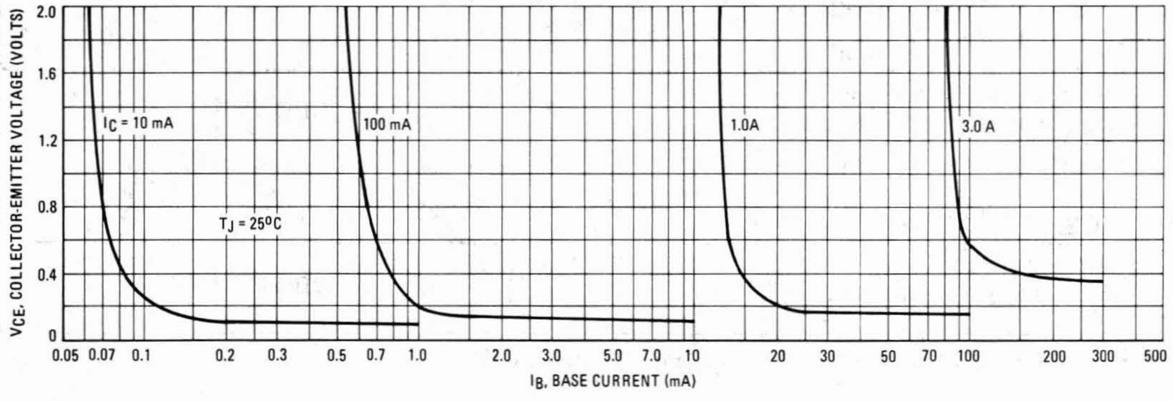


FIGURE 3 – "ON" VOLTAGE

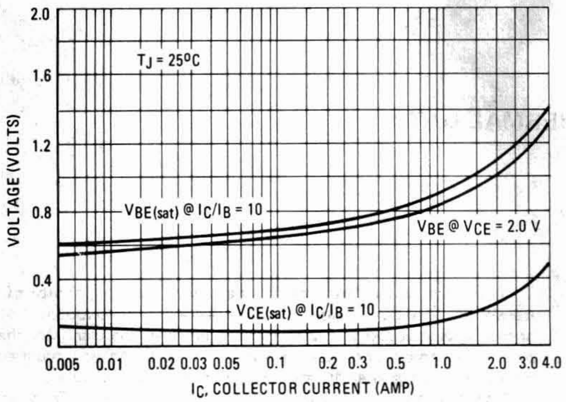
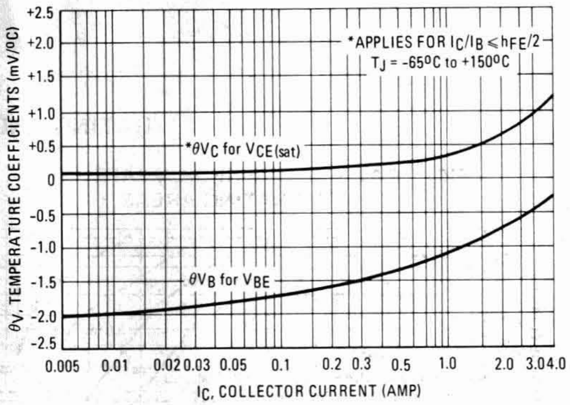


FIGURE 4 – TEMPERATURE COEFFICIENTS



TYPICAL "OFF" REGION CHARACTERISTICS

FIGURE 5 – COLLECTOR CUT-OFF REGION

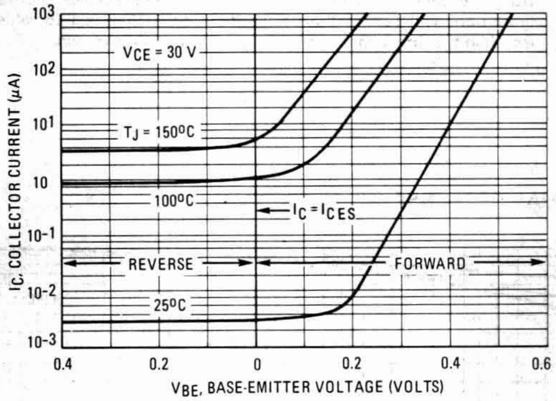


FIGURE 6 – EFFECTS OF BASE-EMITTER RESISTANCE

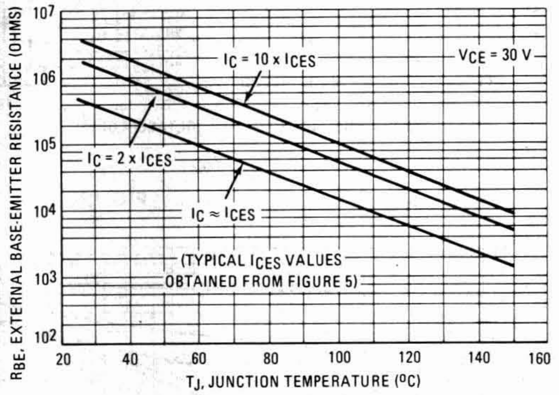


FIGURE 7 – SWITCHING TIME EQUIVALENT CIRCUIT

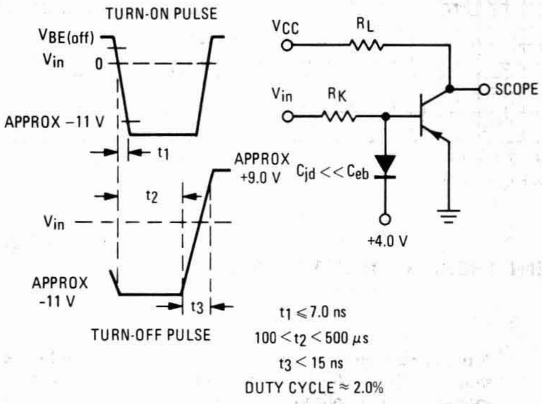

TURN-ON PULSE
$V_{BE(off)}$
V_{in}
0
APPROX −11 V
t_1
APPROX +9.0 V
t_2
V_{in}
APPROX −11 V
t_3
TURN-OFF PULSE
V_{CC}
R_L
V_{in}
R_K
SCOPE
$C_{jd} << C_{eb}$
+4.0 V
$t_1 \leqslant 7.0$ ns
$100 < t_2 < 500$ μs
$t_3 < 15$ ns
DUTY CYCLE ≈ 2.0%

FIGURE 8 – CAPACITANCE

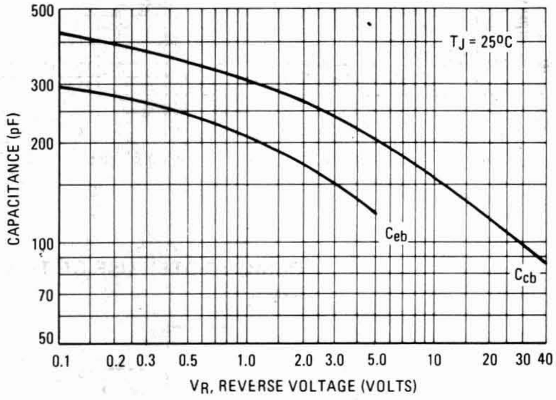


FIGURE 9 – TURN-ON TIME

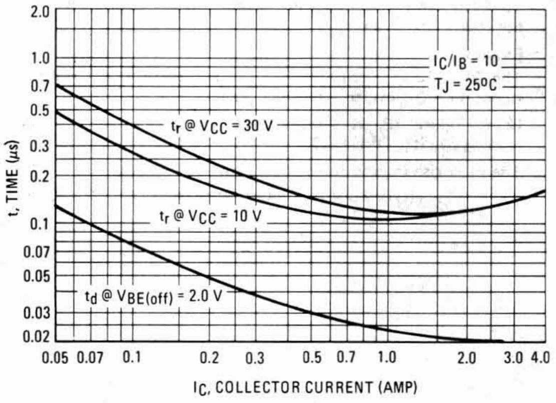
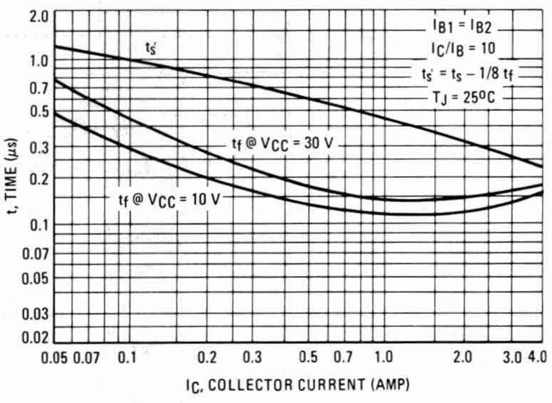
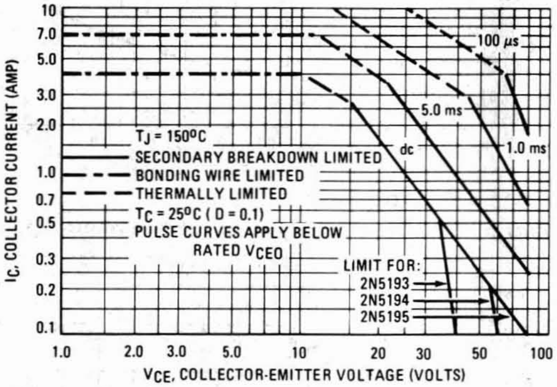


FIGURE 10 – TURN-OFF TIME



RATING AND THERMAL DATA

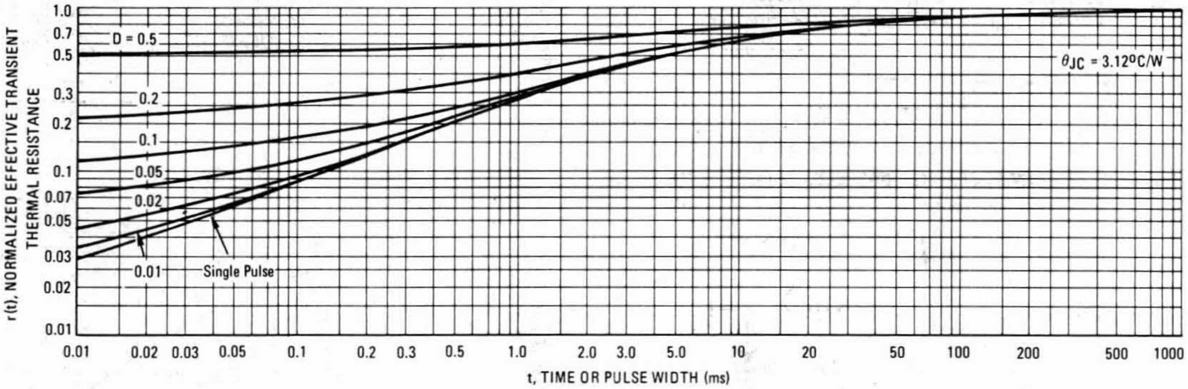
FIGURE 11 – ACTIVE-REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

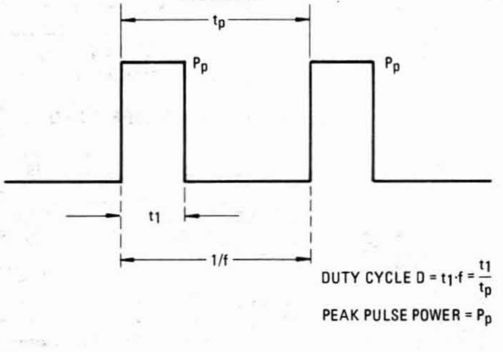
The data of Figure 11 is based on $T_{J(pk)}$ = 150°C; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 150°C$. $T_{J(pk)}$ may be calculated from the data in Figure 12. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 12 – THERMAL RESPONSE



DESIGN NOTE: USE OF TRANSIENT THERMAL RESISTANCE DATA

FIGURE A



A train of periodical power pulses can be represented by the model shown in Figure A. Using the model and the device thermal response, the normalized effective transient thermal resistance of Figure 12 was calculated for various duty cycles.

To find $\theta_{JC}(t)$, multiply the value obtained from Figure 12 by the steady state value θ_{JC}.

Example:

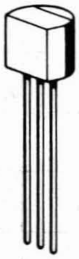
The 2N5193 is dissipating 50 watts under the following conditions: t_1 = 0.1 ms, tp = 0.5 ms. (D = 0.2).

Using Figure 12, at a pulse width of 0.1 ms and D = 0.2, the reading of $r(t_1, D)$ is 0.27.

The peak rise in junction temperature is therefore:

$$\Delta T = r(t) \times P_p \times \theta_{JC} = 0.27 \times 50 \times 3.12 = 42.2°C$$

2N5208 (SILICON)



CASE 29(2)
TO-92

PNP silicon annular amplifier transistor designed for general-purpose RF amplifier applications in the frequency range to 300 MHz.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

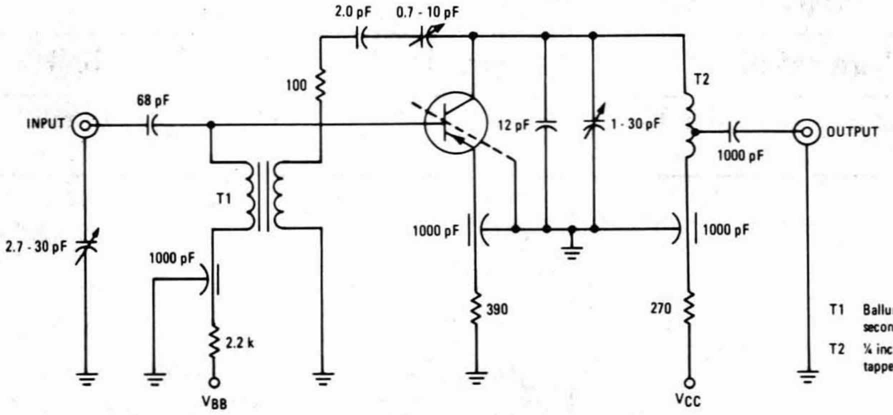
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

2N5208 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)	BV_{CEO}	25	-	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	30	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	3.0	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	10	nAdc
Emitter Cutoff Current (V_{BE} = 2.0 Vdc, I_C = 0)	I_{EBO}	-	100	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 2.0 mAdc, V_{CE} = 10 Vdc)	h_{FE}	20	120	-
Base-Emitter On Voltage (I_C = 2.0 mAdc, V_{CE} = 10 Vdc)	$V_{BE(on)}$	-	0.85	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	1200	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{cb}	-	1.0	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	-	4.0	pF
Collector-Base Time Constant (I_E = 2.0 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)	$r_b'C_c$	-	10	ps
Noise Figure (See Figure 1) (I_C = 2.0 mAdc, V_{CE} = 10 Vdc, R_S = 75 ohms, f = 100 MHz, BW = 1.0 MHz)	NF	-	3.0	dB
FUNCTIONAL TEST				
Common-Emitter Amplifier Power Gain (See Figure 1) (I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	G_{pe}	22	-	dB

FIGURE 1 - 100 MHz POWER GAIN AND NOISE FIGURE TEST CIRCUIT



T1 Ballun Core, 5 turns primary, 5 turns secondary, No. 24 bifilar wound.

T2 ¼ inch inner diameter, 5½ turns tapped up ½ turn, No. 16 buss wire.

COMMON-EMITTER Y PARAMETERS (Polar Plots)

V_{CE} = 10 Vdc, T_A = 25°C

FIGURE 2 - INPUT ADMITTANCE

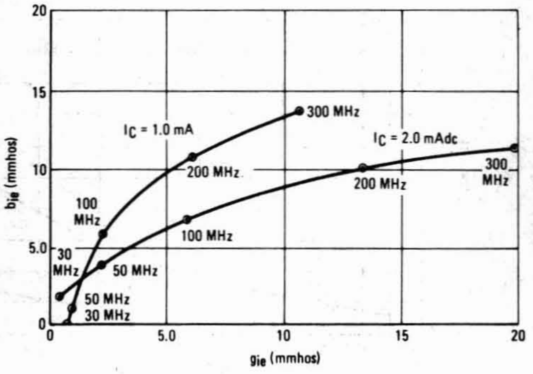


FIGURE 3 - OUTPUT ADMITTANCE

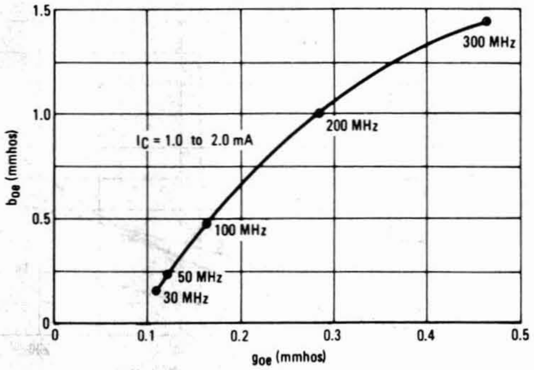


FIGURE 4 - FORWARD TRANSFER ADMITTANCE

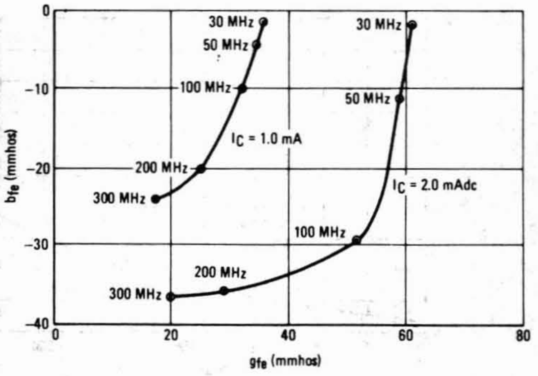
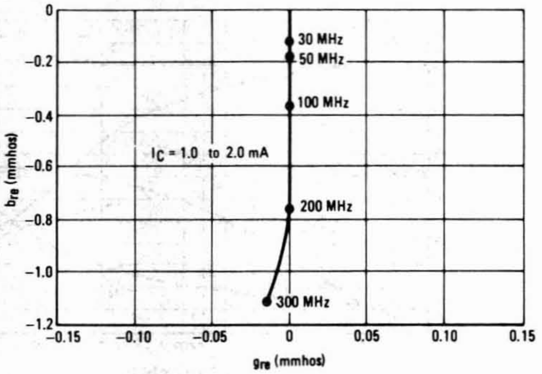


FIGURE 5 - REVERSE TRANSFER ADMITTANCE



STABILITY FACTOR CURVE

FIGURE 6 - POWER GAIN AND NOISE FIGURE

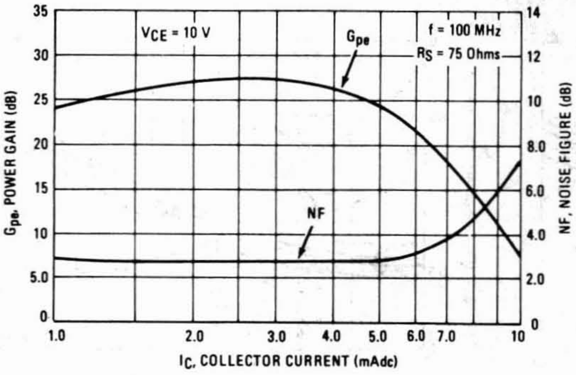
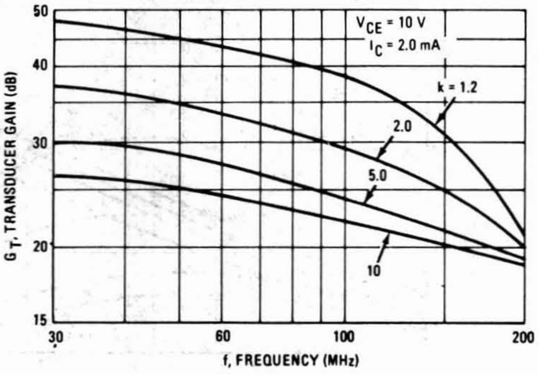


FIGURE 7 - MAXIMUM TRANSDUCER GAIN



COMMON-EMITTER Y PARAMETERS vs FREQUENCY

V_{CE} = 10 Vdc, T_A = 25°C

FIGURE 8 - INPUT ADMITTANCE

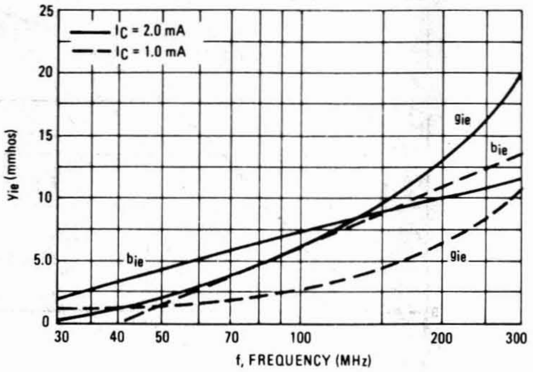


FIGURE 9 - OUTPUT ADMITTANCE

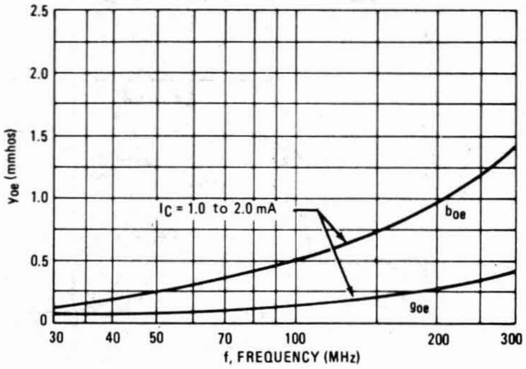


FIGURE 10 - FORWARD TRANSFER ADMITTANCE

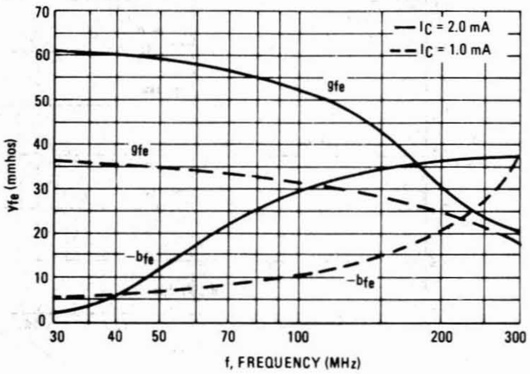
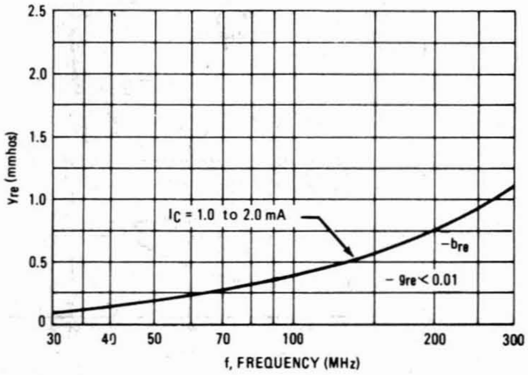


FIGURE 11 - REVERSE TRANSFER ADMITTANCE



STABILITY FACTOR CURVES

FIGURE 12 - OPTIMUM SOURCE ADMITTANCE

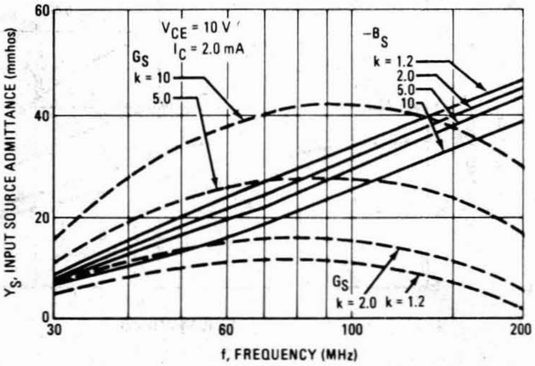
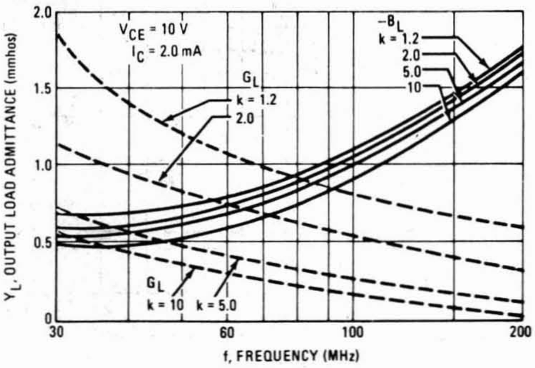


FIGURE 13 - OPTIMUM LOAD ADMITTANCE



When a potentially unstable device is operated without feedback, there is an infinite number of combinations of source and load admittance associated with any given circuit stability factor (k). Equations have been developed for determining the optimum source and load admittance for maximum gain. Figures 7, 12 and 13 provide a solution to the equations for the 2N5208.

NOISE FIGURE

FIGURE 14 - FREQUENCY EFFECTS

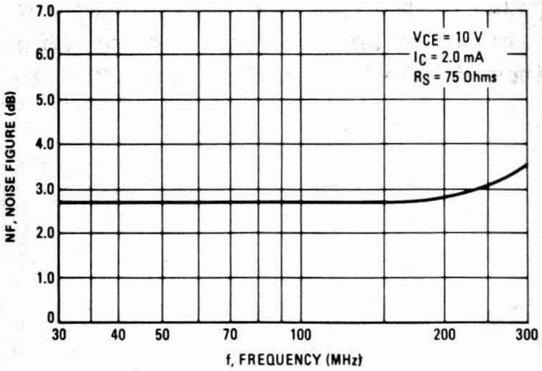


FIGURE 15 - SOURCE RESISTANCE EFFECTS

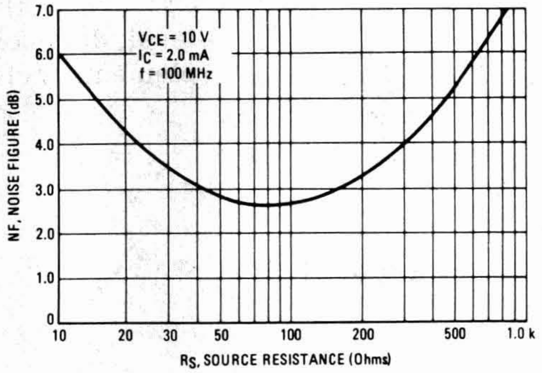


FIGURE 16 - CURRENT-GAIN — BANDWIDTH PRODUCT

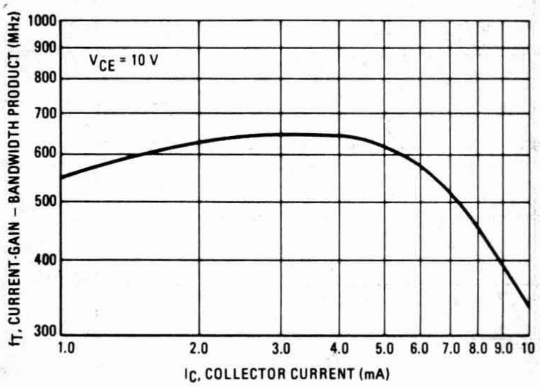


FIGURE 17 - CAPACITANCES

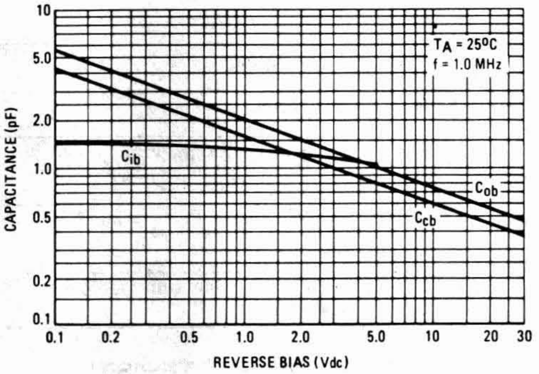
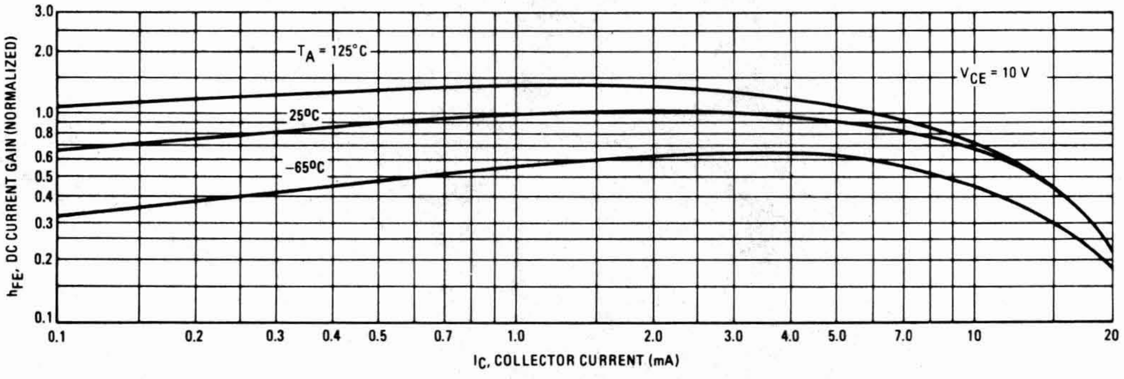
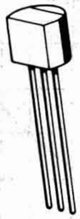


FIGURE 18 - DC CURRENT GAIN



2N5209 (SILICON)
2N5210



CASE 29(1)
(TO-92)

NPN silicon annular transistors designed for low-level, low-noise amplifier applications and for complementary circuitry with PNP types 2N5086 and 2N5087.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Vdc
Collector-Base Voltage	V_{CB}	50	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Collector Current — Continuous Peak	I_C	50 100	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Value	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

2N5209, 2N5210 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)		BV_{CEO}	50	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)		BV_{CBO}	50	-	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0) (V_{CB} = 35 Vdc, I_E = 0)		I_{CBO}	- -	- -	10 50	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0) (V_{BE} = 4.5 Vdc, I_C = 0)		I_{EBO}	- -	- -	50 100	nAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	2N5209 2N5210	h_{FE}	100 200	- -	300 600	-
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	2N5209 2N5210		150 250	- -	- -	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc)	2N5209 2N5210		150 250	- -	- -	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{CE(sat)}$	-	-	0.7	Vdc
Base-Emitter On Voltage (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		$V_{BE(on)}$	-	-	0.85	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 20 MHz)		f_T	30	80	-	MHz
Collector Base Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz) (emitter guarded)		C_{cb}	-	-	4.0	pF
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 1.0 kHz)	2N5209 2N5210	h_{fe}	150 250	- -	600 900	-
Noise Figure (I_C = 20 μAdc, V_{CE} = 5.0 Vdc, R_S = 22 k ohms, f = 10 Hz to 15.7 kHz)	2N5209 2N5210	NF	- -	- -	3.0 2.0	dB
(I_C = 20 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 1.0 kHz)	2N5209 2N5210		- -	1.6 1.4	4.0 3.0	

NOISE FIGURE
(V_{CE} = 5.0 Vdc, T_A = 25°C)

FIGURE 1 – NOISE FIGURE versus FREQUENCY

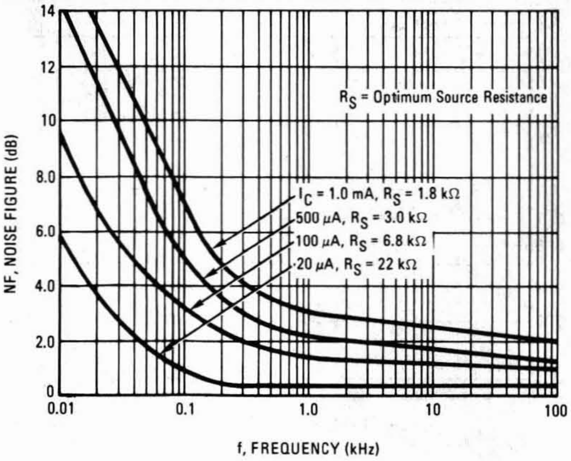
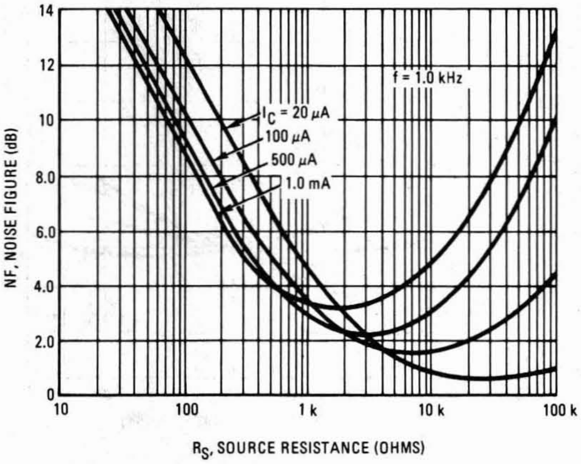


FIGURE 2 – NOISE FIGURE versus SOURCE RESISTANCE



h PARAMETERS

V_{CE} = 10 Vdc, f = 1.0 kHz, T_A = 25°C

(For Figures 3, 4, 5, 6, 8)

This group of graphs illustrates the relationship of the "h" parameters for this series of transistors. To obtain these curves, 4 units were selected and identified by number — the same units were used to develop curves on each graph.

FIGURE 3 – INPUT IMPEDANCE versus COLLECTOR CURRENT

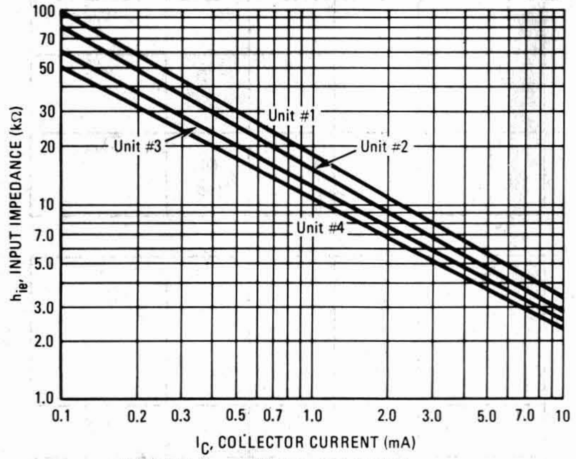


FIGURE 4 – VOLTAGE FEEDBACK RATIO versus COLLECTOR CURRENT

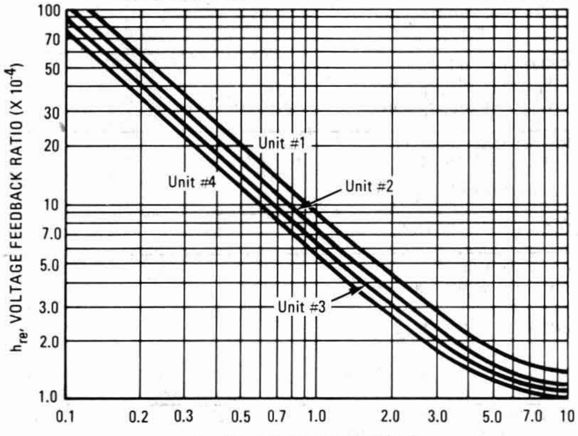


FIGURE 5 – CURRENT GAIN versus COLLECTOR CURRENT

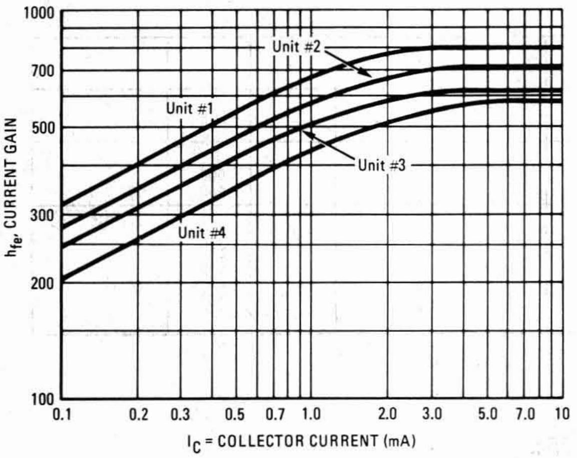


FIGURE 6 – OUTPUT ADMITTANCE versus COLLECTOR CURRENT

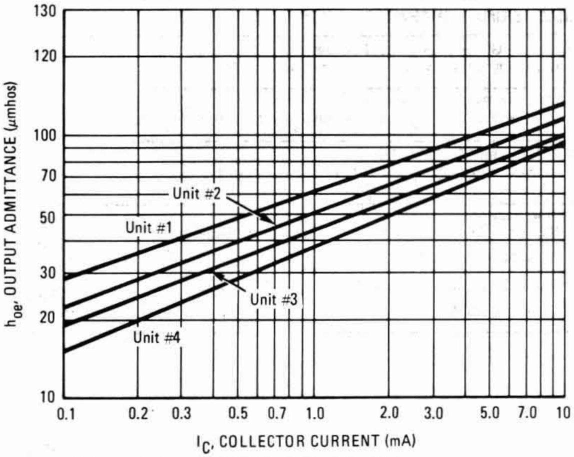


FIGURE 7 – EFFECT OF VOLTAGE

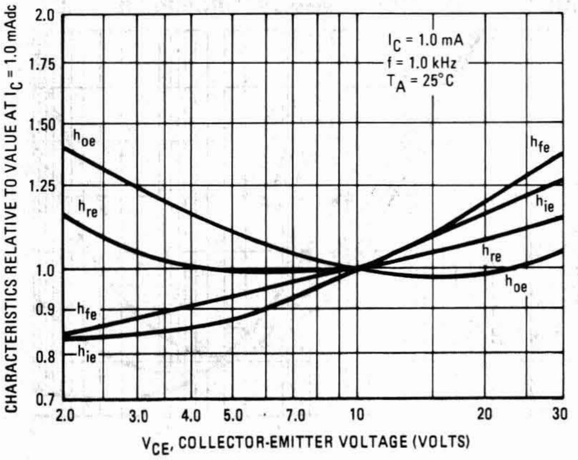
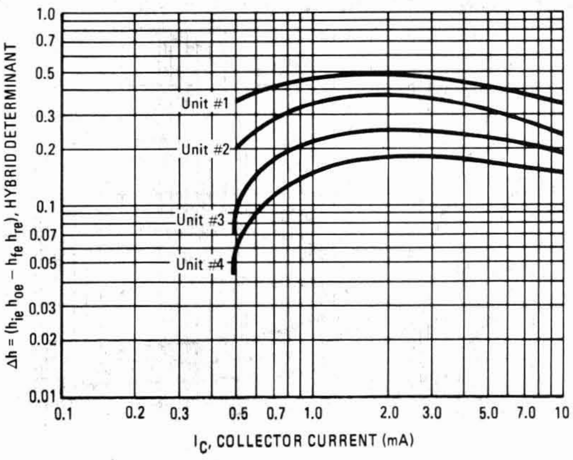


FIGURE 8 – HYBRID DETERMINANT versus COLLECTOR CURRENT



2N5209, 2N5210 (continued)

FIGURE 9 – DC CURRENT GAIN

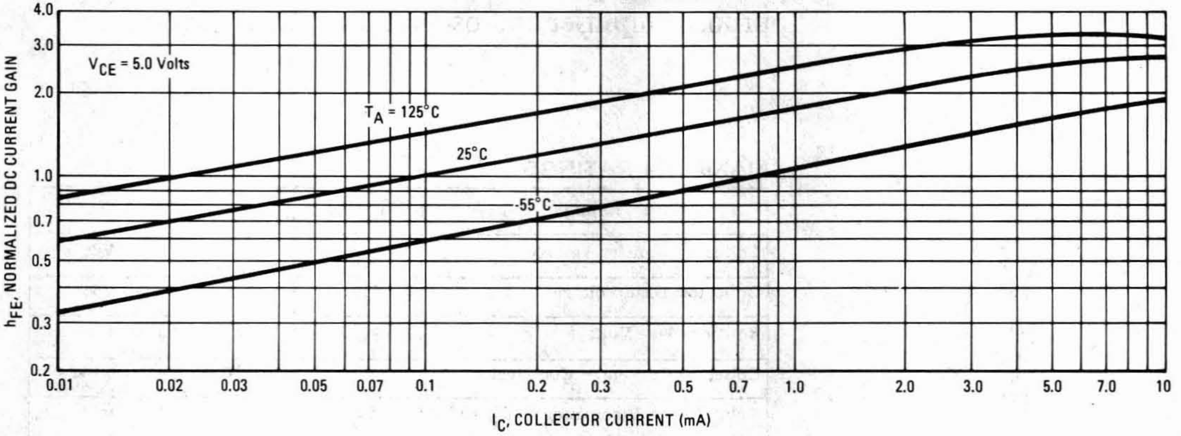


FIGURE 10 – COLLECTOR SATURATION REGION

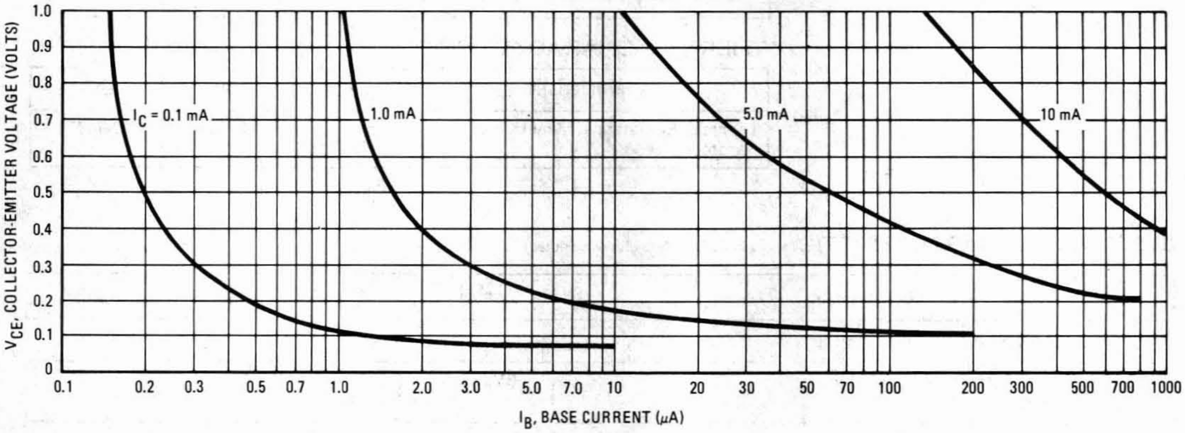


FIGURE 11 – CURRENT-GAIN – BANDWIDTH PRODUCT

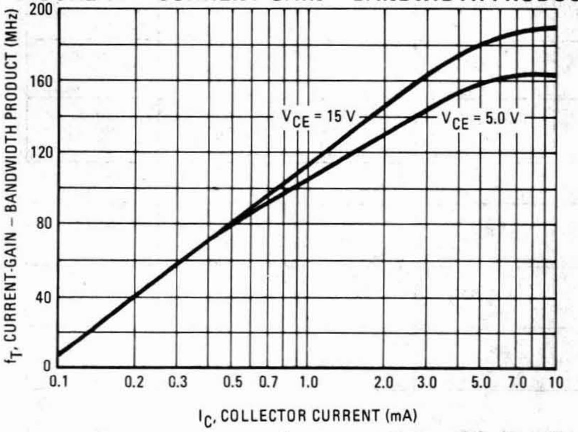
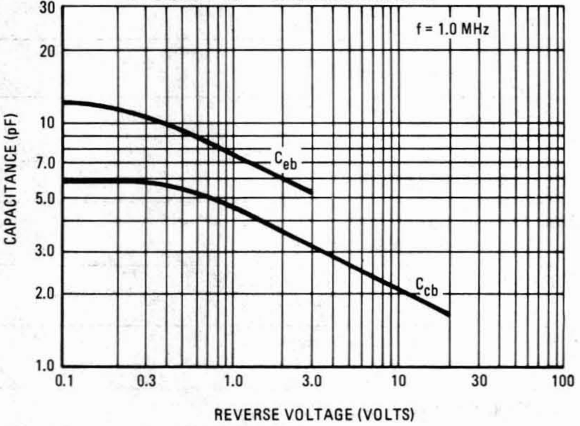
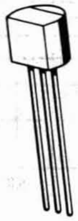


FIGURE 12 – CAPACITANCES



2N5219 (SILICON)

NPN silicon annular transistor. Plastic encapsulated package designed for low-level, small-signal, general-purpose amplifier and oscillator applications.



CASE 29(1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	20	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current — Continuous	I_C	100	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)	BV_{CEO}	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	20	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3.0	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	100	nAdc
Emitter Cutoff Current (V_{BE} = 2.0 Vdc, I_C = 0)	I_{EBO}	-	500	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 2.0 mAdc, V_{CE} = 10 Vdc)	h_{FE}	35	500	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	-	0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	-	1.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc)	f_T	150	-	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{cb}	-	4.0	pF
Small-Signal Current Gain (I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	35	1500	-

2N**5220** (SILICON)

NPN silicon annular transistor. Plastic encapsulated package designed for low-power, large-signal audio and general-purpose amplifier applications and for complementary circuitry with PNP type 2N5221.

CASE 29(1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current — Continuous	I_C	500	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	15	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3.0	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	100	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	100	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 50 mAdc, V_{CE} = 10 Vdc)	h_{FE}	 25 30	 - 600	-
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$	-	0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	-	1.1	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc)	f_T	100	-	MHz
Collector-Base Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{cb}	-	10	pF
Small-Signal Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	30	1800	-

2N5221 (SILICON)

PNP silicon annular transistor. Plastic encapsulated package designed for low-power, large-signal audio and general-purpose amplifier applications, and for complementary circuitry with NPN type 2N5220.

CASE 29(1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 10$ mAdc, $I_B = 0$)	BV_{CEO}	15	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 100\ \mu$Adc, $I_E = 0$)	BV_{CBO}	15	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu$Adc, $I_C = 0$)	BV_{EBO}	3.0	-	Vdc
Collector Cutoff Current ($V_{CB} = 10$ Vdc, $I_E = 0$)	I_{CBO}	-	100	nAdc
Emitter Cutoff Current ($V_{BE} = 3.0$ Vdc, $I_C = 0$)	I_{EBO}	-	100	nAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 10$ mAdc, $V_{CE} = 10$ Vdc) ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc)	h_{FE}	 25 30	 - 600	-
Collector-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{CE(sat)}$	-	0.5	Vdc
Base-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{BE(sat)}$	-	1.1	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain-Bandwidth Product ($I_C = 20$ mAdc, $V_{CE} = 10$ Vdc)	f_T	100	-	MHz
Collector-Base Capacitance ($V_{CB} = 5.0$ Vdc, $I_E = 0$, f = 1.0 MHz)	C_{cb}	-	15	pF
Small-Signal Current Gain ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)	h_{fe}	30	1800	-

2N5222 (SILICON)

NPN silicon annular transistor. Plastic encapsulated package designed for RF amplifier, mixer, and video IF applications in AM/FM radio and television receivers.

CASE 29(2)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	20	Vdc
Emitter-Base Voltage	V_{EB}	2.0	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

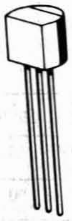
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)	BV_{CEO}	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	20	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	2.0	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	100	nAdc
Emitter Cutoff Current (V_{BE} = 2.0 Vdc, I_C = 0)	I_{EBO}	-	100	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 4.0 mAdc, V_{CE} = 10 Vdc)	h_{FE}	20	1500	-
Collector-Emitter Saturation Voltage (I_C = 4.0 mAdc, I_B = 400 μAdc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Saturation Voltage (I_C = 4.0 mAdc, I_B = 400 μAdc)	$V_{BE(sat)}$	-	1.2	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 4.0 mAdc, V_{CE} = 10 Vdc	f_T	450	-	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{cb}	-	1.3	pF
Small-Signal Current Gain (I_C = 4.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	20	3000	-

2N5223 (SILICON)

NPN silicon annular transistor. Plastic encapsulated package designed for low-level, small-signal, general-purpose amplifier and oscillator applications.



CASE 29(1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	100	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 1.0$ mAdc, $I_B = 0$)	BV_{CEO}	20	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 100\ \mu$Adc, $I_E = 0$)	BV_{CBO}	25	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu$Adc, $I_C = 0$)	BV_{EBO}	3.0	-	Vdc
Collector Cutoff Current ($V_{CB} = 10$ Vdc, $I_E = 0$)	I_{CBO}	-	100	nAdc
Emitter Cutoff Current ($V_{BE} = 3.0$ Vdc, $I_C = 0$)	I_{EBO}	-	500	nAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 2.0$ mAdc, $V_{CE} = 10$ Vdc)	h_{FE}	50	800	-
Collector-Emitter Saturation Voltage ($I_C = 10$ mAdc, $I_B = 1.0$ mAdc)	$V_{CE(sat)}$	-	0.7	Vdc
Base-Emitter Saturation Voltage ($I_C = 10$ mAdc, $I_B = 1.0$ mAdc)	$V_{BE(sat)}$	-	1.2	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product ($I_C = 10$ mAdc, $V_{CE} = 10$ Vdc)	f_T	150	-	MHz
Collector-Base Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 1.0 MHz)	C_{cb}	-	4.0	pF
Small-Signal Current Gain ($I_C = 2.0$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)	h_{fe}	50	1600	-

2N5224 (SILICON)

NPN silicon annular transistor. Plastic encapsulated package designed for general-purpose, low-level switching applications.

CASE 29(1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

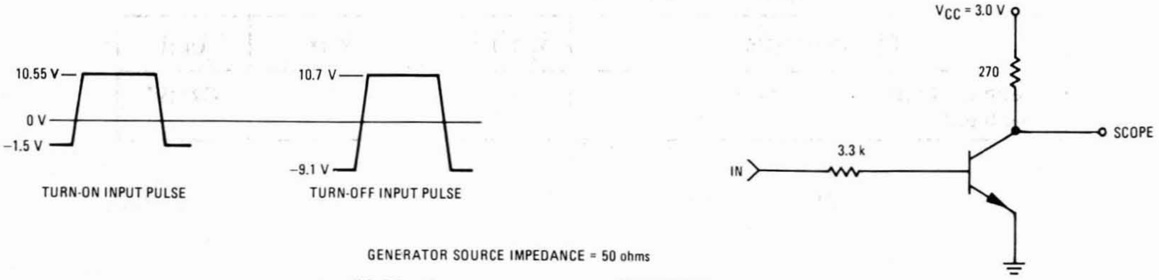
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	12	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	25	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)	I_{CBO}	-	500	nAdc
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	100	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	 40 15	 400 -	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 3.0 mAdc)	$V_{CE(sat)}$	-	0.35	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 3.0 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250	-	MHz
Collector-Base Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{cb}	-	4.0	pF
SWITCHING CHARACTERISTICS				
Delay Time (See Figure 1)	t_d	-	25	ns
Rise Time (See Figure 1)	t_r	-	20	ns
Storage Time (See Figure 1)	t_s	-	35	ns
Fall Time (See Figure 1)	t_f	-	25	ns

*Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2.0%.

FIGURE 1 – SWITCHING TIME TEST CIRCUIT



GENERATOR SOURCE IMPEDANCE = 50 ohms

INPUT PULSE:
RISE TIME ≤ 2.0 ns
FALL TIME ≤ 2.0 ns
NOMINAL PULSEWIDTH = 300 ns
NOMINAL DUTY CYCLE = 2.0%

OSCILLOSCOPE:
RISE TIME ≤ 0.4 ns
INPUT RESISTANCE ≥ 50 ohms
INPUT CAPACITANCE ≤ 4.0 pF

2N5225 (SILICON)

NPN silicon annular transistor. Plastic encapsulated package designed for medium-current amplifier applications and for complementary circuitry with PNP type 2N5226.

CASE 29(1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	25	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	25	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4.0	-	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)	I_{CBO}	-	300	nAdc
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	500	nAdc
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			-
(I_C = 10 mAdc, V_{CE} = 10 Vdc)		25	-	
(I_C = 50 mAdc, V_{CE} = 10 Vdc)		30	600	
Collector-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{CE(sat)}$	-	0.8	Vdc
Base-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{BE(sat)}$	-	1.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc)	f_T	50	-	MHz
Collector-Base Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{cb}	-	20	pF
Small-Signal Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	30	1800	-

2N5226 (SILICON)

PNP silicon annular transistor. Plastic encapsulated package designed for medium-current, amplifier applications and for complementary circuitry with NPN type 2N5225.

CASE 29(1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 10$ mAdc, $I_B = 0$)	BV_{CEO}	25	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 100\ \mu$Adc, $I_E = 0$)	BV_{CBO}	25	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100\ \mu$Adc, $I_C = 0$)	BV_{EBO}	4.0	-	Vdc
Collector Cutoff Current ($V_{CB} = 15$ Vdc, $I_E = 0$)	I_{CBO}	-	300	nAdc
Emitter Cutoff Current ($V_{BE} = 4.0$ Vdc, $I_C = 0$)	I_{EBO}	-	500	nAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 10$ mAdc, $V_{CE} = 10$ Vdc) ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc)	h_{FE}	 25 30	 - 600	-
Collector-Emitter Saturation Voltage ($I_C = 100$ mAdc, $I_B = 10$ mAdc)	$V_{CE(sat)}$	-	0.8	Vdc
Base-Emitter Saturation Voltage ($I_C = 100$ mAdc, $I_B = 10$ mAdc)	$V_{BE(sat)}$	-	1.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product ($I_C = 20$ mAdc, $V_{CE} = 10$ Vdc)	f_T	50	-	MHz
Collector-Base Capacitance ($V_{CB} = 5.0$ Vdc, $I_E = 0$, f = 1.0 MHz)	C_{cb}	-	20	pF
Small-Signal Current Gain ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 kHz)	h_{fe}	30	1800	-

2N5227 (SILICON)

PNP silicon annular transistor. Plastic encapsulated package designed for low-level, small-signal general-purpose amplifier and oscillator applications.

CASE 29(1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)	BV_{CEO}	30	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	30	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3.0	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	100	nAdc
Emitter Cutoff Current (V_{BE} = 2.0 Vdc, I_C = 0)	I_{EBO}	-	500	nAdc
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			-
(I_C = 100 μAdc, V_{CE} = 10 Vdc)		30	-	
(I_C = 2.0 mAdc, V_{CE} = 10 Vdc)		50	700	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	-	0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	-	1.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain-Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc)	f_T	100	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)	C_{cb}	-	5.0	pF
Small-Signal Current Gain (I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	50	1500	-

2N5228 (SILICON)

CASE 29(1)
(TO-92)

PNP silicon annular transistor. Plastic encapsulated package designed for general-purpose, low level switching applications.

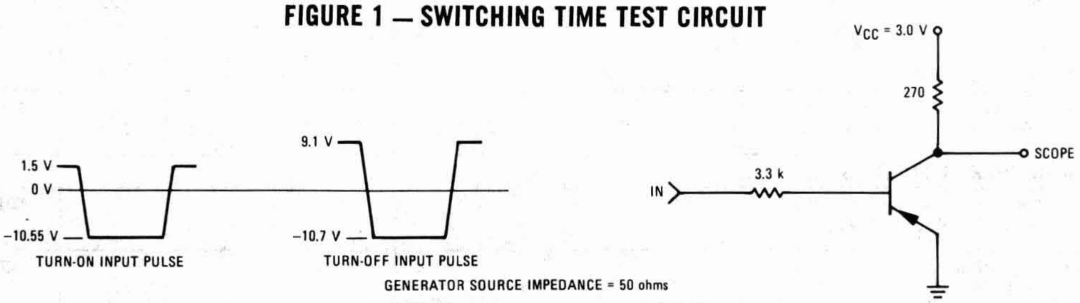
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	5.0	Vdc
Collector-Emitter Voltage	V_{CES}	6.0	Vdc
Collector-Base Voltage	V_{CB}	5.0	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

FIGURE 1 — SWITCHING TIME TEST CIRCUIT



GENERATOR SOURCE IMPEDANCE = 50 ohms

INPUT PULSE:
- RISE TIME ≤ 2.0 ns
- FALL TIME ≤ 2.0 ns
- NOMINAL PULSEWIDTH = 300 ns
- NOMINAL DUTY CYCLE = 2.0%

OSCILLOSCOPE:
- RISE TIME ≤ 0.4 ns
- INPUT RESISTANCE ≥ 50 ohms
- INPUT CAPACITANCE ≤ 4.0 pF

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	5.0	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	6.0	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	5.0	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3.0	-	Vdc
Collector Cutoff Current (V_{CE} = 4.0 Vdc, V_{BE} = 0)	I_{CES}	-	100	nAdc
Emitter Cutoff Current (V_{BE} = 2.5 Vdc, I_C = 0)	I_{EBO}	-	100	μAdc
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			-
(I_C = 10 mAdc, V_{CE} = 0.3 Vdc)		30	-	
(I_C = 50 mAdc, V_{CE} = 1.0 Vdc)		15	-	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 3.0 mAdc)	$V_{CE(sat)}$	-	0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 3.0 mAdc)	$V_{BE(sat)}$	0.65	1.25	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 10 mAdc, V_{CE} = 5.0 Vdc, f = 100 MHz)	f_T	300	-	MHz
Collector-Base Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{cb}	-	5.0	pF
SWITCHING CHARACTERISTICS				
Delay Time (See Figure 1)	t_d	-	25	ns
Rise Time (See Figure 1)	t_r	-	50	ns
Storage Time (See Figure 1)	t_s	-	90	ns
Fall Time (See Figure 1)	t_f	-	50	ns

2N5265
thru
2N5270

P-Channel junction depletion mode (Type A) field-effect transistors designed for general-purpose amplifier applications.

CASE 20(5)
(TO-72)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	60	Vdc
Drain-Gate Voltage	V_{DG}	60	Vdc
Reverse Gate-Source Voltage	$V_{GS(r)}$	60	Vdc
Drain Current	I_D	20	mAdc
Gate Current-forward	$I_{G(f)}$	10	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 2.0	mW mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Operating Junction Temperature Range	T_J	-65 to +175	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	60	-	Vdc
Gate-Source Cutoff Voltage (V_{DS} = 15 Vdc, I_D = 1.0 μAdc) 2N5265, 2N5266	$V_{GS(off)}$	-	3.0	Vdc
2N5267, 2N5268		-	6.0	
2N5269, 2N5270		-	8.0	
Gate Reverse Current (V_{GS} = 30 Vdc, V_{DS} = 0)	I_{GSS}	-	2.0	nAdc
(V_{GS} = 30 Vdc, V_{DS} = 0, T_A = 150°C)		-	2.0	μAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current (V_{DS} = 15 Vdc, V_{GS} = 0) 2N5265	I_{DSS}	0.5	1.0	mAdc
2N5266		0.8	1.6	
2N5267		1.5	3.0	
2N5268		2.5	5.0	
2N5269		4.0	8.0	
2N5270		7.0	14	
Gate-Source Voltage (V_{DS} = 15 Vdc, I_D = 0.05 mAdc) 2N5265	V_{GS}	0.3	1.5	Vdc
(V_{DS} = 15 Vdc, I_D = 0.08 mAdc) 2N5266		0.4	2.0	
(V_{DS} = 15 Vdc, I_D = 0.15 mAdc) 2N5267		1.0	4.0	
(V_{DS} = 15 Vdc, I_D = 0.25 mAdc) 2N5268		1.0	4.0	
(V_{DS} = 15 Vdc, I_D = 0.4 mAdc) 2N5269		2.0	6.0	
(V_{DS} = 15 Vdc, I_D = 0.7 mAdc) 2N5270		2.0	6.0	
SMALL-SIGNAL CHARACTERISTICS				
Forward Transadmittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz) 2N5265	$\|y_{fs}\|$	900	2700	μmhos
2N5266		1000	3000	
2N5267		1500	3500	
2N5268		2000	4000	
2N5269		2200	4500	
2N5270		2500	5000	
Forward Transconductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz) 2N5265	$Re(y_{fs})$	800	-	μmhos
2N5266		900	-	
2N5267		1400	-	
2N5268		1700	-	
2N5269		1900	-	
2N5270		2100	-	
Output Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	$\|y_{os}\|$	-	75	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	-	7.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	-	2.0	pF
Common-Source Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_G = 1.0 M ohm, f = 100 Hz, BW = 1.0 Hz)	NF	-	2.5	dB
Equivalent Short-Circuit Input Noise Voltage (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 Hz, BW = 1.0 Hz)	e_n	-	115	nV/$\sqrt{Hz}$

FIGURE 1–6 TRANSFER CHARACTERISTIC CURVES
FOR MIN/MAX I_{DSS} LIMITS

FIGURE 1

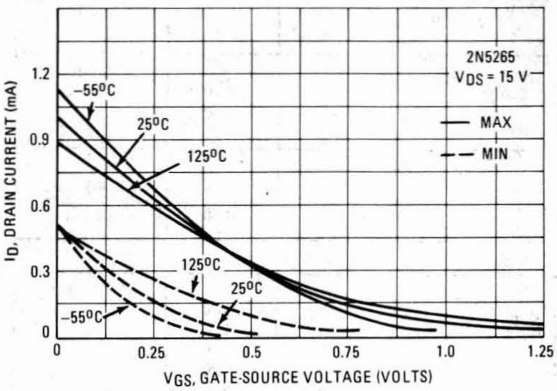


FIGURE 2

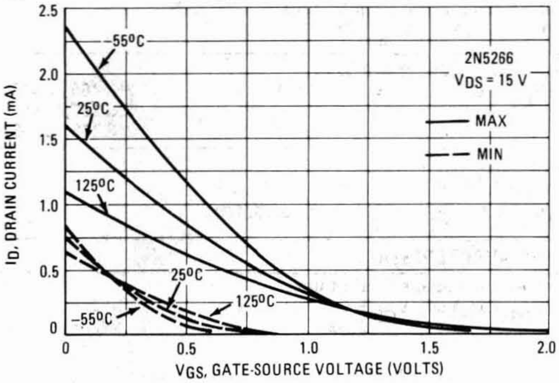


FIGURE 3

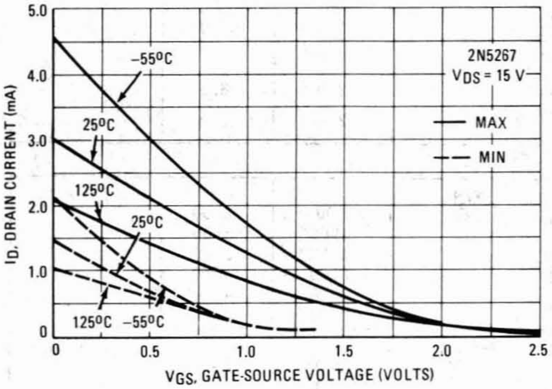


FIGURE 4

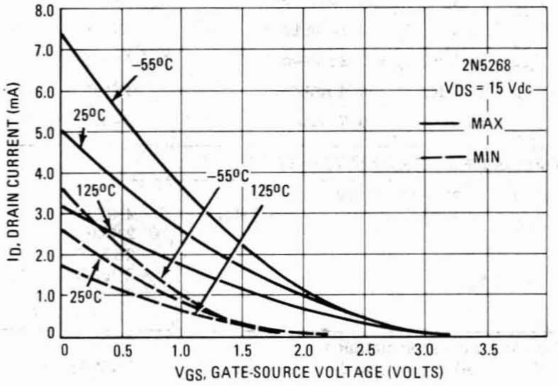


FIGURE 5

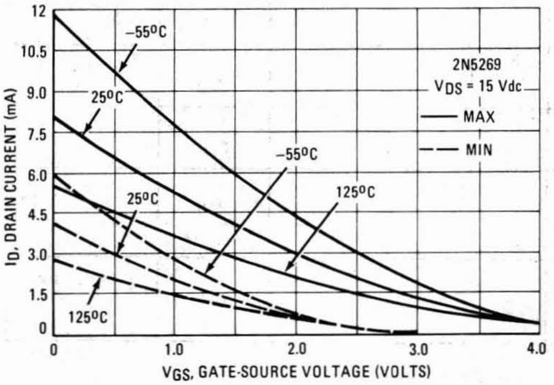
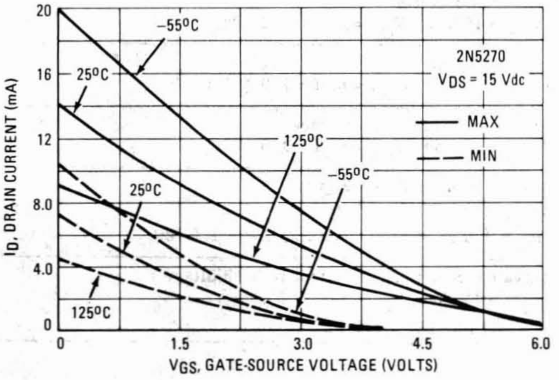


FIGURE 6



FIGURES 7-12 – TYPICAL AND MINIMUM FORWARD TRANSFER ADMITTANCE

FIGURE 7

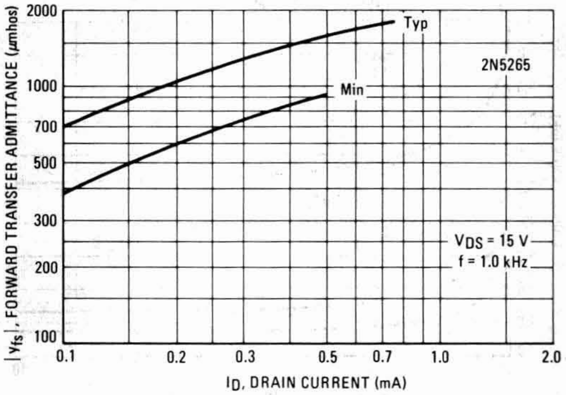


FIGURE 8

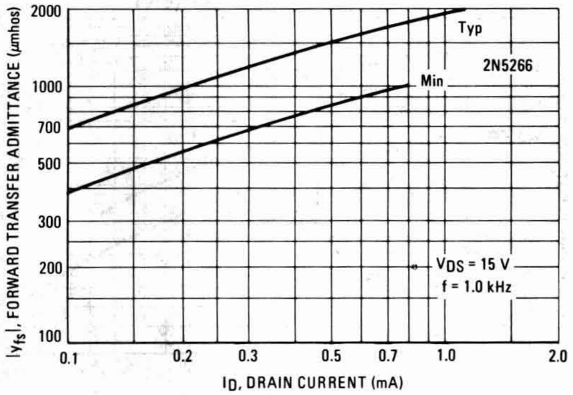


FIGURE 9

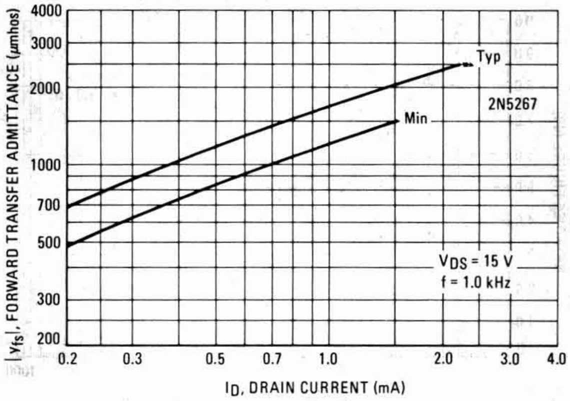


FIGURE 10

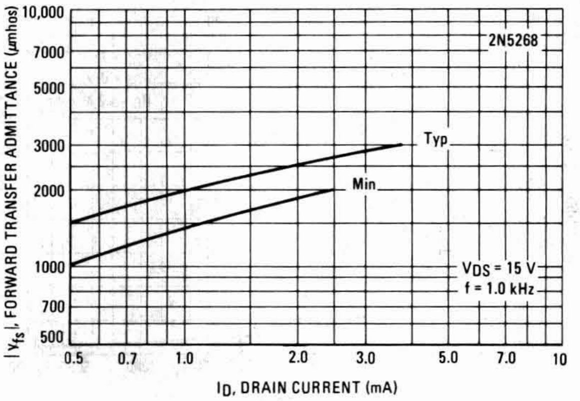


FIGURE 11

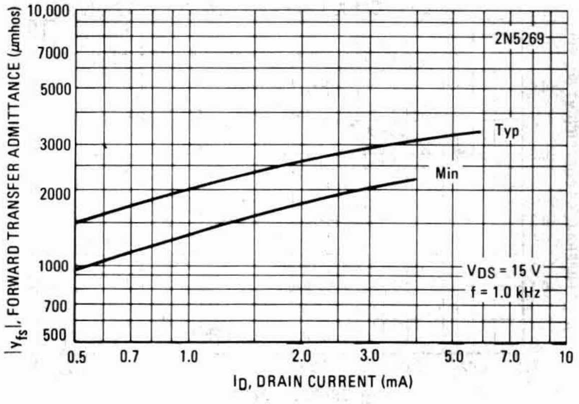
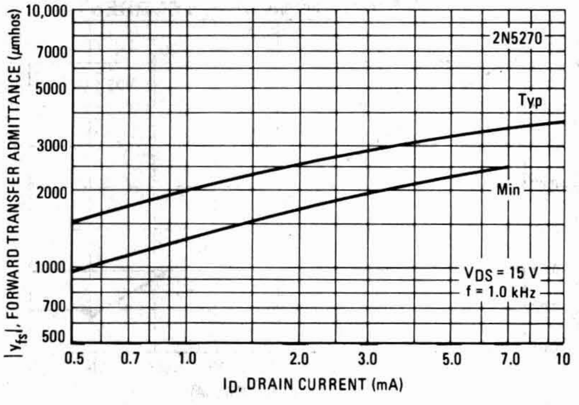


FIGURE 12



TYPICAL CURVES

FIGURE 13 – OUTPUT RESISTANCE versus DRAIN CURRENT

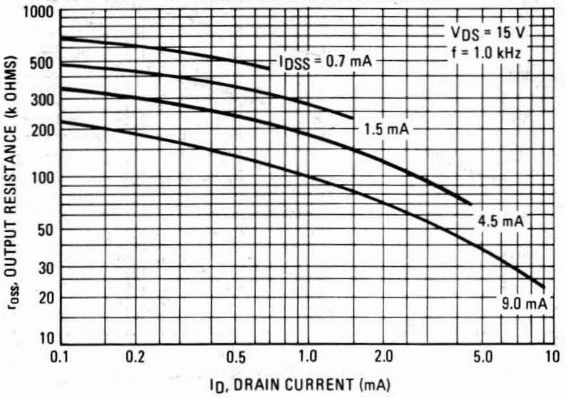


FIGURE 14 – CAPACITANCE versus DRAIN-SOURCE VOLTAGE

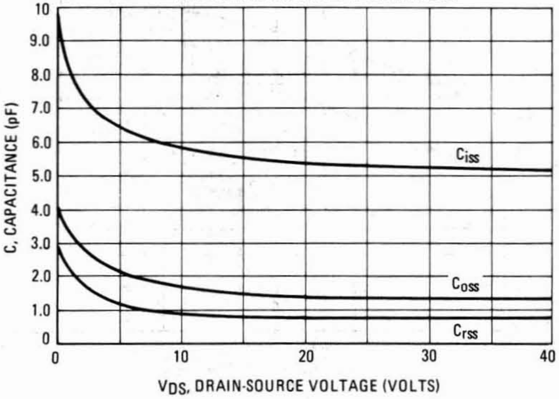


FIGURE 15 – NOISE FIGURE versus FREQUENCY

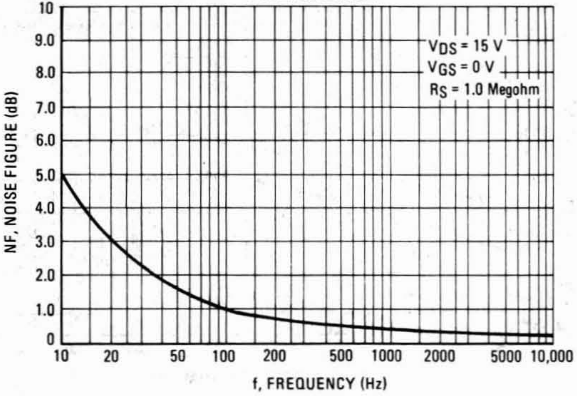


FIGURE 16 – NOISE FIGURE versus SOURCE RESISTANCE

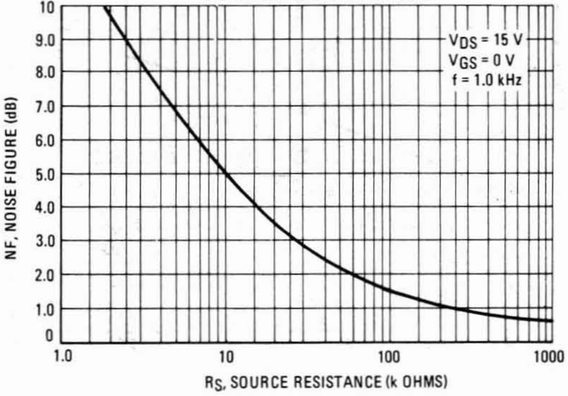


FIGURE 17 – DRAIN CURRENT TEMPERATURE COEFFICIENT versus DRAIN CURRENT

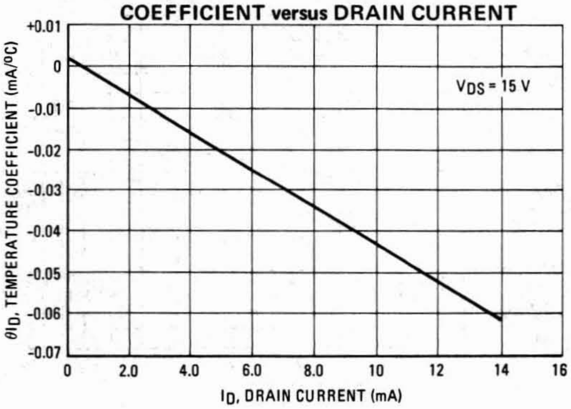


FIGURE 18 – FORWARD TRANSADMITTANCE COEFFICIENT versus DRAIN CURRENT

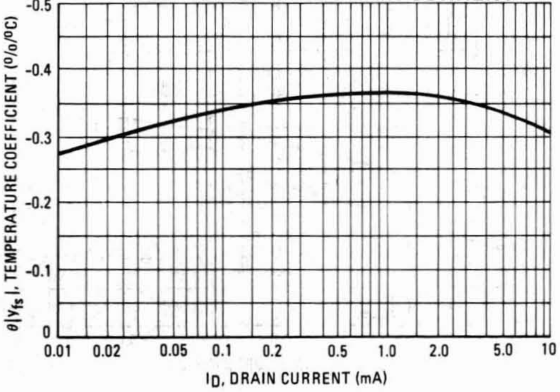
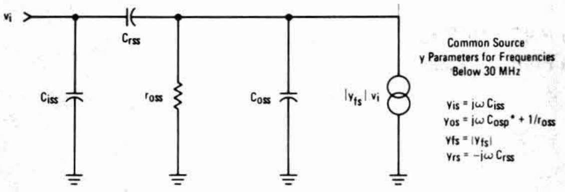


FIGURE 19 – EQUIVALENT LOW FREQUENCY CIRCUIT



Common Source
y Parameters for Frequencies
Below 30 MHz

$y_{is} = j\omega C_{iss}$
$y_{os} = j\omega C_{osp}{}^{*} + 1/r_{oss}$
$y_{fs} = |y_{fs}|$
$y_{rs} = -j\omega C_{rss}$

*C_{osp} is C_{oss} in parallel with Series Combination of C_{iss} and C_{rss}.

BIAS NETWORK DESIGN FOR WORST CASE I_{DSS} VARIANCE

This Designers Data Sheet has been published to assist the circuit designer in optimizing his "worst case" design. The following example illustrates the use of the forward transfer characteristics curves (Pigures 1 thru 6) in the design of a typical bias network.

Given: V_{DD} = -30 Vdc, I_D = 1.0 ± 0.25 mAdc from -55°C to +125°C

Procedure: The 2N5268 "worst case" bias conditions across the temperature range (from Figure 4) are reproduced in Figure A. The first step in the bias network design is to determine the value of the source resistance (R_S) necessary to hold the ± 0.25 mAdc I_D bias tolerance. To solve R_S, plot $I_{D(max)}$ and $I_{D(min)}$ on Figure A and calculate R_S, and V_G.

$$R_S = \frac{V_{GS(max)} - V_{GS(min)}}{I_{D(max)} - I_{D(min)}} = \frac{1.9\ \text{Vdc} - 0.8\ \text{Vdc}}{(1.25\ \text{mA} - 0.75\ \text{mA})} = 2.2\ \text{k Ohms}$$

$$V_G = \frac{I_{D(max)}\, V_{GS(min)} - I_{D(min)}\, V_{GS(max)}}{I_{D(max)} - I_{D(min)}}$$

$$= \frac{1.25 \times 0.80 - 0.75 \times 1.9}{0.5} = -0.9\ \text{Vdc}$$

In Figure B the maximum allowable value for R_1 will be determined by loading due to gate reverse current. Gate reverse current variations with temperature follow the pattern of all silicon devices, and, as a rule, we can assume that it will double with each 15°C temperature rise. Therefore, we can assume a maximum reverse current of approximately 0.5 μAdc at 125°C, based on the specified maximum 2.0 μAdc reverse at 150°C. The variation in V_G bias versus temperature will not be too great if we chose a value for R_1 which results in a bias network current (I_1 in Figure B) greater than 5 times the maximum reverse current. Assuming a value for R_1 of 9.1 Megohms, R_2 can be solved from the equation:

$$V_G = -0.9\ \text{Vdc} \approx \frac{-30\ R_2}{9.1 + R_2}\ (\text{Ignoring } I_G)$$

$$R_2 \approx 300\ \text{k Ohms}$$

Using the above values of R_1 and R_2, the variation in V_G can be computed for I_G = 0 to I_G = 0.5 μAdc. V_G will vary from 0.81 Vdc at I_G = 0.5 μAdc to 0.96 Vdc @ I_G = 0. This variation will have a minimal effect on I_D, as can be seen from Figure A by plotting load lines with a slope equal to $1/R_S$ from V_G = 0.81 Vdc and 0.96 Vdc respectively.

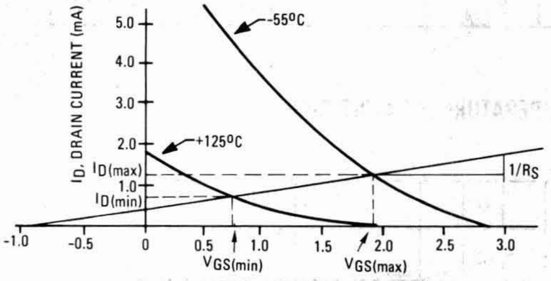


FIGURE A

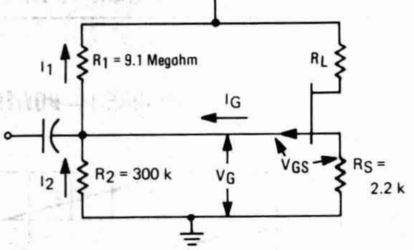
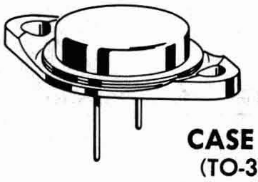


FIGURE B

2N5301 (SILICON)
2N5302
2N5303

High-power NPN silicon transistors for use in power amplifier and switching circuits applications.

2N5301 complement to PNP 2N4398.
2N5302 complement to PNP 2N4399.



CASE 3
(TO-3)

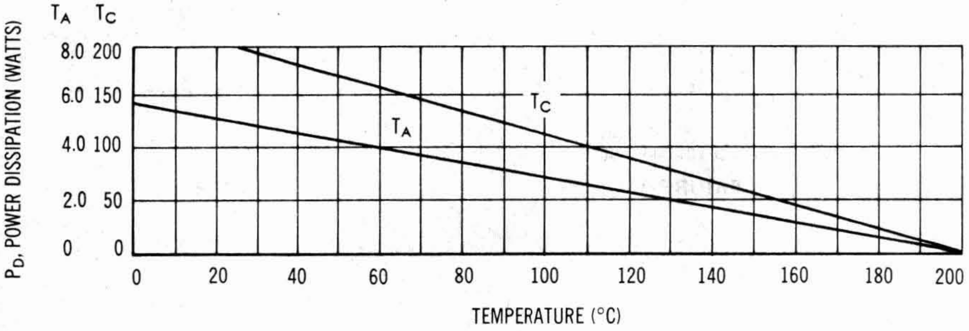
MAXIMUM RATINGS

Rating	Symbol	2N5301	2N5302	2N5303	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	40	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 5.0 →			Vdc
Collector Current - Continuous	I_C	← 30 →			Adc
Base Current	I_B	← 7.5 →			Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	200 1.14			Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.875	°C/W
Thermal Resistance, Case to Ambient	θ_{CA}	34	°C/W

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



2N5301, 2N5302, 2N5303 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Sustaining Voltage*		$BV_{CEO(sus)}$*			Vdc
(I_C = 200 mAdc, I_B = 0)	2N5301		40	-	
	2N5302		60	-	
	2N5303		80	-	
Collector Cutoff Current		I_{CEO}			mAdc
(V_{CE} = 40 Vdc, I_B = 0)	2N5301		-	5.0	
(V_{CE} = 60 Vdc, I_B = 0)	2N5302		-	5.0	
(V_{CE} = 80 Vdc, I_B = 0)	2N5303		-	5.0	
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 40 Vdc, V_{BE} = 1.5 Vdc)	2N5301		-	1.0	
(V_{CE} = 60 Vdc, V_{BE} = 1.5 Vdc)	2N5302		-	1.0	
(V_{CE} = 80 Vdc, V_{BE} = 1.5 Vdc)	2N5303		-	1.0	
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 40 Vdc, V_{EB} = 1.5 Vdc, T_C = 150°C)	2N5301		-	10	
(V_{CE} = 60 Vdc, V_{EB} = 1.5 Vdc, T_C = 150°C)	2N5302		-	10	
(V_{CE} = 80 Vdc, V_{EB} = 1.5 Vdc, T_C = 150°C)	2N5303		-	10	
Collector Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 40 Vdc, I_E = 0)	2N5301		-	1.0	
(V_{CB} = 60 Vdc, I_E = 0)	2N5302		-	1.0	
(V_{CB} = 80 Vdc, I_E = 0)	2N5303		-	1.0	
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		I_{EBO}	-	5.0	mAdc

ON CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
DC Current Gain*		h_{FE}*			-
(I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)			40	-	
(I_C = 10 Adc, V_{CE} = 4.0 Vdc)	2N5303		15	60	
(I_C = 15 Adc, V_{CE} = 2.0 Vdc)	2N5301, 2N5302		15	60	
(I_C = 20 Adc, V_{CE} = 4.0 Vdc)	2N5303		5.0	-	
(I_C = 30 Adc, V_{CE} = 4.0 Vdc)	2N5301, 2N5302		5.0	-	
Collector-Emitter Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 10 Adc, I_B = 1.0 Adc)	2N5301, 2N5302		-	0.75	
(I_C = 10 Adc, I_B = 1.0 Adc)	2N5303		-	1.0	
(I_C = 15 Adc, I_B = 1.5 Adc)	2N5303		-	1.5	
(I_C = 20 Adc, I_B = 2.0 Adc)	2N5301, 2N5302		-	2.0	
(I_C = 20 Adc, I_B = 4.0 Adc)	2N5303		-	2.0	
(I_C = 30 Adc, I_B = 6.0 Adc)	2N5301, 2N5302		-	3.0	
Base-Emitter Saturation Voltage*		$V_{BE(sat)}$*			Vdc
(I_C = 10 Adc, I_B = 1.0 Adc)			-	1.7	
(I_C = 15 Adc, I_B = 1.5 Adc)	2N5301, 2N5302		-	1.8	
(I_C = 15 Adc, I_B = 1.5 Adc)	2N5303		-	2.0	
(I_C = 20 Adc, I_B = 2.0 Adc)	2N5301, 2N5302		-	2.5	
(I_C = 20 Adc, I_B = 4.0 Adc)	2N5303		-	2.5	
Base-Emitter On Voltage*		$V_{BE(on)}$*			Vdc
(I_C = 10 Adc, V_{CE} = 2.0 Vdc)	2N5303		-	1.5	
(I_C = 15 Adc, V_{CE} = 2.0 Vdc)	2N5301, 2N5302		-	1.7	
(I_C = 20 Adc, V_{CE} = 4.0 Vdc)	2N5303		-	2.5	
(I_C = 30 Adc, V_{CE} = 4.0 Vdc)	2N5301, 2N5302		-	3.0	

DYNAMIC CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Current-Gain–Bandwidth Product (I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 MHz)	f_T	2.0	-	MHz
Small-Signal Current Gain (I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	40	-	-

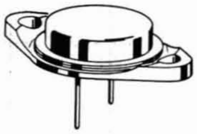
SWITCHING CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Rise Time	(V_{CC} = 30 Vdc, I_C = 10 Adc, I_{B1} = I_{B2} = 1.0 Adc)	t_r	-	1.0	μs
Storage Time		t_s	-	2.0	μs
Fall Time		t_f	-	1.0	μs

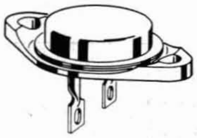
*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N5324 (GERMANIUM)
2N5325

PNP germanium power transistors designed primarily for switching, inverter, TV deflection and industrial power supply applications.



CASE 11
(TO-3)



CASE 4-04
(TO-41)

For units with solder lugs attached, specify devices MP5324 or MP5325. (TO-41 package)

MAXIMUM RATINGS

Rating	Symbol	2N5324	2N5325	Unit
Collector-Emitter Voltage	V_{CEO}	150	200	Vdc
Collector-Base Voltage	V_{CB}	250	325	Vdc
Emitter-Base Voltage	V_{EB}	4.0		Vdc
Collector Current - Continuous	I_C	10		Adc
Base Current - Continuous	I_B	3.0		Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	56 0.67		Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110		°C

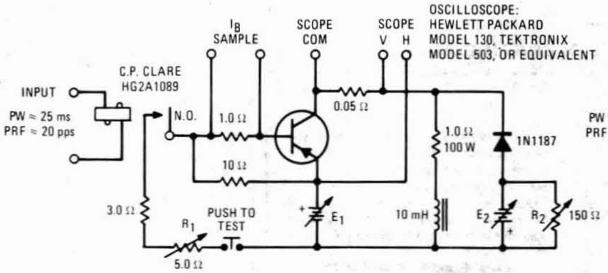
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.5	°C/W

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 0.1 Adc, I_B = 0)	2N5324 2N5325	BV_{CEO}	150 200	- -	Vdc
Collector-Emitter Sustaining Voltage (I_C = 3.0 Adc, R_{BE} = 10 Ohms) (Figure 1, Test Condition 1)	2N5324 2N5325	$V_{CER(sus)}$	165 200	- -	Vdc
(I_C = 10 Adc, R_{BE} = 10 Ohms) (Figure 1, Test Condition 2)	2N5324 2N5325		100 115	- -	
Collector Cutoff Current (V_{CEX} = 250 Vdc, V_{BE} = 0.2 Vdc)	2N5324	I_{CEX}	-	7.0	mAdc
(V_{CEX} = 250 Vdc, V_{BE} = 0.2 Vdc, T_C = 85°C)			-	35	
(V_{CEX} = 325 Vdc, V_{BE} = 0.2 Vdc)	2N5325		-	7.0	
(V_{CEX} = 325 Vdc, V_{BE} = 0.2 Vdc, T_C = 85°C)			-	35	
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)		I_{EBO}	-	100	mAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)		h_{FE}	20	60	-
Collector-Emitter Saturation Voltage (I_C = 10 Adc, I_B = 1.0 Adc)		$V_{CE(sat)}$	-	0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 10 Adc, I_B = 1.0 Adc)		$V_{BE(sat)}$	-	0.75	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product (I_C = 0.5 Adc, V_{CE} = 5.0 Vdc, f = 0.5 MHz)		f_T	2.0	-	MHz
SWITCHING CHARACTERISTICS					
Rise Time	(I_C = 5.0 Adc, I_{B1} = I_{B2} = 0.5 Adc) (See Figure 2)	t_r	-	15	μs
Storage Time		t_s	-	10	μs
Fall Time		t_f	-	7.0	μs

FIGURE 1 - COLLECTOR-EMITTER SUSTAINING VOLTAGE TEST CIRCUIT


I_B SAMPLE
SCOPE COM
SCOPE V H
OSCILLOSCOPE: HEWLETT PACKARD MODEL 130, TEKTRONIX MODEL 503, OR EQUIVALENT
C.P. CLARE HG2A1089
INPUT
PW ≈ 25 ms
PRF ≈ 20 pps
N.O.
1.0 Ω
0.05 Ω
10 Ω
1.0 Ω 100 W
1N1187
3.0 Ω
R_1
PUSH TO TEST
5.0 Ω
E_1
10 mH
E_2
R_2
150 Ω

TEST CONDITION 1

Adjust E_1 for I_C = 3.0 Adc

Adjust E_2 - 2N5324; V_{CE} = 165 Vdc
- 2N5325; V_{CE} = 200 Vdc

Adjust R_1 for I_B = 0.3 Adc

TEST CONDITION 2

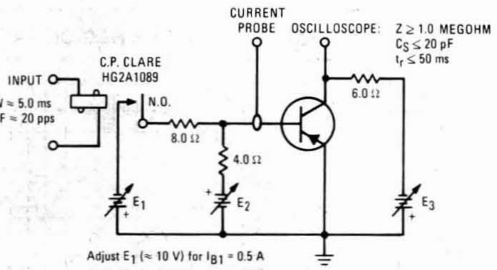
Adjust E_1 for I_C = 10 Adc

Adjust E_2 - 2N5324; V_{CE} = 100 Vdc
- 2N5325; V_{CE} = 115 Vdc

Adjust R_1 for I_B = 1.0 Adc

R_2: Set to allow reverse surge current to bypass E_2 power supply. Not needed for power supply with low reverse impedance.

FIGURE 2 - SWITCHING TIME TEST CIRCUIT


CURRENT PROBE
OSCILLOSCOPE: Z ≥ 1.0 MEGOHM
C_S ≤ 20 pF
t_r ≤ 50 ms
C.P. CLARE HG2A1089
INPUT
PW ≈ 5.0 ms
PRF ≈ 20 pps
N.O.
8.0 Ω
4.0 Ω
6.0 Ω
E_1
E_2
E_3

Adjust E_1 (≈ 10 V) for I_{B1} = 0.5 A

Adjust E_2 (≈ 2.0 V) for I_{B2} = 0.5 A

Adjust E_3 (≈ 30 V) for I_C = 5.0 A

2N5334 (SILICON)
2N5335

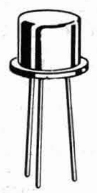
HIGH-SPEED NPN SILICON POWER TRANSISTORS

. . . designed for fast switching and amplifier applications.

- Total Switching Time — 1.15 μs Max
- High Current Switching Specified at 1.0 Adc —
  t_{on} = 100 ns Max
  t_{off} = 1.05 μs Max
- Collector-Emitter Saturation Voltage —
  $V_{CE(sat)}$ = 0.7 Vdc (Max) @ I_C = 2.0 Adc

3 AMPERE POWER TRANSISTORS

60-80 VOLTS
6 WATTS

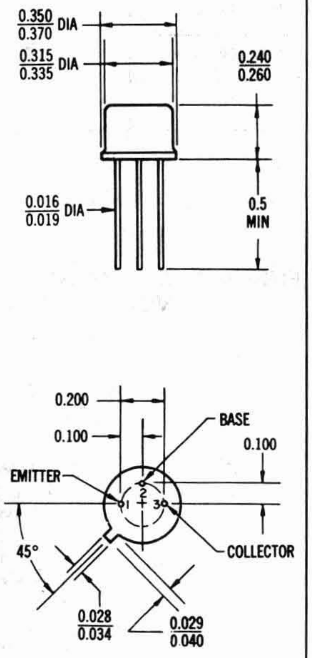


MAXIMUM RATINGS

Rating	Symbol	2N5334	2N5335	Unit
Collector-Emitter Voltage	V_{CEO}	60	80	Vdc
Collector-Base Voltage	V_{CB}	60	80	Vdc
Emitter-Base Voltage	V_{EB}	8.0		Vdc
Collector Current - Continuous	I_C	3.0		Adc
Base Current - Continuous	I_B	0.5		Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	6.0 34		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

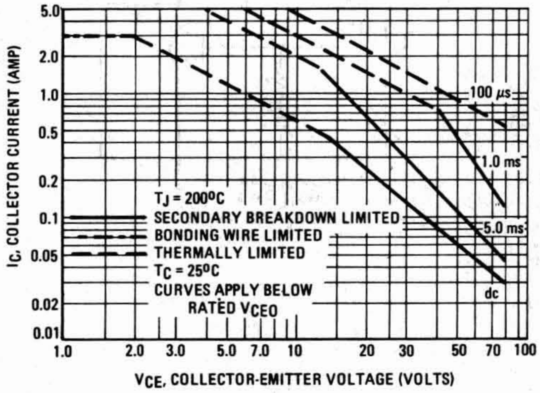
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	29.1	°C/W



TO-39
CASE 79

FIGURE 1 — ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 1 is based on $T_{J(pk)}$ = 200°C; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq$ 200°C. $T_{J(pk)}$ may be calculated from the data in Figure 3. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

2N5334, 2N5335 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Sustaining Voltage* (I_C = 50 mAdc, I_B = 0)	2N5334 2N5335	$BV_{CEO(sus)}$*	60 80	- -	Vdc
Collector Cutoff Current (V_{CE} = 60 Vdc, $V_{EB(off)}$ = 1.5 Vdc)	2N5334	I_{CEX}	-	1.0	μAdc
(V_{CE} = 80 Vdc, $V_{EB(off)}$ = 1.5 Vdc)	2N5335		-	1.0	
(V_{CE} = 60 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	2N5334		-	500	
(V_{CE} = 80 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	2N5335		-	500	
Collector Cutoff Current (V_{CB} = 60 Vdc, I_E = 0)	2N5334	I_{CBO}	-	5.0	μAdc
(V_{CB} = 80 Vdc, I_E = 0)	2N5335		-	5.0	
Emitter Cutoff Current (V_{BE} = 8.0 Vdc, I_C = 0)		I_{EBO}	-	100	μAdc

ON CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
DC Current Gain* (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}*	30	150	-
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)		15	-	
Collector-Emitter Saturation Voltage* (I_C = 2.0 Adc, I_B = 0.2 Adc)	$V_{CE(sat)}$*	-	0.7	Vdc
Base-Emitter Saturation Voltage* (I_C = 2.0 Adc, I_B = 0.2 Adc)	$V_{BE(sat)}$*	-	1.5	Vdc

DYNAMIC CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
Current-Gain–Bandwidth Product (I_C = 0.1 Adc, V_{CE} = 10 Vdc, f = 10 MHz)	f_T	60	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	75	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	250	pF

SWITCHING CHARACTERISTICS

Characteristic	Conditions	Symbol	Min	Max	Unit
Delay Time	(V_{CC} = 20 Vdc, $V_{EB(off)}$ = 3.7 Vdc, I_C = 1.0 Adc, I_{B1} = I_{B2} = 100 mAdc) (See Figure 2)	t_d	-	50	ns
Rise Time		t_r	-	50	ns
Storage Time		t_s	-	950	ns
Fall Time		t_f	-	100	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 2 – SWITCHING TIME CIRCUIT

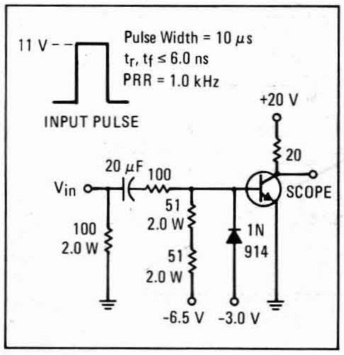
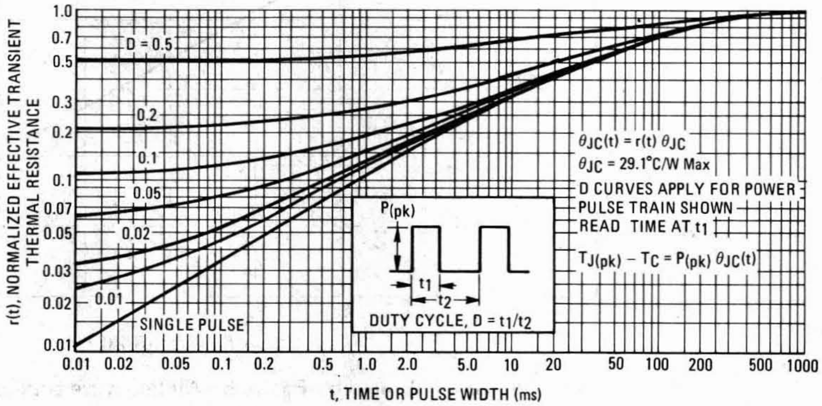
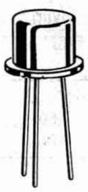


FIGURE 3 – THERMAL RESPONSE



2N5336 (SILICON)
thru
2N5339



Medium-power NPN silicon transistors designed for switching and wide band amplifier applications.

CASE 79
(TO-39)

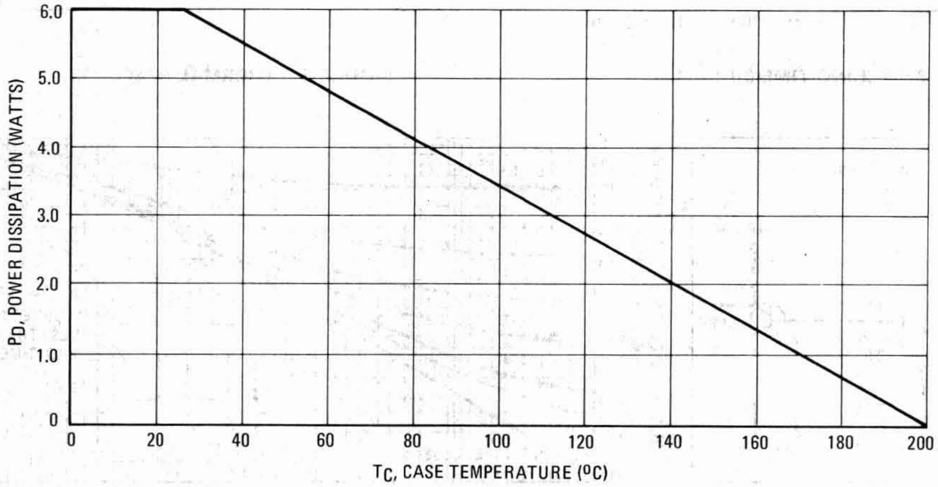
MAXIMUM RATINGS

Rating	Symbol	2N5336 2N5337	2N5338 2N5339	Unit
Collector-Emitter Voltage	V_{CEO}	80	100	Vdc
Collector-Base Voltage	V_{CB}	80	100	Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current — Continuous	I_C	5.0		Adc
Base Current	I_B	1.0		Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	6.0 34.3		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	29.2	°C/W

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 5. All limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage* (I_C = 50 mAdc, I_B = 0)	2N5336, 2N5337	-	$BV_{CEO(sus)}$*	80	-	Vdc
	2N5338, 2N5339			100	-	
Collector Cutoff Current (V_{CE} = 75 Vdc, I_B = 0)	2N5336, 2N5337	-	I_{CEO}	-	100	μAdc
(V_{CE} = 90 Vdc, I_B = 0)	2N5338, 2N5339			-	100	
Collector Cutoff Current (V_{CE} = 75 Vdc, $V_{EB(off)}$ = 1.5 Vdc)	2N5336, 2N5337	12	I_{CEX}	-	10	μAdc
(V_{CE} = 90 Vdc, $V_{EB(off)}$ = 1.5 Vdc)	2N5338, 2N5339			-	10	
(V_{CE} = 75 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	2N5336, 2N5337			-	1.0	mAdc
(V_{CE} = 90 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	2N5338, 2N5339			-	1.0	
Collector Cutoff Current (V_{CB} = 80 Vdc, I_E = 0)	2N5336, 2N5337	-	I_{CBO}	-	10	μAdc
(V_{CB} = 100 Vdc, I_E = 0)	2N5338, 2N5339			-	10	
Emitter Cutoff Current (V_{BE} = 6.0 Vdc, I_C = 0)		-	I_{EBO}	-	100	μAdc
ON CHARACTERISTICS						
DC Current Gain* (I_C = 500 mAdc, V_{CE} = 2.0 Vdc)	2N5336, 2N5338	8	h_{FE}*	30	-	-
	2N5337, 2N5339			60	-	
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	2N5336, 2N5338			30	120	
	2N5337, 2N5339			60	240	
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	2N5336, 2N5338			20	-	
	2N5337, 2N5339			40	-	
Collector-Emitter Saturation Voltage* (I_C = 2.0 Adc, I_B = 0.2 Adc)		9, 11, 13	$V_{CE(sat)}$*	-	0.7	Vdc
(I_C = 5.0 Adc, I_B = 0.5 Adc)				-	1.2	
Base-Emitter Saturation Voltage* (I_C = 2.0 Adc, I_B = 0.2 Adc)		11, 13	$V_{BE(sat)}$*	-	1.2	Vdc
(I_C = 5.0 Adc, I_B = 0.5 Adc)				-	1.8	
DYNAMIC CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 0.5 Adc, V_{CE} = 10 Vdc, f = 10 MHz)		-	f_T	30	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		7	C_{ob}	-	250	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 100 kHz)		7	C_{ib}	-	1,000	pF
SWITCHING CHARACTERISTICS						
Delay Time	(V_{CC} = 40 Vdc, $V_{EB(off)}$ = 3.0 Vdc, I_C = 2.0 Adc, I_{B1} = 0.2 Adc)	2,3	t_d	-	100	ns
Rise Time			t_r	-	100	ns
Storage Time	(V_{CC} = 40 Vdc, I_C = 2.0 Adc, I_{B1} = I_{B2} = 0.2 Adc)	2,6	t_s	-	2.0	μs
Fall Time			t_f	-	200	ns

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

2N5336 thru 2N5339 (continued)

FIGURE 2 – SWITCHING TIME TEST CIRCUIT

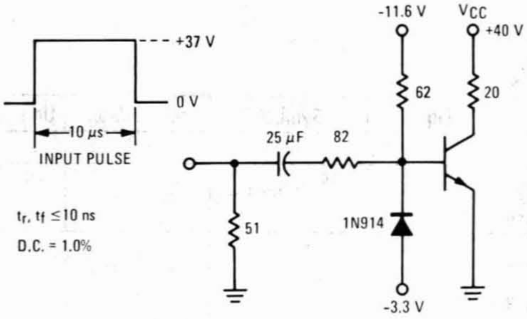


FIGURE 3 – TURN ON TIME

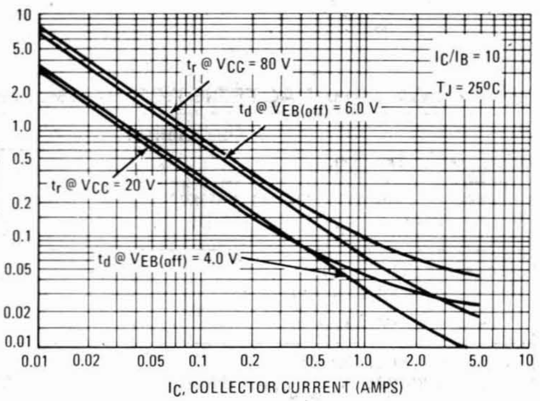


FIGURE 4 – THERMAL RESPONSE

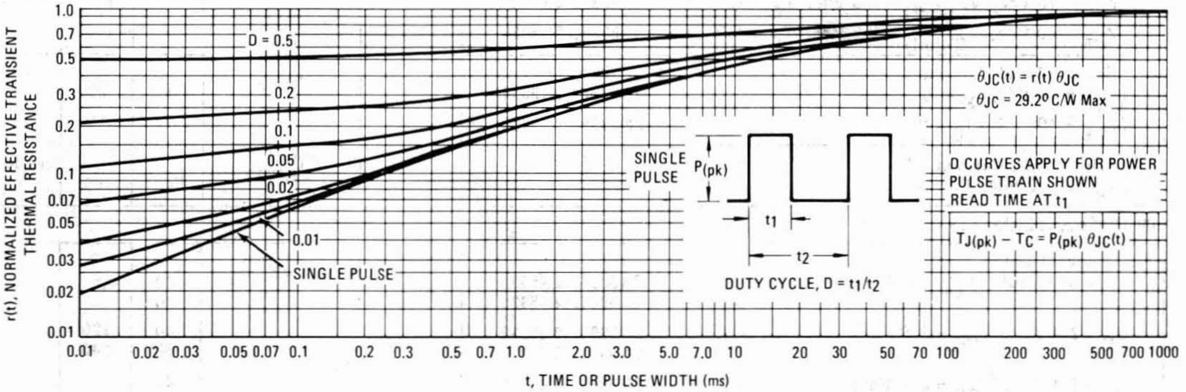
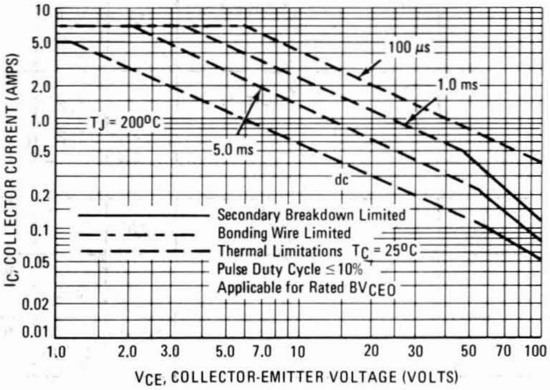


FIGURE 5 – ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 – TURN-OFF TIME

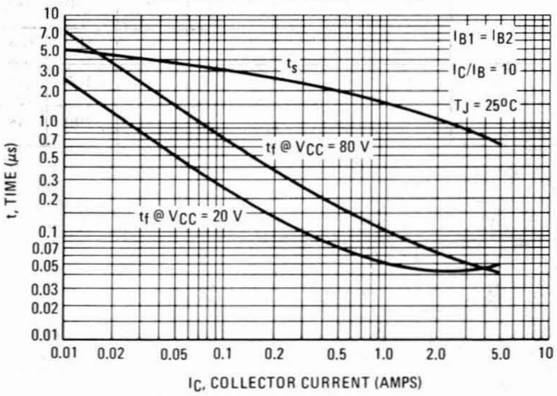


FIGURE 7 – CAPACITANCE versus VOLTAGE

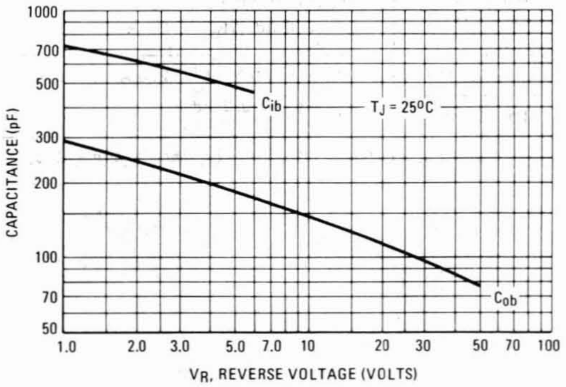


FIGURE 8 – DC CURRENT GAIN

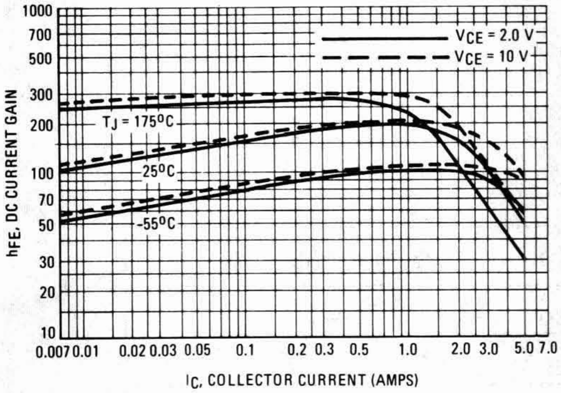


FIGURE 9 – COLLECTOR SATURATION REGION

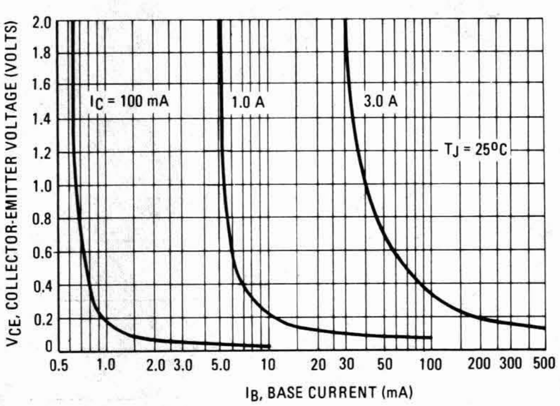


FIGURE 10 – EFFECTS OF BASE-EMITTER RESISTANCE

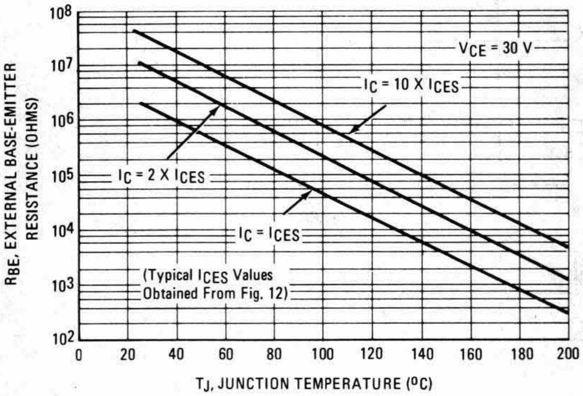


FIGURE 11 – ON VOLTAGES

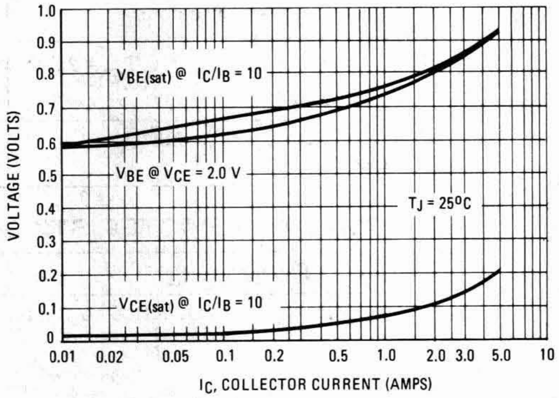


FIGURE 12 – COLLECTOR CUT-OFF REGION

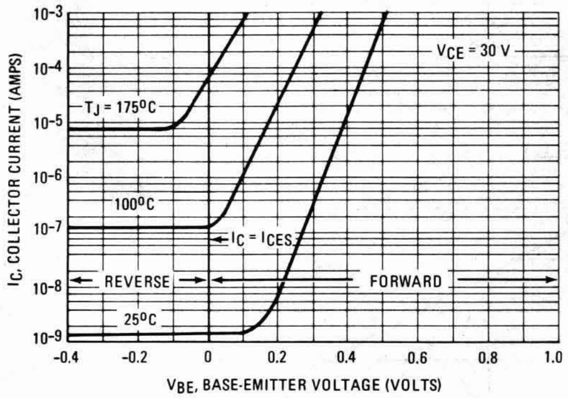
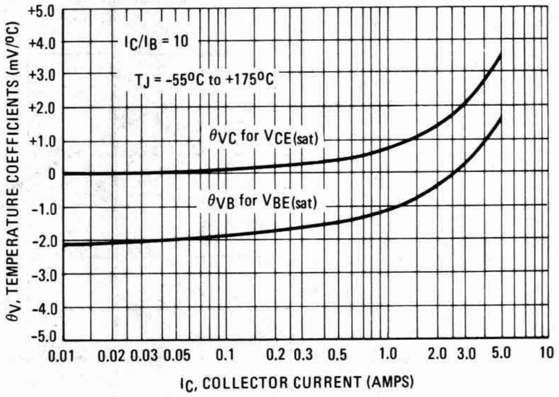
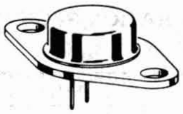


FIGURE 13 – TEMPERATURE COEFFICIENTS



2N5344 (SILICON)
2N5345

High voltage power PNP silicon transistors designed for high-voltage switching and amplifier applications.



CASE 80
(TO-66)

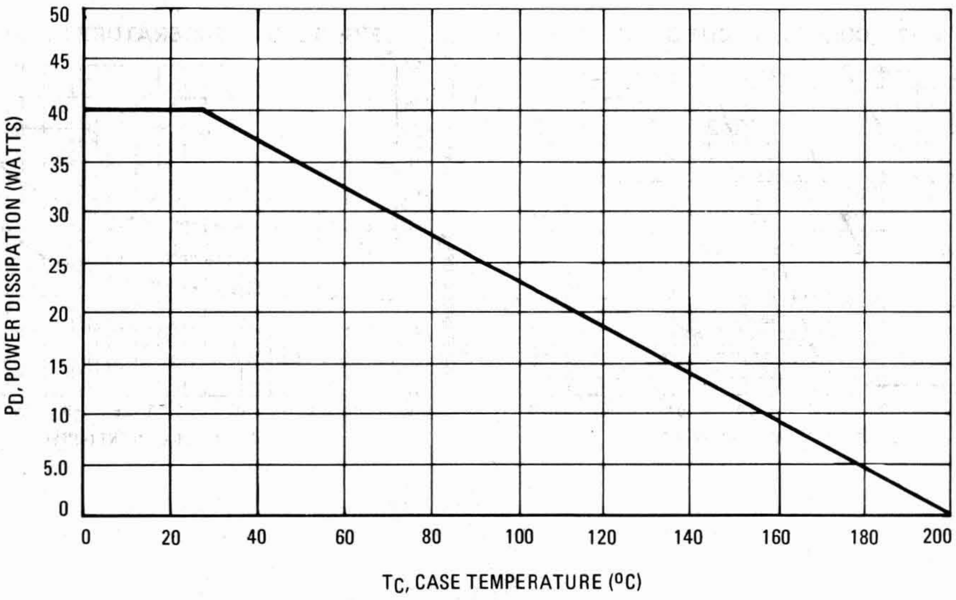
MAXIMUM RATINGS

Rating	Symbol	2N5344	2N5345	Unit
Collector-Emitter Voltage	V_{CEO}	250	300	Vdc
Collector-Base Voltage	V_{CB}	250	300	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current — Continuous	I_C	1.0		Adc
Base Current — Continuous	I_B	0.5		Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	40 228		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	4.38	°C/W

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves Are Indicated By Figure 5. All Limits Are Applicable And Must Be Observed

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	 2N5344 2N5345	5	$BV_{CEO(sus)}$*	 250 300	 - -	Vdc
Collector Cutoff Current (V_{CE} = 225 Vdc, $V_{BE(off)}$ = 1.5 Vdc) (V_{CE} = 270 Vdc, $V_{BE(off)}$ = 1.5 Vdc) (V_{CE} = 225 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C) (V_{CE} = 270 Vdc, $V_{BE(off)}$ = 1.5 Vdc, T_C = 150°C)	 2N5344 2N5345 2N5344 2N5345	10, 12	I_{CEX}	 - - - -	 100 100 1.0 1.0	μAdc mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)		-	I_{CBO}	-	0.1	mAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)		-	I_{EBO}	-	0.1	mAdc
ON CHARACTERISTICS						
DC Current Gain* (I_C = 500 mAdc, V_{CE} = 5.0 Vdc) (I_C = 1.0 Adc, V_{CE} = 5.0 Vdc)		8	h_{FE}*	 25 7.0	 100 -	-
Collector-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 0.2 Adc)		9, 11, 13	$V_{CE(sat)}$	-	3.0	Vdc
Base-Emitter Saturation Voltage (I_C = 1.0 Adc, I_B = 0.2 Adc)		11, 13	$V_{BE(sat)}$	-	1.5	Vdc
DYNAMIC CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 100 mAdc, V_{CE} = 20 Vdc, f = 10 MHz)		-	f_T	60	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0)		7	C_{ob}	-	200	pF
SWITCHING CHARACTERISTICS						
Delay Time	(V_{CC} = 100 Vdc, $V_{BE(off)}$ = 0.85 Vdc, I_C = 500 mAdc, I_{B1} = 50 mAdc)	2, 3	t_d	-	100	ns
Rise Time		2, 3	t_r	-	100	ns
Storage Time	(V_{CC} = 100 Vdc, I_C = 500 mAdc, I_{B1} = I_{B2} = 50 mAdc)	2, 6	t_s	-	600	ns
Fall Time		2, 6	t_f	-	100	ns

* Pulse Test: Pulse Width ≈ 300 μs, Duty Cycle ≈ 2.0%.

FIGURE 2 – SWITCHING TIME TEST CIRCUIT

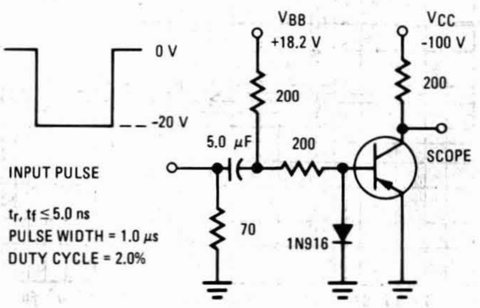


FIGURE 3 – TURN-ON TIME

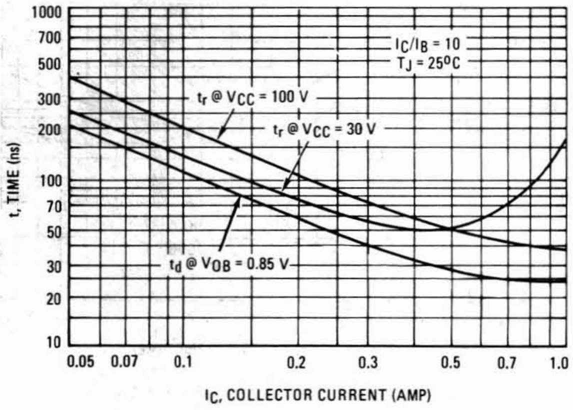


FIGURE 4 – THERMAL RESPONSE

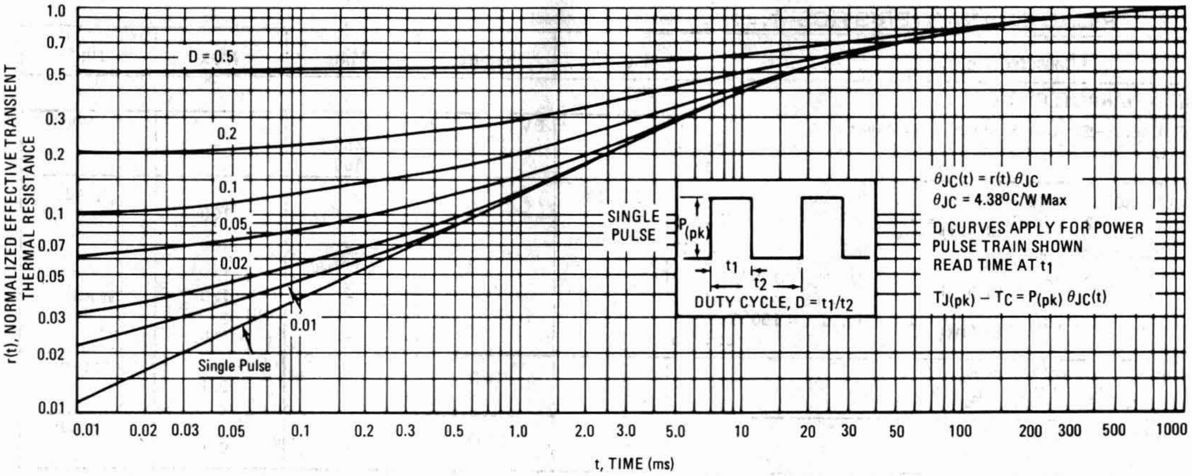
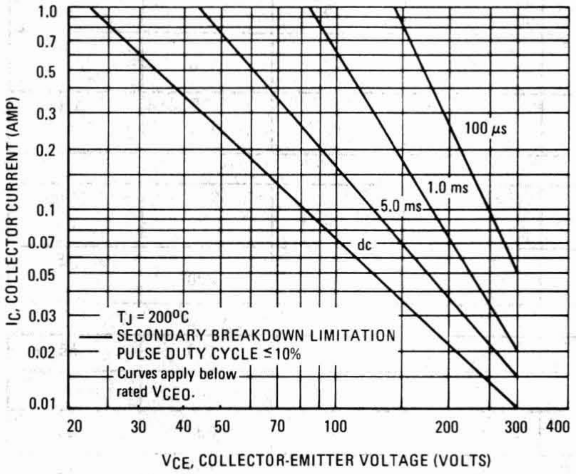


FIGURE 5 – ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 – TURN-OFF TIME

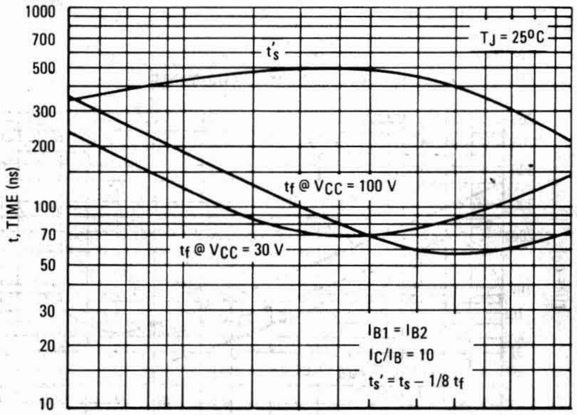
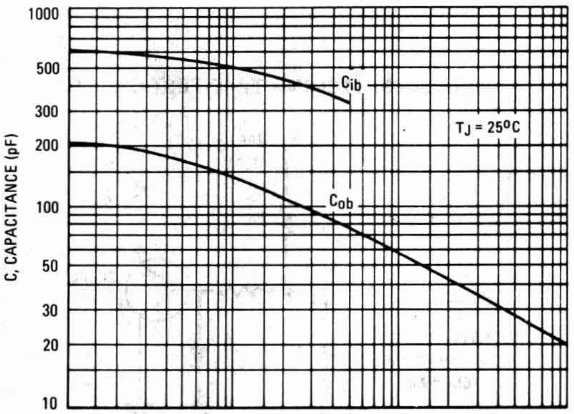


FIGURE 7 – CAPACITANCES



TYPICAL DC CHARACTERISTICS

FIGURE 8 – DC CURRENT GAIN

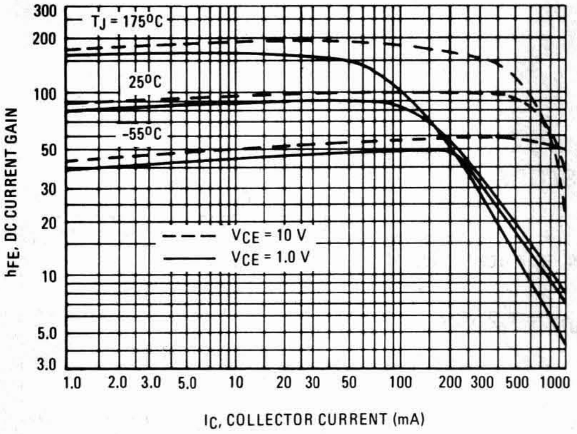


FIGURE 9 – COLLECTOR SATURATION REGION

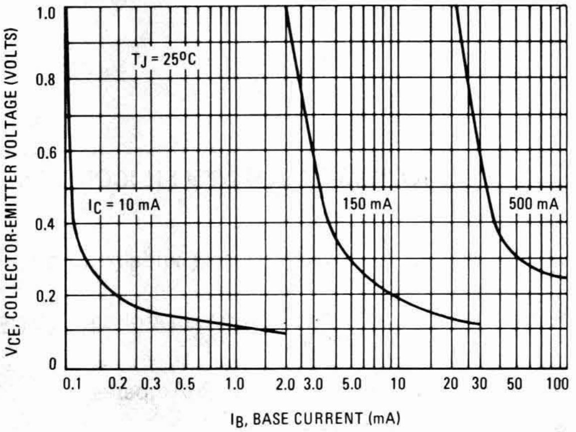


FIGURE 10 – EFFECTS OF BASE-EMITTER RESISTANCE

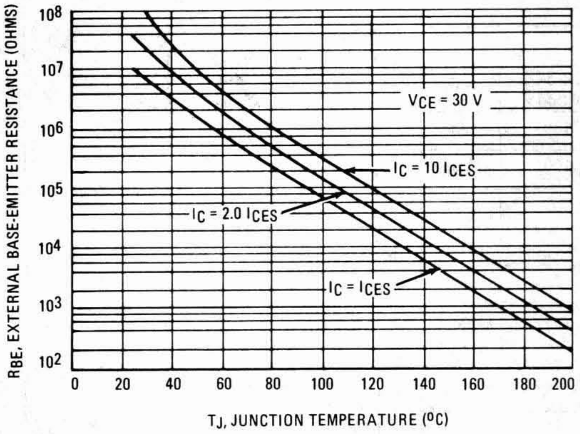


FIGURE 11 – "ON" VOLTAGES

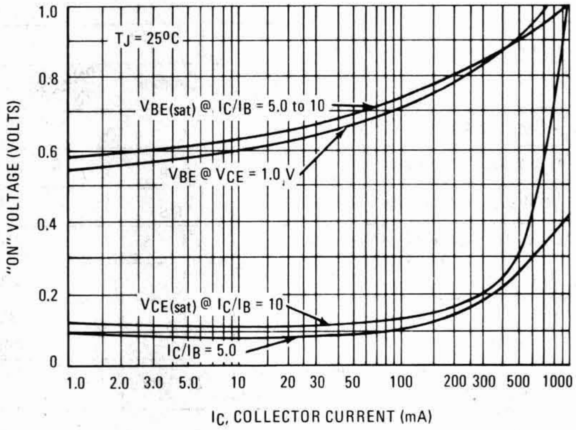


FIGURE 12 – COLLECTOR CUT-OFF REGION

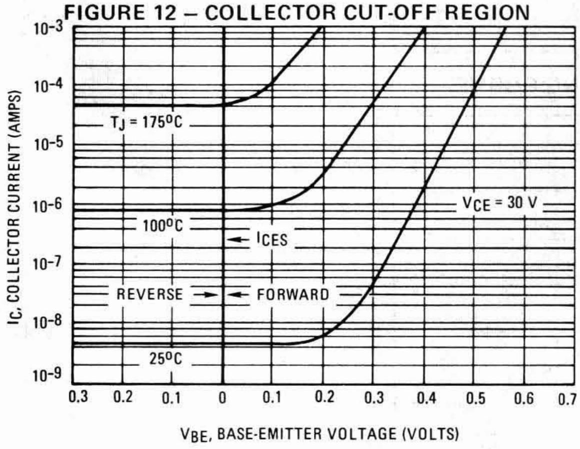
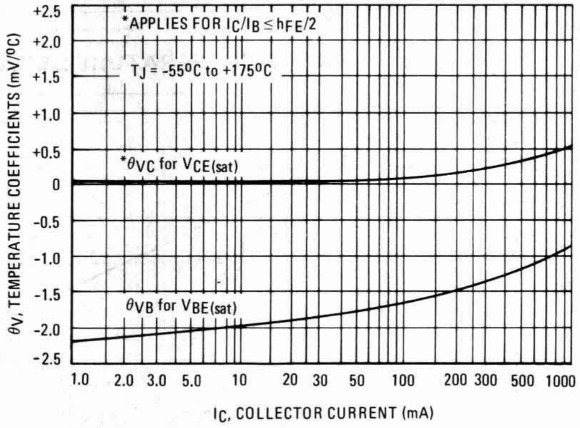


FIGURE 13 – TEMPERATURE COEFFICIENTS



2N5346 (SILICON)
thru
2N5349

MEDIUM-POWER NPN SILICON TRANSISTORS

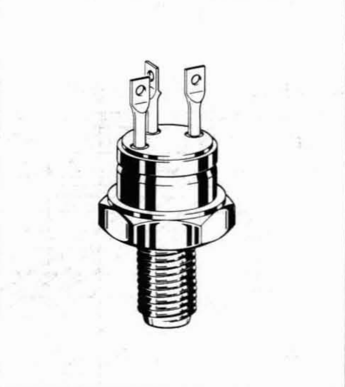
. . . designed for switching and wide-band amplifier applications.

- Low Collector-Emitter Saturation Voltage — $V_{CE(sat)}$ = 1.2 Vdc (Max) @ I_C = 7.0 Adc
- DC Current Gain Specified to 5 Amperes
- Excellent Safe Operating Area
- Packaged in the Compact, High Dissipation TO-59 Case
- Isolated Collector Configuration

7 AMPERE
POWER TRANSISTORS

NPN SILICON

80-100 VOLTS
60 WATTS

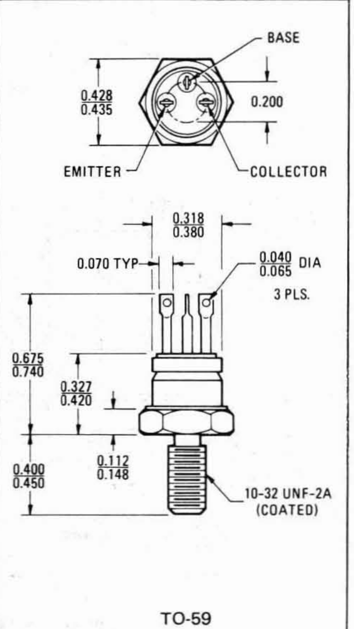


MAXIMUM RATINGS

Rating	Symbol	2N5346 2N5347	2N5348 2N5349	Unit
Collector-Emitter Voltage	V_{CEO}	80	100	Vdc
Collector-Base Voltage	V_{CB}	80	100	Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current — Continuous	I_C	7.0		Adc
Base Current	I_B	1.0		Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	60 343		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

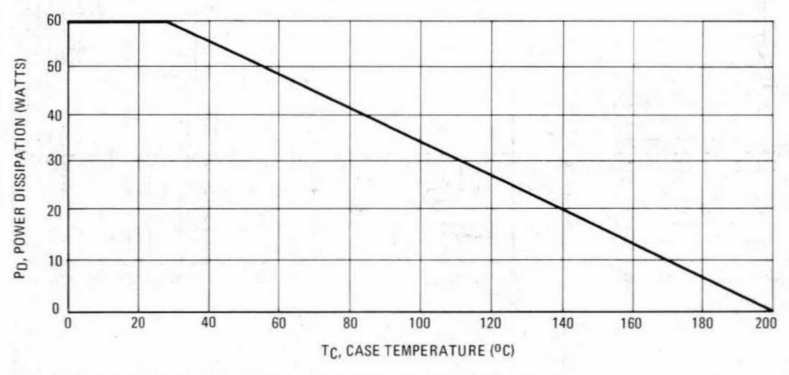
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	2.91	°C/W


BASE
0.428
0.435
0.200
EMITTER
COLLECTOR
0.318
0.380
0.070 TYP
0.040
0.065 DIA
3 PLS.
0.675
0.740
0.327
0.420
0.400
0.450
0.112
0.148
10-32 UNF-2A
(COATED)

TO-59
CASE 160

ISOLATED COLLECTOR

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 5. All limits are applicable and must be observed.

2N5346 thru 2N5349 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage* (I_C = 50 mAdc, I_B = 0)	2N5346, 2N5347 2N5348, 2N5349	-	$BV_{CEO(sus)}$*	80 100	- -	Vdc
Collector Cutoff Current (V_{CE} = 75 Vdc, I_B = 0) (V_{CE} = 90 Vdc, I_B = 0)	2N5346, 2N5347 2N5348, 2N5349	-	I_{CEO}	- -	100 100	µAdc
Collector Cutoff Current (V_{CE} = 75 Vdc, $V_{EB(off)}$ = 1.5 Vdc) (V_{CE} = 90 Vdc, $V_{EB(off)}$ = 1.5 Vdc) (V_{CE} = 75 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C) (V_{CE} = 90 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	2N5346, 2N5347 2N5348, 2N5349 2N5346, 2N5347 2N5348, 2N5349	12	I_{CEX}	- - - -	10 10 1.0 1.0	µAdc mAdc
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)		-	I_{CBO}	-	10	µAdc
Emitter Cutoff Current (V_{EB} = 6.0 Vdc, I_C = 0)		-	I_{EBO}	-	100	µAdc
ON CHARACTERISTICS						
DC Current Gain* (I_C = 500 mAdc, V_{CE} = 2.0 Vdc)	2N5346, 2N5348 2N5347, 2N5349	8	h_{FE}*	30 60	- -	-
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	2N5346, 2N5348 2N5347, 2N5349			30 60	120 240	
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	2N5346, 2N5348 2N5347, 2N5349			20 40	- -	
Collector-Emitter Saturation Voltage* (I_C = 2.0 Adc, I_B = 0.2 Adc) (I_C = 7.0 Adc, I_B = 0.7 Adc)		9,11,13	$V_{CE(sat)}$*	- -	0.7 1.2	Vdc
Base-Emitter Saturation Voltage* (I_C = 2.0 Adc, I_B = 0.2 Adc) (I_C = 7.0 Adc, I_B = 0.7 Adc)		11, 13	$V_{BE(sat)}$*	- -	1.2 2.0	Vdc
DYNAMIC CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 500 mAdc, V_{CE} = 10 Vdc, f = 10 MHz)		-	f_T	30	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		7	C_{ob}	-	250	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 100 kHz)		7	C_{ib}	-	1,000	pF
SWITCHING CHARACTERISTICS						
Delay Time	(V_{CC} = 40 Vdc, $V_{EB(off)}$ = 3.0 Vdc, I_C = 2.0 Adc, I_{B1} = 200 mAdc)	2,3	t_d	-	100	ns
Rise Time			t_r	-	100	ns
Storage Time	(V_{CC} = 40 Vdc, I_C = 2.0 Adc, I_{B1} = I_{B2} = 200 mAdc)	2,6	t_s	-	2.0	µs
Fall Time			t_f	-	200	ns

* Pulse Test: Pulse Width ≈ 300 µs, Duty Cycle ≈ 2.0%.

FIGURE 2 – SWITCHING TIME TEST CIRCUIT

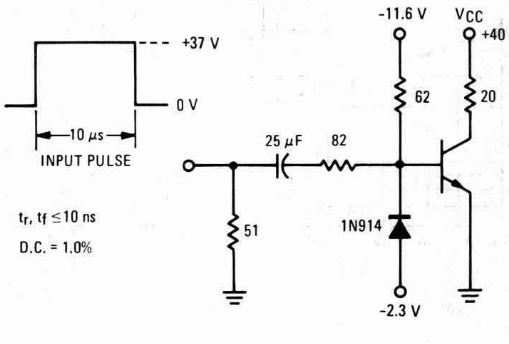


FIGURE 3 – TURN-ON TIME

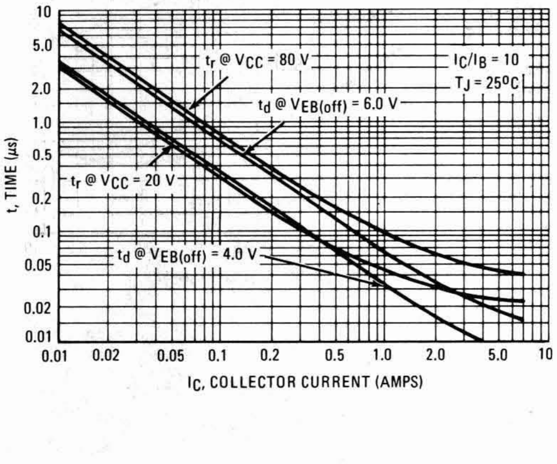


FIGURE 4 – THERMAL RESPONSE

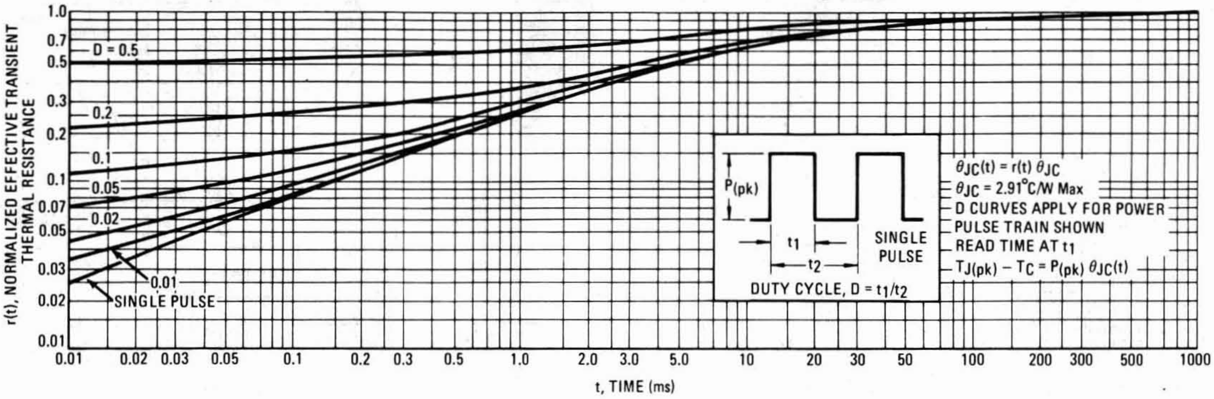
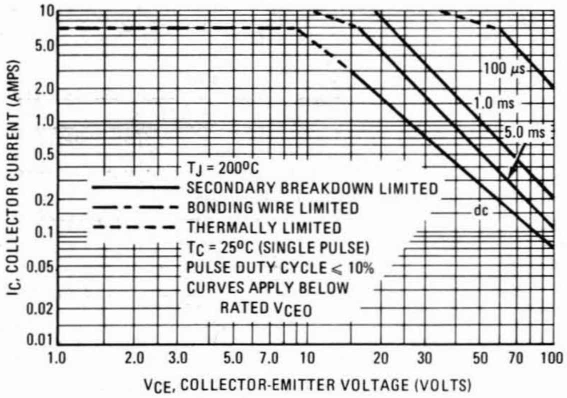


FIGURE 5 – ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)} = 200^\circ C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq 200^\circ C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 – TURN-OFF TIME

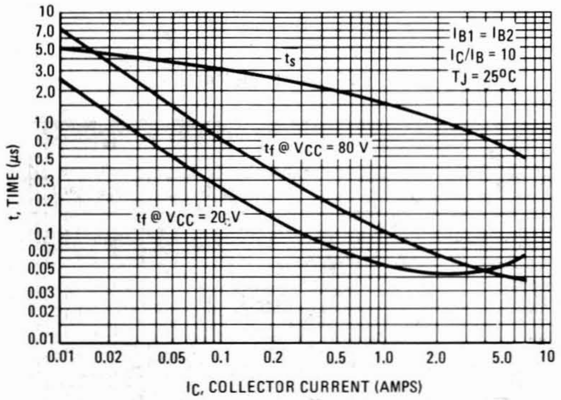


FIGURE 7 – CAPACITANCE versus VOLTAGE

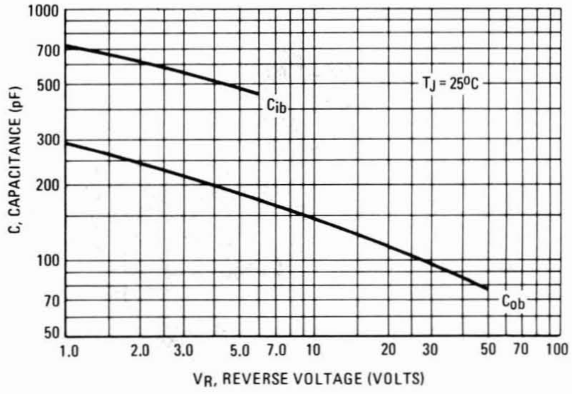


FIGURE 8 – DC CURRENT GAIN

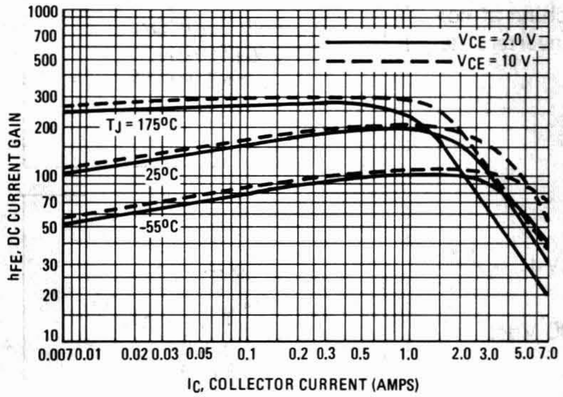


FIGURE 9 – COLLECTOR SATURATION REGION

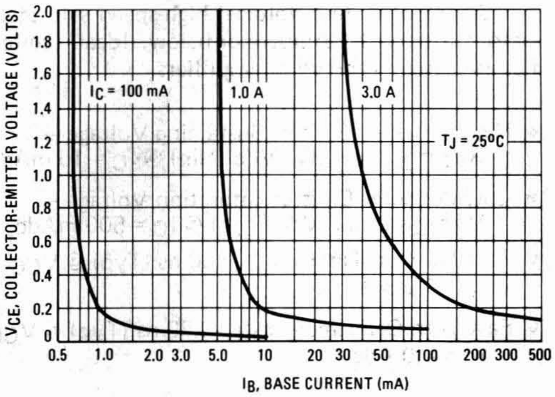


FIGURE 10 – EFFECTS OF BASE-EMITTER RESISTANCE

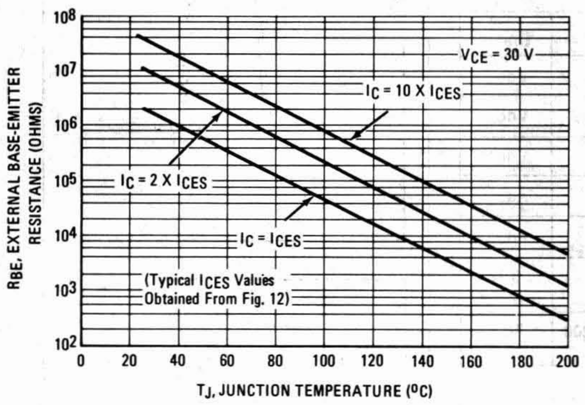


FIGURE 11 – "ON" VOLTAGES

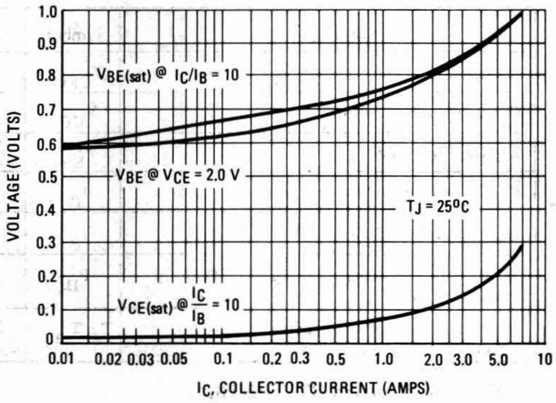


FIGURE 12 – COLLECTOR CUT-OFF REGION

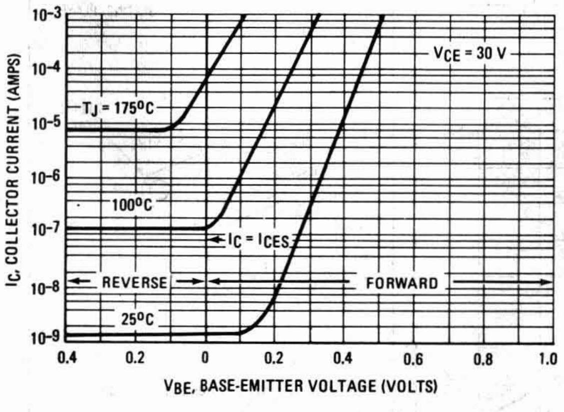
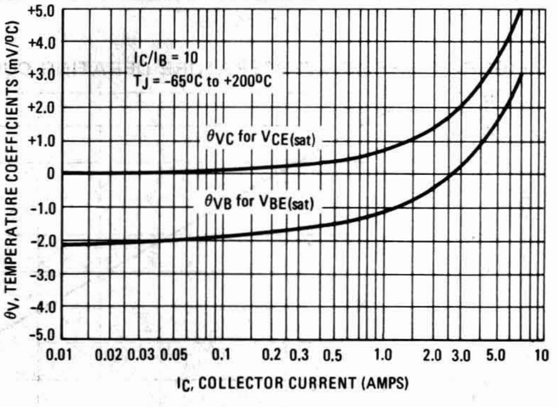


FIGURE 13 – TEMPERATURE COEFFICIENTS



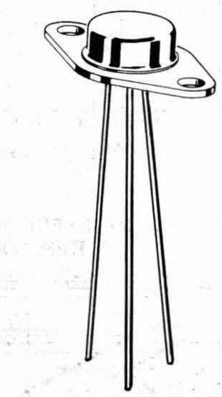
2N5357 (SILICON)

PNP SILICON ANNULAR EPITAXIAL TRANSISTOR

. . . designed for high-voltage, high-speed saturated switching at collector currents of 1 Ampere or below. Ideally suited for inverters, deflection circuits and servo amplifiers.

- High Collector-Emitter Sustaining Voltage — $BV_{CEO(sus)}$ = 300 Vdc (Min) @ I_C = 10 mAdc
- Low Collector-Emitter Saturation Voltage — $V_{CE(sat)}$ = 0.3 Vdc (Typ) @ I_C = 500 mAdc
- Fast Turn-On Time — t_{on} = 60 ns (Typ) @ V_{CC} = 100 Vdc, I_C = 1.0 Adc
- Fast Turn-Off Time — t_{off} = 280 ns (Typ) @ V_{CC} = 100 Vdc, I_C = 1.0 Adc

PNP SILICON
SWITCHING
TRANSISTOR



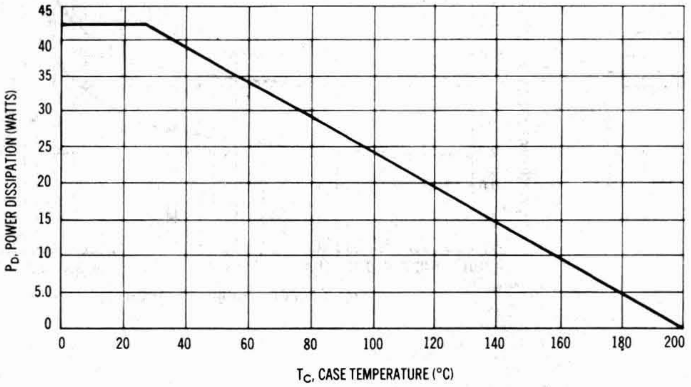
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	300	Vdc
Collector-Base Voltage	V_{CB}	300	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current - Continuous	I_C	3.0	Adc
Base Current - Continuous	I_B	1.0	Adc
Total Device Dissipation @ T_C = 75°C Derate above 75°C	P_D	30 240	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

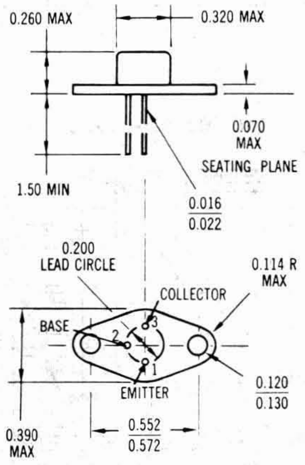
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	4.16	°C/W

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves Are Indicated By Figure 5. All Limits Are Applicable And Must Be Observed.


0.260 MAX
0.320 MAX
0.070
MAX
SEATING PLANE
1.50 MIN
0.016
0.022
0.200
LEAD CIRCLE
0.114 R
MAX
COLLECTOR
BASE
2
3
1
EMITTER
0.120
0.130
0.390
MAX
0.552
0.572

Collector Connected to Case

Case 39
TO-37

2N5357 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$	300	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	300	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 200 Vdc, $V_{BE(off)}$ = 0.5 Vdc, T_A = 100°C) (V_{CE} = 300 Vdc, $V_{BE(off)}$ = 0.5 Vdc)	I_{CEX}	- -	100 10	μAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0) (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	- -	100 100	nAdc μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 500 μAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C) (I_C = 500 mAdc, V_{CE} = 5.0 Vdc) (I_C = 1.0 Adc, V_{CE} = 5.0 Vdc)	h_{FE}	45 50 40 20 25 10	- - - - 100 -	-
Collector-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1.0 Adc, I_B = 100 mAdc)	$V_{CE(sat)}$	- - -	0.3 1.0 3.0	Vdc
Base-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1.0 Adc, I_B = 100 mAdc)	$V_{BE(sat)}$	- - -	1.0 1.3 1.5	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 70 mAdc, V_{CE} = 20 Vdc, f = 20 MHz)	f_T	50	-	MHz
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	60	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	600	pF
SWITCHING CHARACTERISTICS				
Delay Time — (V_{CC} = 100 Vdc, I_C = 500 mAdc, I_{B1} = 50 mAdc) (See Figure 2)	t_d	-	50	ns
Rise Time — (V_{CC} = 100 Vdc, I_C = 500 mAdc, I_{B1} = 50 mAdc) (See Figure 2)	t_r	-	100	ns
Storage Time — (V_{CC} = 100 Vdc, I_C = 500 mAdc, I_{B1} = I_{B2} = 50 mAdc) (See Figure 2)	t_s	-	600	ns
Fall Time — (V_{CC} = 100 Vdc, I_C = 500 mAdc, I_{B1} = I_{B2} = 50 mAdc) (See Figure 2)	t_f	-	100	ns

FIGURE 2 – SWITCHING TIME TEST CIRCUIT

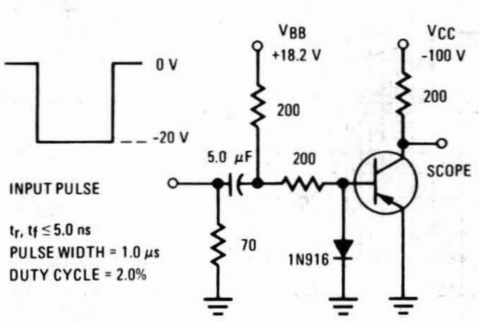


FIGURE 3 – TURN-ON TIME

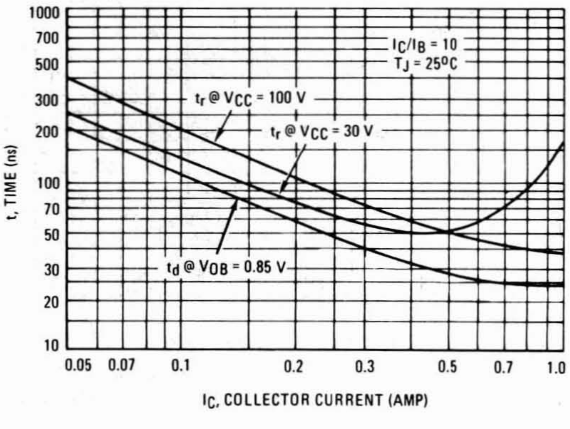


FIGURE 4 – THERMAL RESPONSE

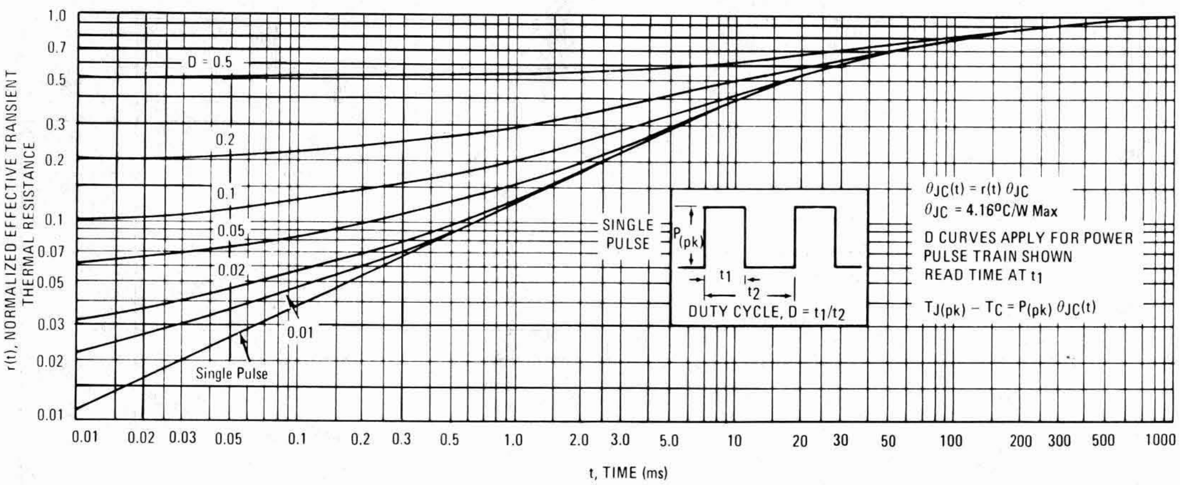
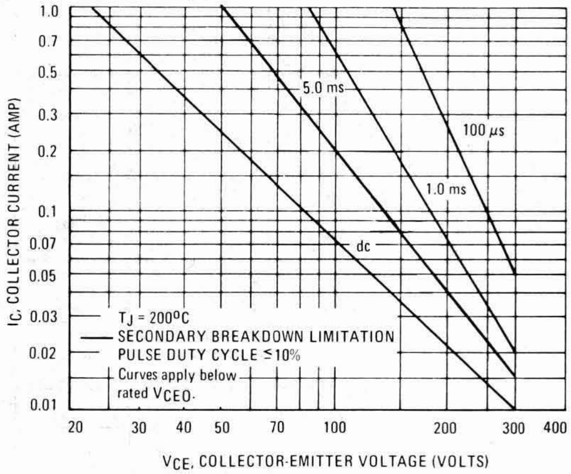


FIGURE 5 – ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate I_C—V_{CE} limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 – TURN-OFF TIME

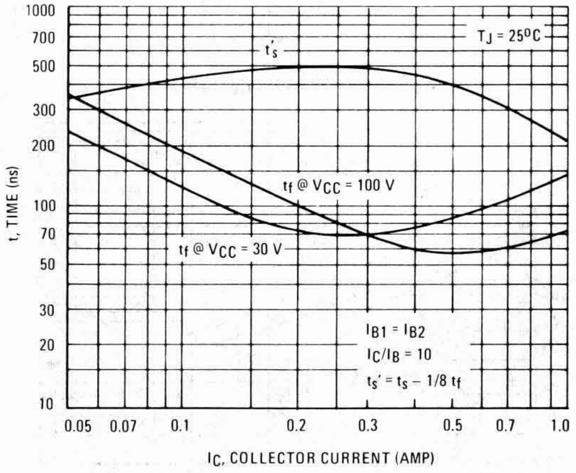
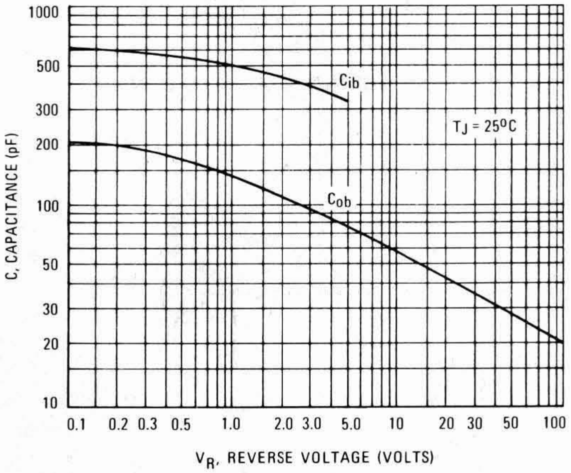


FIGURE 7 – CAPACITANCES



TYPICAL DC CHARACTERISTICS

FIGURE 8 – DC CURRENT GAIN

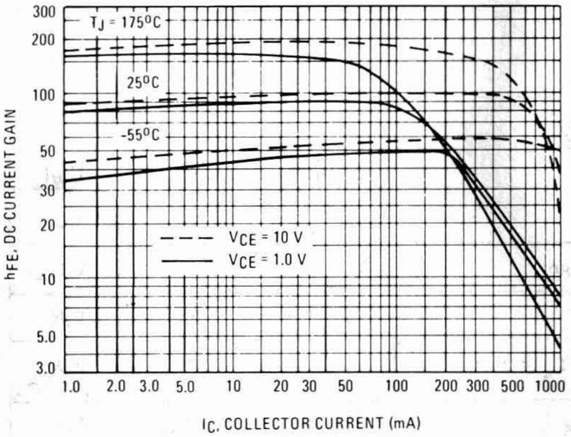


FIGURE 9 – COLLECTOR SATURATION REGION

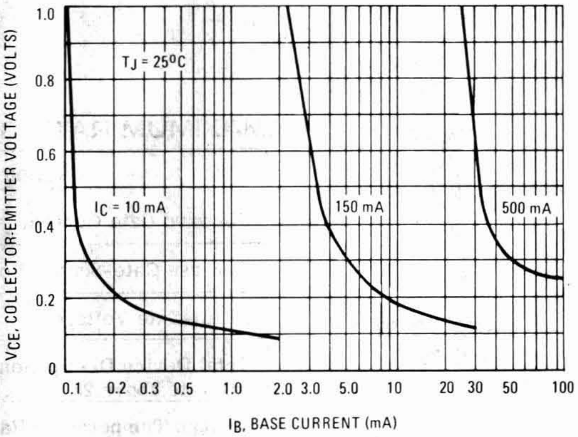


FIGURE 10 – EFFECTS OF BASE-EMITTER RESISTANCE

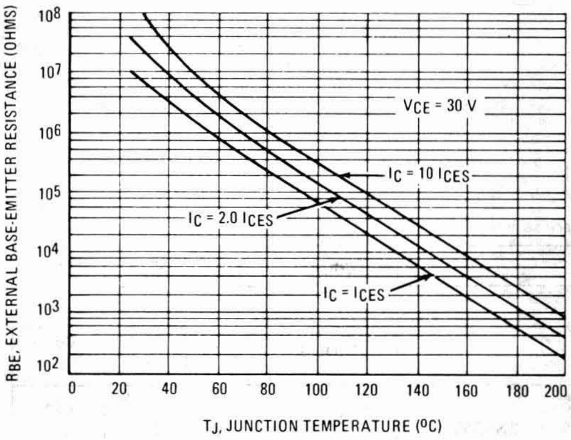


FIGURE 11 – "ON" VOLTAGES

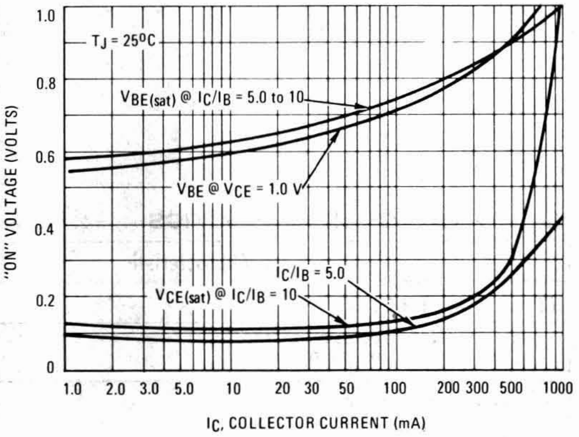


FIGURE 12 – COLLECTOR CUT-OFF REGION

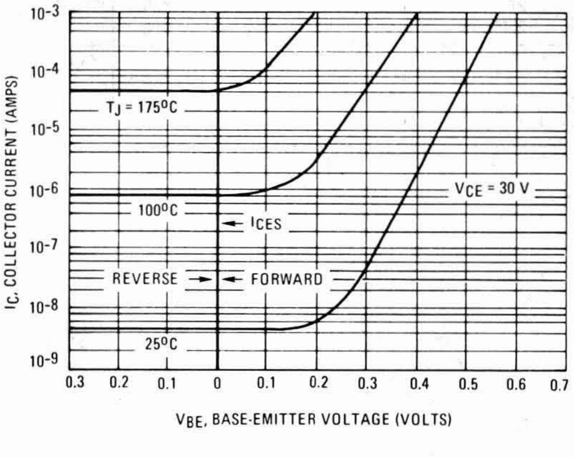
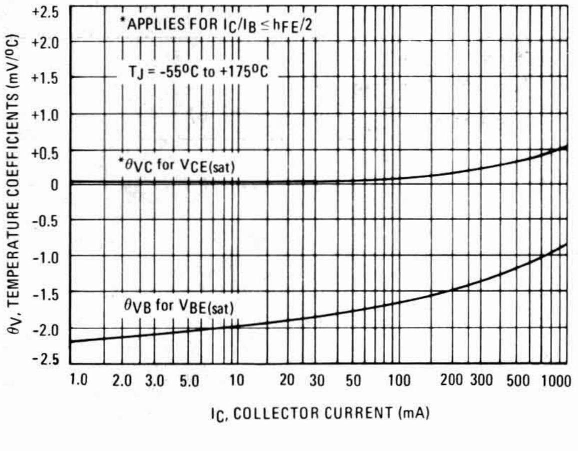
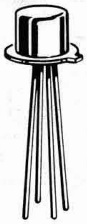


FIGURE 13 – TEMPERATURE COEFFICIENTS



2N5358 (SILICON)
thru
2N5364

Silicon N-channel junction field-effect transistors depletion mode (Type A) devices designed primarily for general-purpose amplifier applications.



CASE 20(3)
(TO-72)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Forward Gate Current	$I_{G(f)}$	10	mAdc
Reverse Gate-Source Voltage	$V_{GS(r)}$	40	Vdc
Drain-Gate Voltage	V_{DG}	40	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 2.0	mW mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Operating Junction Temperature Range	T_J	-65 to +175	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage ($I_G = 10\ \mu Adc$, $V_{DS} = 0$)		$V_{(BR)GSS}$	40	-	Vdc
Gate-Source Cutoff Voltage ($V_{DS} = 15$ Vdc, $I_D = 100$ nAdc)	2N5358	$V_{GS(off)}$	0.5	3.0	Vdc
	2N5359		0.8	4.0	
	2N5360		0.8	4.0	
	2N5361		1.0	6.0	
	2N5362		2.0	7.0	
	2N5363		2.5	8.0	
	2N5364		2.5	8.0	
Gate Reverse Current ($V_{GS} = 20$ Vdc, $V_{DS} = 0$)		I_{GSS}	-	0.1	nAdc
($V_{GS} = 20$ Vdc, $V_{DS} = 0$, $T_A = 150°C$)			-	0.1	μAdc

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Max	Unit
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current (V_{DS} = 15 Vdc, V_{GS} = 0)	2N5358	I_{DSS}	0.5	1.0	mAdc
	2N5359		0.8	1.6	
	2N5360		1.5	3.0	
	2N5361		2.5	5.0	
	2N5362		4.0	8.0	
	2N5363		7.0	14	
	2N5364		9.0	18	
Gate-Source Voltage (V_{DS} = 15 Vdc, I_D = 50 μAdc)	2N5358	V_{GS}	0.3	1.5	Vdc
(V_{DS} = 15 Vdc, I_D = 80 μAdc)	2N5359		0.4	2.0	
(V_{DS} = 15 Vdc, I_D = 150 μAdc)	2N5360		0.5	2.5	
(V_{DS} = 15 Vdc, I_D = 250 μAdc)	2N5361		1.0	5.0	
(V_{DS} = 15 Vdc, I_D = 400 μAdc)	2N5362		1.3	5.0	
(V_{DS} = 15 Vdc, I_D = 700 μAdc)	2N5363		2.0	6.0	
(V_{DS} = 15 Vdc, I_D = 900 μAdc)	2N5364		2.0	6.0	
SMALL-SIGNAL CHARACTERISTICS					
Forward Transadmittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	2N5358	$\|y_{fs}\|$	1000	3000	μmhos
	2N5359		1200	3600	
	2N5360		1400	4200	
	2N5361		1500	4500	
	2N5362		2000	5500	
	2N5363		2500	6000	
	2N5364		2700	6500	
Forward Transconductance (V_{DS} = 15 Vdc, V_{GS} = 0 Vdc, f = 100 MHz)	2N5358	$Re(y_{fs})$	800	-	μmhos
	2N5359		900	-	
	2N5360		1400	-	
	2N5361		1700	-	
	2N5362		1900	-	
	2N5363		2100	-	
	2N5364		2200	-	
Output Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	2N5358, 2N5359	$\|y_{os}\|$	-	10	μmhos
	2N5360, 2N5361			20	
	2N5362, 2N5363			40	
	2N5364			60	
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{iss}	-	6.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{rss}	-	2.0	pF
Common-Source Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_G = 1.0 Megohm, f = 100 Hz, BW = 1.0 Hz)		NF	-	2.5	dB
Equivalent Short-Circuit Input Noise Voltage (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 Hz, BW = 1.0 Hz)		e_n	-	115	nV/$\sqrt{\text{Hz}}$

DRAIN CURRENT versus GATE SOURCE VOLTAGE

FIGURE 1 – 2N5358

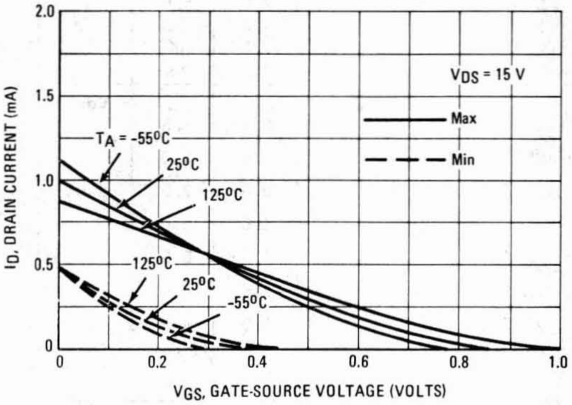


FIGURE 3 – 2N5359

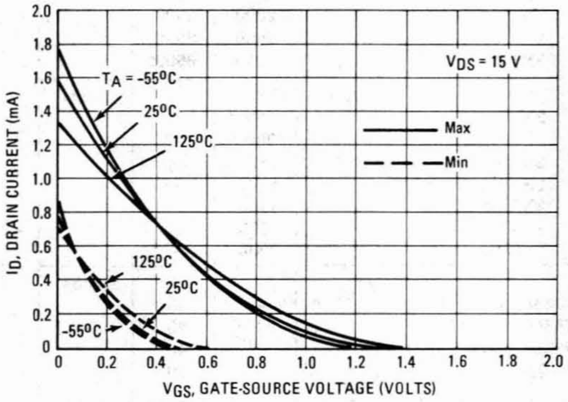
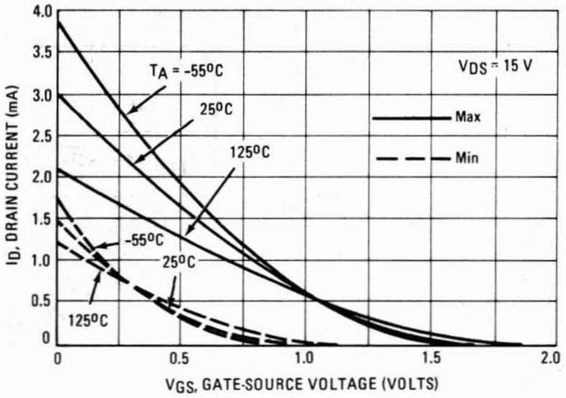


FIGURE 5 – 2N5360



FORWARD TRANSFER ADMITTANCE versus DRAIN CURRENT

FIGURE 2 – 2N5358

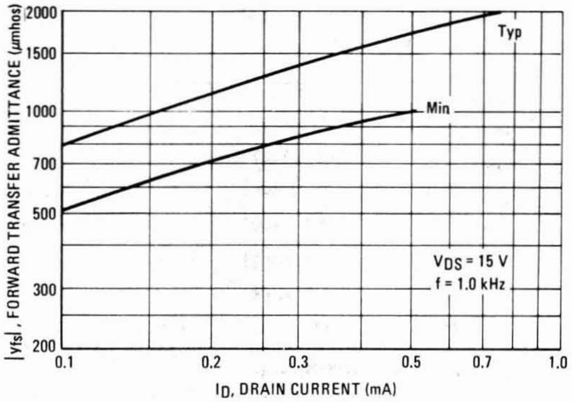


FIGURE 4 – 2N5359

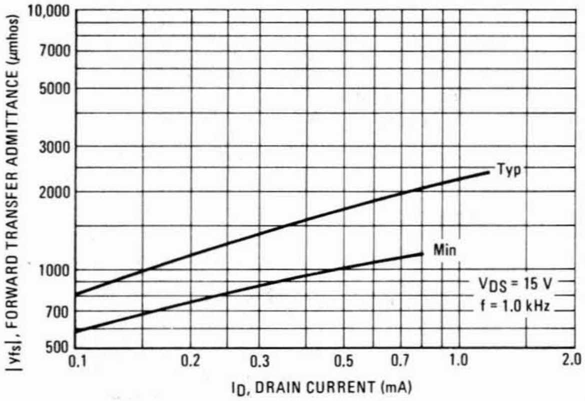
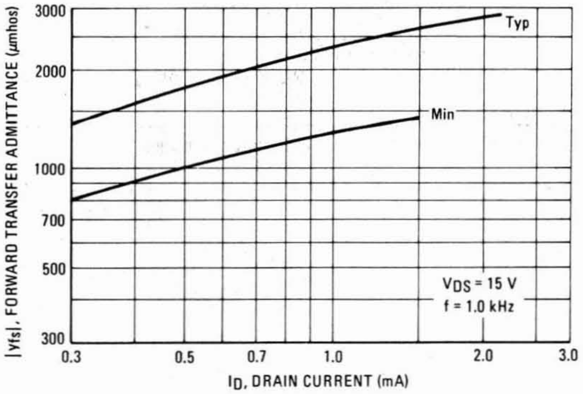


FIGURE 6 – 2N5360



DRAIN CURRENT versus GATE SOURCE VOLTAGE

FIGURE 7 – 2N5361

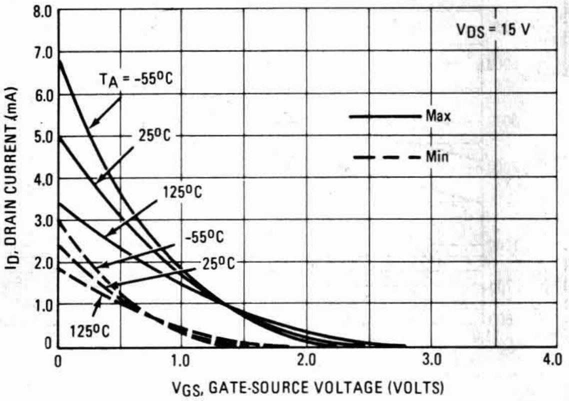


FIGURE 9 – 2N5362

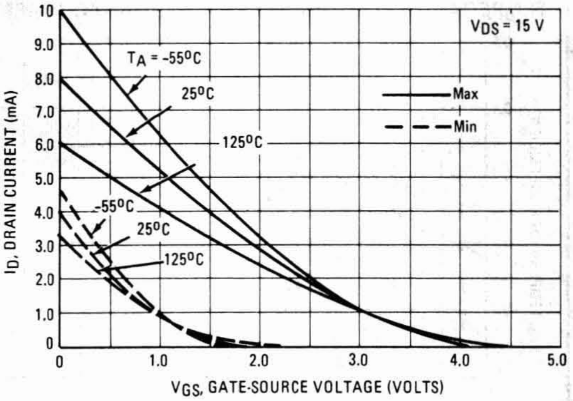
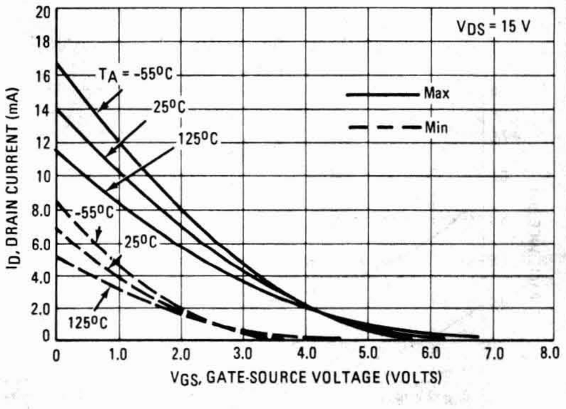


FIGURE 11 – 2N5363



FORWARD TRANSFER ADMITTANCE versus DRAIN CURRENT

FIGURE 8 – 2N5361

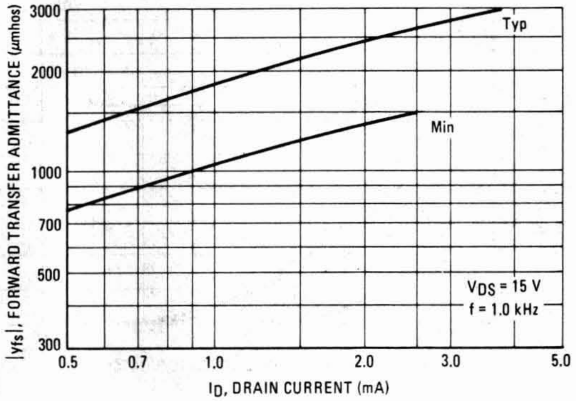


FIGURE 10 – 2N5362

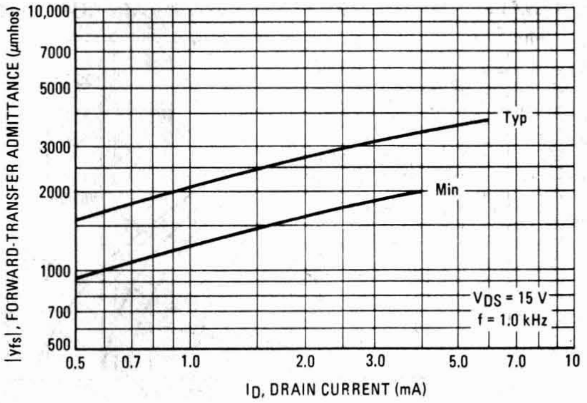
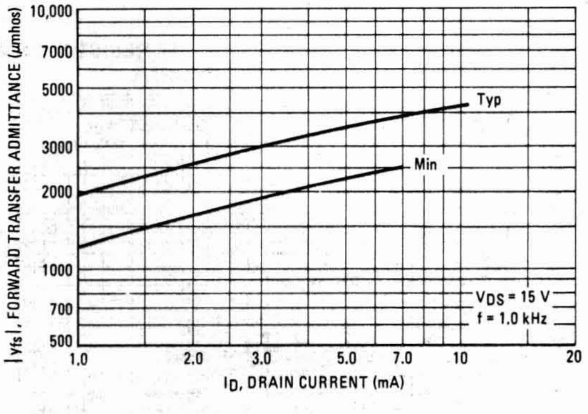
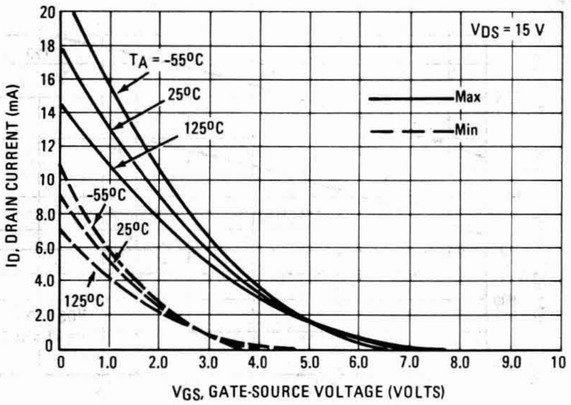


FIGURE 12 – 2N5363



DRAIN CURRENT versus GATE-SOURCE VOLTAGE
FIGURE 13 – 2N5364



FORWARD TRANSFER ADMITTANCE versus DRAIN CURRENT
FIGURE 14 – 2N5364

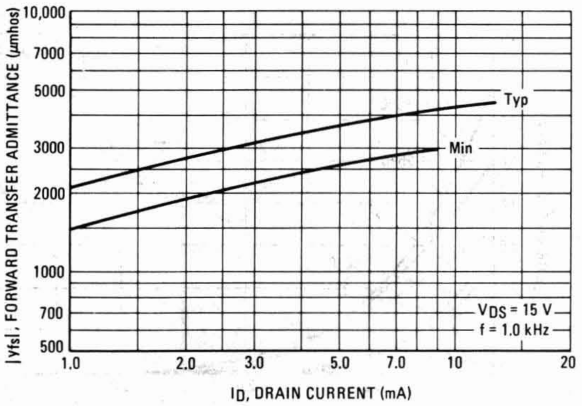


FIGURE 15 – TYPICAL DRAIN CURRENT TEMPERATURE COEFFICIENT versus DRAIN CURRENT

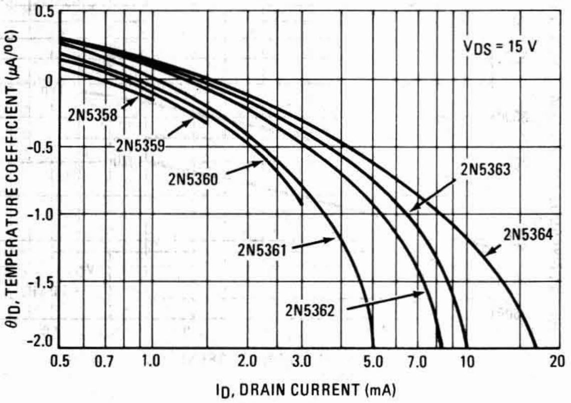


FIGURE 16 – TYPICAL FORWARD TRANSADMITTANCE TEMPERATURE COEFFICIENT versus DRAIN CURRENT

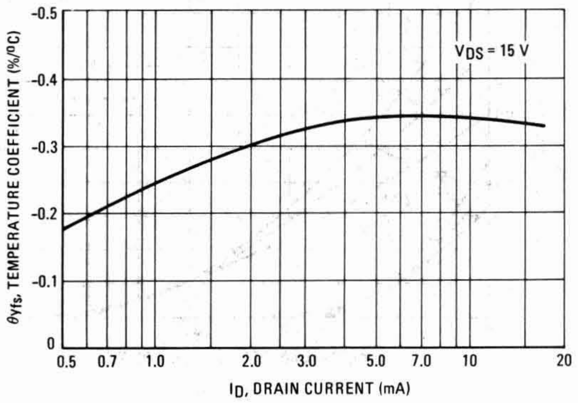


FIGURE 17 – TYPICAL OUTPUT RESISTANCE versus DRAIN CURRENT

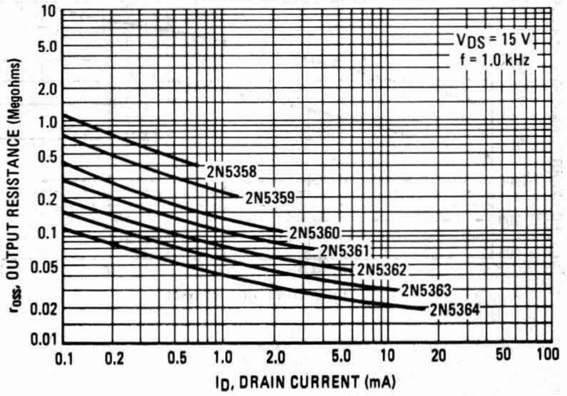


FIGURE 18 – TYPICAL CAPACITANCE versus VOLTAGE

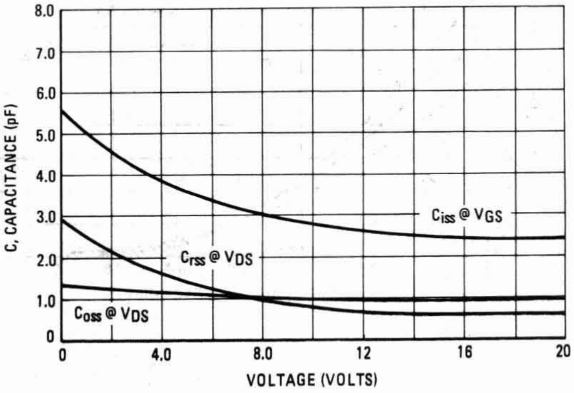


FIGURE 19 – TYPICAL NOISE FIGURE versus FREQUENCY

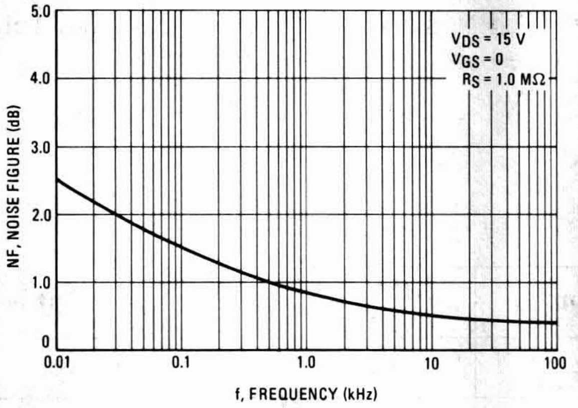


FIGURE 20 – TYPICAL NOISE FIGURE versus SOURCE RESISTANCE

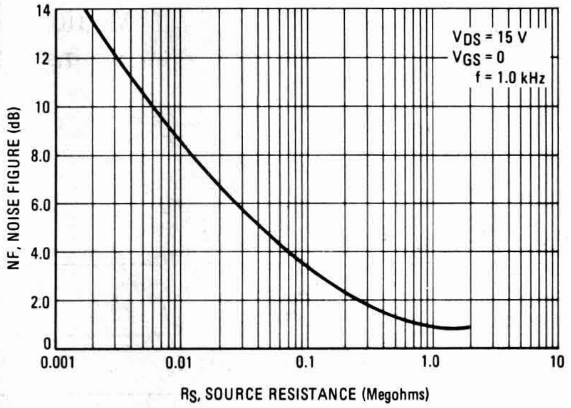
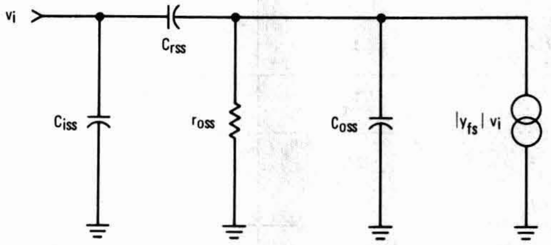


FIGURE 21 – EQUIVALENT LOW FREQUENCY CIRCUIT



Common Source
y Parameters for Frequencies
Below 30 MHz

$y_{is} = j\omega C_{iss}$

$y_{os} = j\omega C_{osp}{}^{*} + 1/r_{oss}$

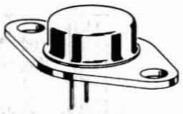
$y_{fs} = |y_{fs}|$

$y_{rs} = -j\omega C_{rss}$

*C_{osp} is C_{oss} in parallel with Series Combination of C_{iss} and C_{rss}.

NOTE: Graphical data is presented for dc conditions. Tabular data is given for pulsed conditions (Pulse Width = 630 ms, Duty Cycle = 10%).

2N5427 (SILICON)
thru
2N5430



CASE 80
(TO-66)

Medium-power NPN silicon transistors designed for switching and wide-band amplifier applications.

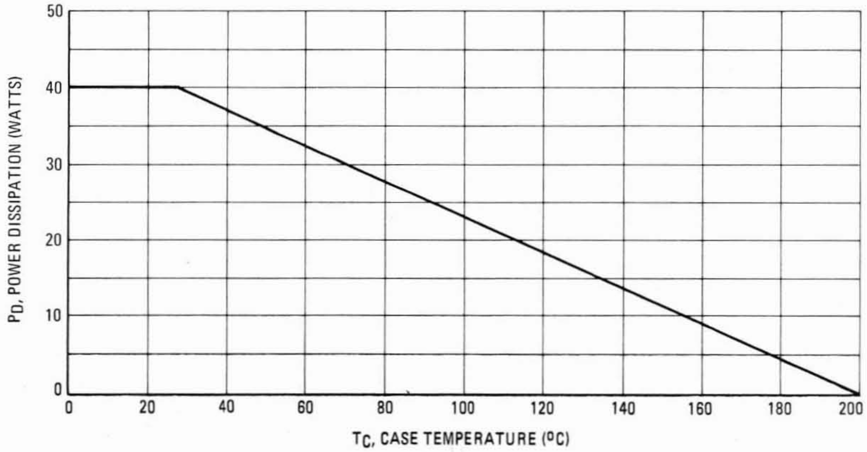
MAXIMUM RATINGS

Rating	Symbol	2N5427 2N5428	2N5429 2N5430	Unit
Collector-Emitter Voltage	V_{CEO}	80	100	Vdc
Collector-Base Voltage	V_{CB}	80	100	Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current — Continuous	I_C	7.0		Adc
Base Current	I_B	1.0		Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	40 228		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	4.37	°C/W

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 5. All limits are applicable and must be observed.

2N5427 thru 2N5430 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 50 mAdc, I_B = 0) 2N5427, 2N5428	-	$BV_{CEO(sus)}$*	80	-	Vdc
2N5429, 2N5430			100	-	
Collector Cutoff Current (V_{CE} = 75 Vdc, I_B = 0) 2N5427, 2N5428		I_{CEO}	-	100	μAdc
(V_{CE} = 90 Vdc, I_B = 0) 2N5429, 2N5430			-	100	
Collector Cutoff Current (V_{CE} = 75 Vdc, $V_{EB(off)}$ = 1.5 Vdc) 2N5427, 2N5428	12	I_{CEX}	-	10	μAdc
(V_{CE} = 90 Vdc, $V_{EB(off)}$ = 1.5 Vdc) 2N5429, 2N5430			-	10	
(V_{CE} = 75 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C) 2N5427, 2N5428			-	1.0	mAdc
(V_{CE} = 90 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C) 2N5429, 2N5430			-	1.0	
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)	-	I_{CBO}	-	10	μAdc
Emitter Cutoff Current (V_{BE} = 6.0 Vdc, I_C = 0)	-	I_{EBO}	-	100	μAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 500 mAdc, V_{CE} = 2.0 Vdc) 2N5427, 2N5429	8	h_{FE}*	30	-	-
2N5428, 2N5430			60	-	
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc) 2N5427, 2N5429			30	120	
2N5428, 2N5430			60	240	
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc) 2N5427, 2N5429			20	-	
2N5428, 2N5430			40	-	
Collector-Emitter Saturation Voltage* (I_C = 2.0 Adc, I_B = 0.2 Adc)	9, 11, 13	$V_{CE(sat)}$*	-	0.7	Vdc
(I_C = 7.0 Adc, I_B = 0.7 Adc)			-	1.2	
Base-Emitter Saturation Voltage* (I_C = 2.0 Adc, I_B = 0.2 Adc)	11, 13	$V_{BE(sat)}$*	-	1.2	Vdc
(I_C = 7.0 Adc, I_B = 0.7 Adc)			-	2.0	
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 500 mAdc, V_{CE} = 10 Vdc, f = 10 MHz)	-	f_T	30	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	7	C_{ob}	-	250	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 100 kHz)	7	C_{ib}	-	1,000	pF
SWITCHING CHARACTERISTICS					
Delay Time (V_{CC} = 40 Vdc, $V_{EB(off)}$ = 3.0 Vdc, I_C = 2.0 Adc, I_{B1} = 200 mAdc)	2,3	t_d	-	100	ns
Rise Time		t_r	-	100	ns
Storage Time (V_{CC} = 40 Vdc, I_C = 2.0 Adc, I_{B1} = I_{B2} = 200 mAdc)	2,6	t_s	-	2.0	μs
Fall Time		t_f	-	200	ns

* Pulse Test: Pulse Width ≈ 300 μs, Duty Cycle ≈ 2.0%.

FIGURE 2 – SWITCHING TIME TEST CIRCUIT

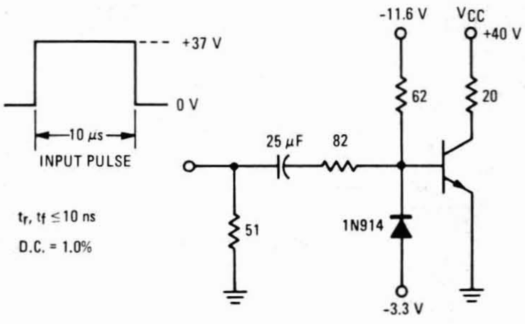


FIGURE 3 – TURN-ON TIME

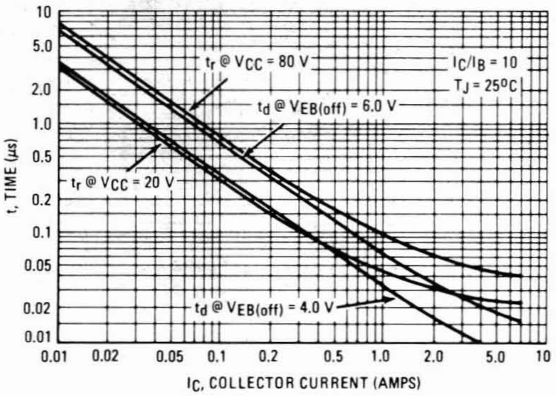


FIGURE 4 – THERMAL RESPONSE

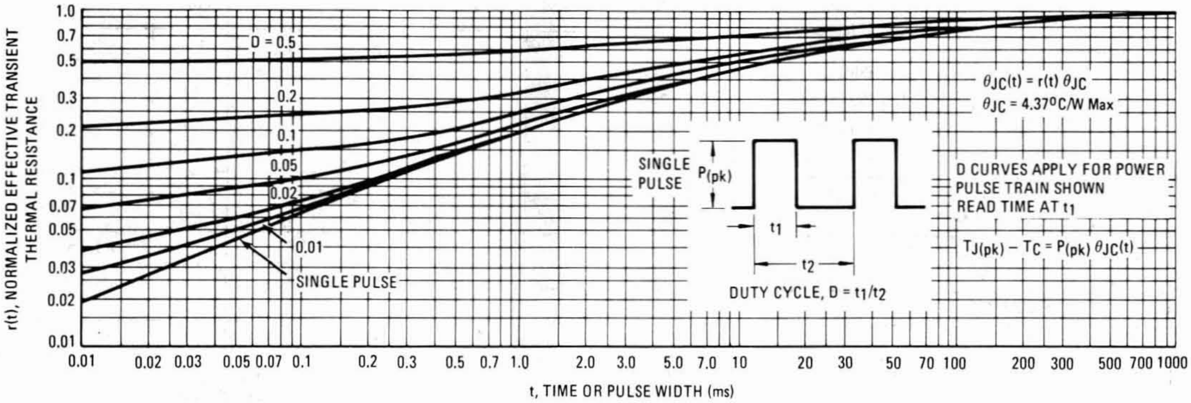
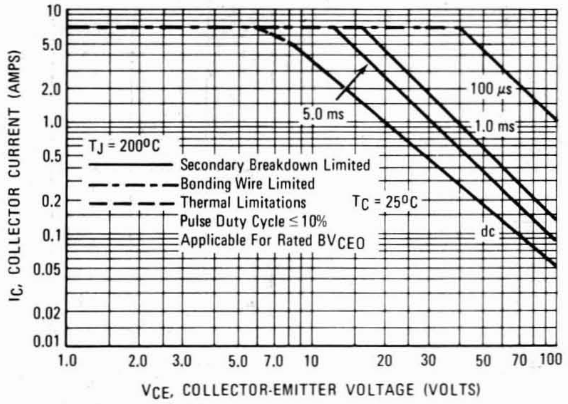


FIGURE 5 – ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)}$ = 200°C; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq$ 200°C. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 – TURN-OFF TIME

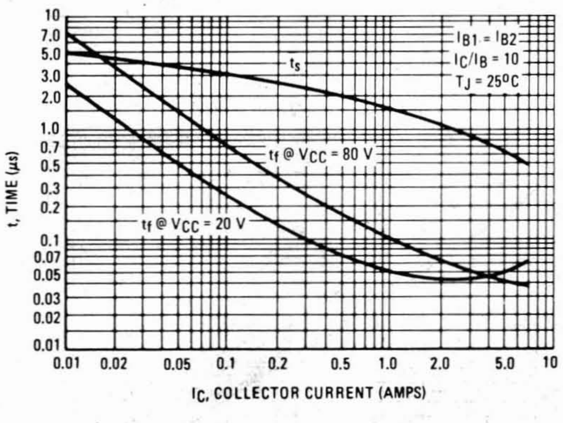


FIGURE 7 – CAPACITANCE versus VOLTAGE

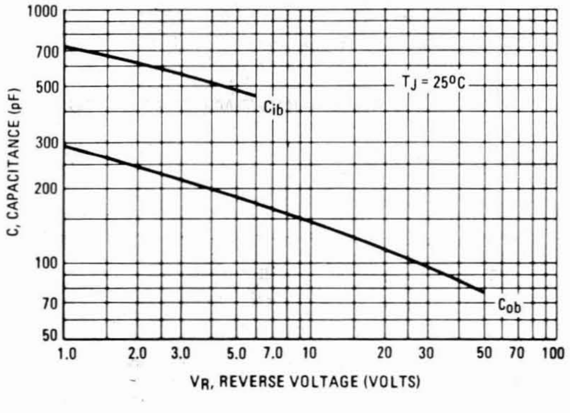


FIGURE 8 – DC CURRENT GAIN

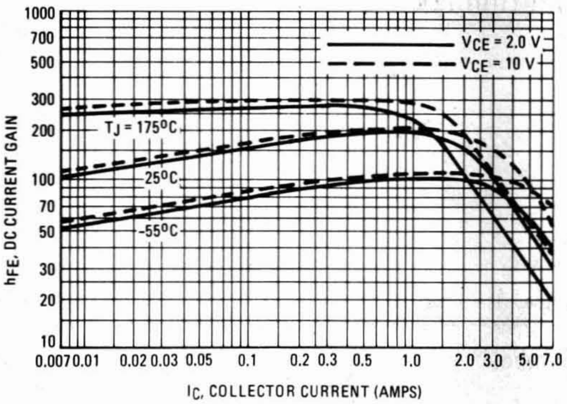


FIGURE 9 – COLLECTOR SATURATION REGION

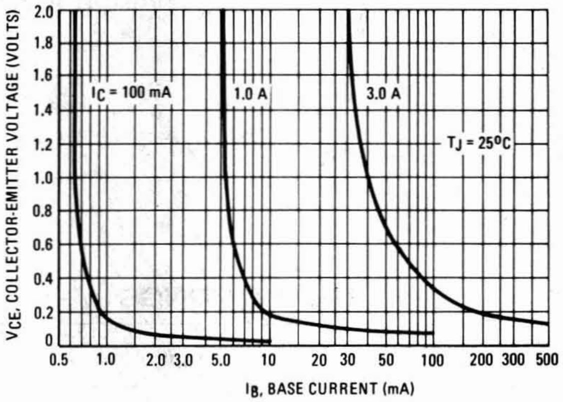


FIGURE 10 – EFFECTS OF BASE-EMITTER RESISTANCE

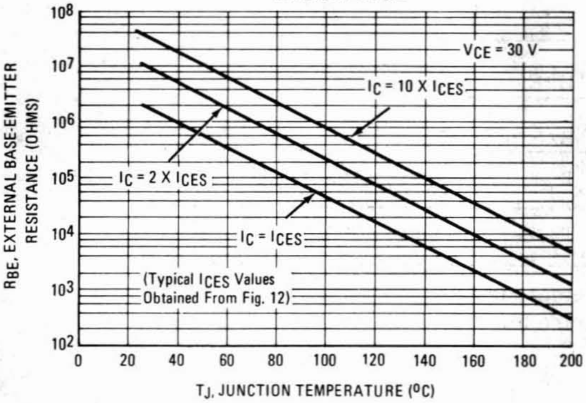


FIGURE 11 – "ON" VOLTAGES

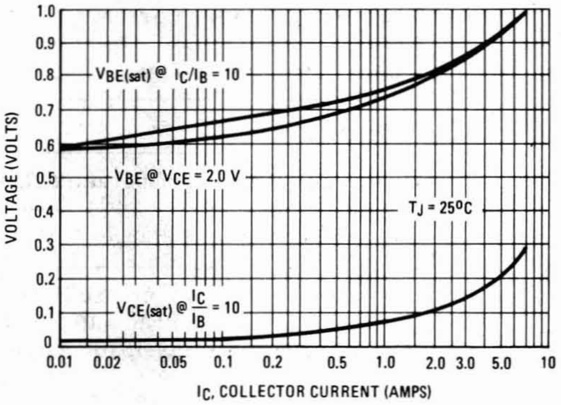


FIGURE 12 – COLLECTOR CUT-OFF REGION

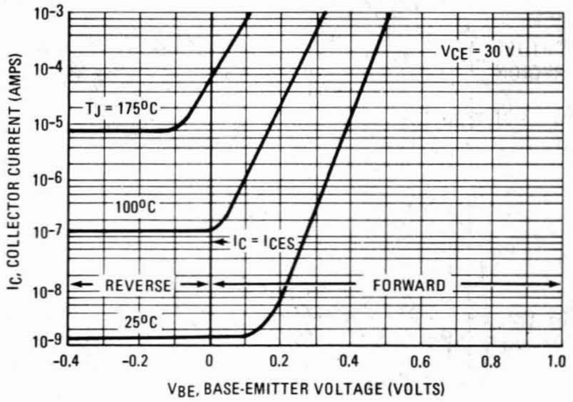
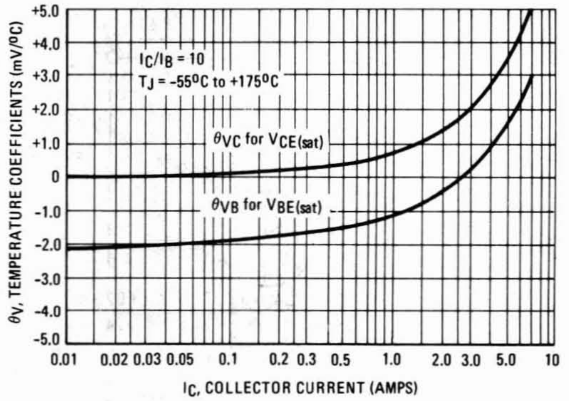


FIGURE 13 – TEMPERATURE COEFFICIENTS



2N5431 (SILICON)

CASE 22A
(TO-18 Modified)
Lead 3 connected to case

Silicon annular unijunction transistors characterized primarily for low interbase-voltage operation in sensing, pulse triggering, and timing circuits.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	P_D*	300	mW
RMS Emitter Current	I_e	50	mA
Peak-Pulse Emitter Current **	i_e**	1.5	A
Emitter Reverse Voltage	V_{B2E}	30	V
Interbase Voltage ‡	V_{B2B10}‡	35	V
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

*Derate 3.0 mW/°C increase in ambient temperature.
**Duty Cycle ≤ 1.0%, PRR = 10 PPS (see figure 5).
‡Based upon power dissipation at T_A = 25°C.

FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

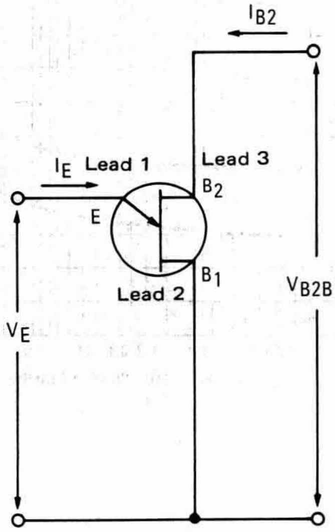
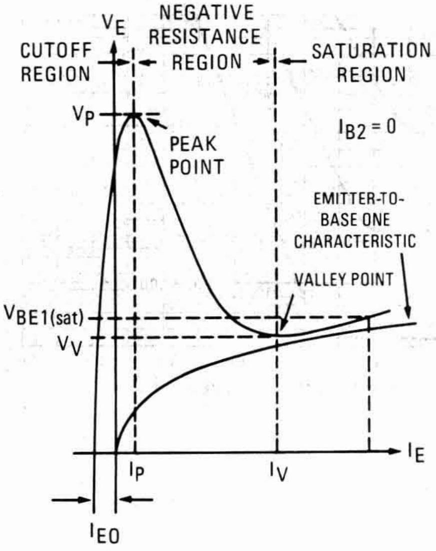


FIGURE 2 — STATIC EMITTER CHARACTERISTICS CURVES



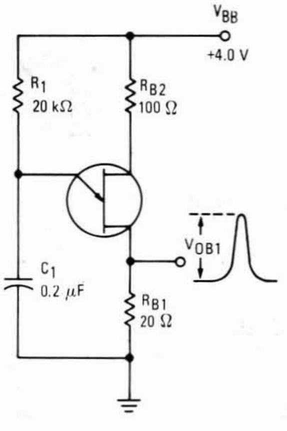
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
Intrinsic Standoff Ratio① (V_{B2B1} = 10 V)	4	η①	0.72	0.80	-
Interbase Resistance (V_{B2B1} = 3.0 V, I_E = 0)		R_{BB}	6.0	8.5	kΩ
Interbase Resistance Temperature Coefficient (V_{B2B1} = 3.0 V, I_E = 0, T_A = 0 to 100°C)		αR_{BB}	0.4	0.8	%/°C
Emitter Saturation Voltage ② (V_{B2B1} = 10 V, I_E = 50 mA)		$V_{EB1(sat)}$②	-	3.0	V
Modulated Interbase Current (V_{B2B1} = 10 V, I_E = 50 mA)		$I_{B2(mod)}$	5.0	30	mA
Emitter Reverse Current (V_{B2E} = 30 V, I_{B1} = 0)		I_{EB2O}	-	10	nA
Peak-Point Emitter Current (V_{B2B1} = 25 V) (V_{B2B1} = 4.0 V)		I_P	- -	0.4 4.0	µA
Valley-Point Current ② (V_{B2B1} = 20 V, R_{B2} = 100 ohms)		I_V②	2.0	-	mA
Base-One Peak Pulse Voltage (V_{BB} = 4.0 volts)	3	V_{OB1}	1.0	-	V

①η, Intrinsic standoff ratio, is defined in terms of the peak-point voltage, V_P, by means of the equation: $V_P = \eta V_{B2B10} + V_F$, where V_F is about 0.49 volt at 25°C @ I_F = 10 µA and decreases with temperature at about 2.5 mV/°C. The test circuit is shown in Figure 4. Components R_1, C_1, and the UJT form a relaxation oscillator; the remaining circuitry serves as a peak-voltage detector. The forward drop of Diode D_1 compensates for V_F. To use, the "cal" button is pushed, and R_3 is adjusted to make the current meter, M_1, read full scale. When the "cal" button is released, the value of η is read directly from the meter, if full scale on the meter reads 1.0.

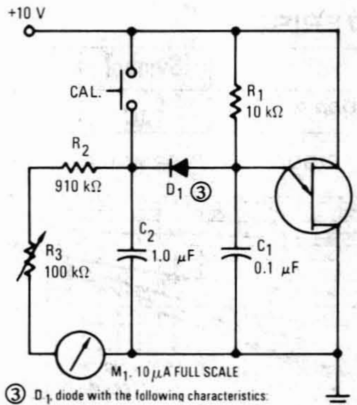
② Use pulse techniques: PW ≈ 300 µs, Duty Cycle ≤ 2.0% to avoid internal heating, which may result in erroneous readings.

FIGURE 3 — V_{OB1} TEST CIRCUIT



V_{BB}
+4.0 V
R_1 20 kΩ
R_{B2} 100 Ω
V_{OB1}
C_1 0.2 µF
R_{B1} 20 Ω

FIGURE 4 — η TEST CIRCUIT

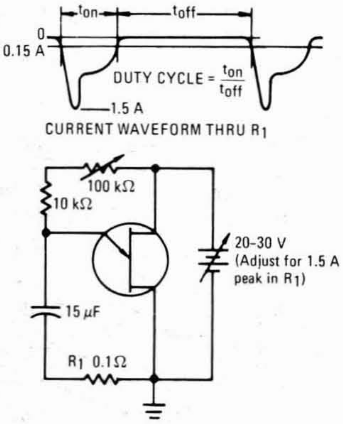


+10 V
CAL.
R_1 10 kΩ
R_2 910 kΩ
D_1 ③
R_3 100 kΩ
C_2 1.0 µF
C_1 0.1 µF
M_1, 10µA FULL SCALE

③ D_1, diode with the following characteristics:
V_F = 0.49 V @ I_F = 10 µA
I_R ≤ 2.0 µA @ V_R = 20 V

FIGURE 5 — PRR TEST CIRCUIT AND WAVEFORM

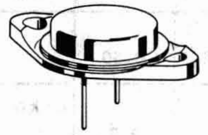
DUTY CYCLE ≤ 1.0%, PRR ≤ 10 PPS



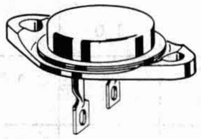
t_{on}
t_{off}
0
0.15 A
DUTY CYCLE = $\frac{t_{on}}{t_{off}}$
1.5 A
CURRENT WAVEFORM THRU R_1
100 kΩ
10 kΩ
20-30 V (Adjust for 1.5 A peak in R_1)
15 µF
R_1 0.1Ω

2N5435 (GERMANIUM)
thru
2N5440

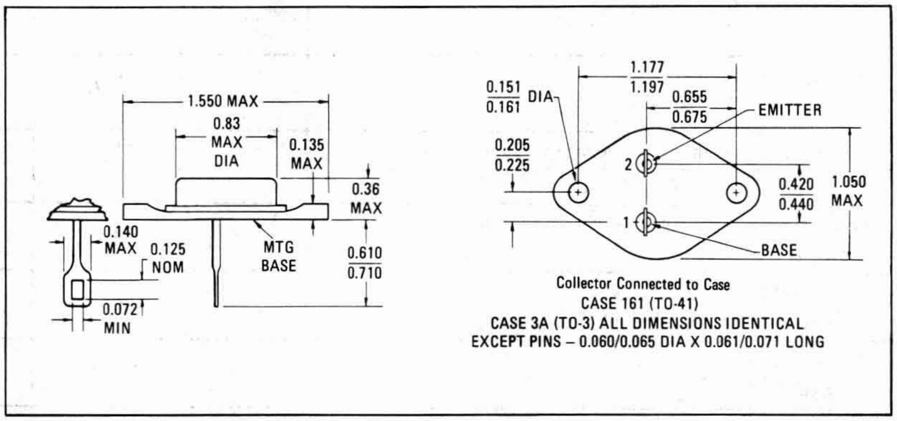
PNP germanium power switching transistors designed for high-current, fast-switching applications requiring low saturation voltage and excellent safe operating area.



CASE 3A
TO-3 Package
2N5435/5440



CASE 161
TO-41 Package
MP5435/5440


1.550 MAX
0.83 MAX DIA
0.135 MAX
0.36 MAX
0.140 MAX
0.125 NOM
MTG BASE
0.610
0.710
0.072 MIN
0.151
0.161
DIA
1.177
1.197
0.655
0.675
EMITTER
0.205
0.225
2
0.420
0.440
1.050 MAX
1
BASE

Collector Connected to Case
CASE 161 (TO-41)
CASE 3A (TO-3) ALL DIMENSIONS IDENTICAL
EXCEPT PINS – 0.060/0.065 DIA X 0.061/0.071 LONG

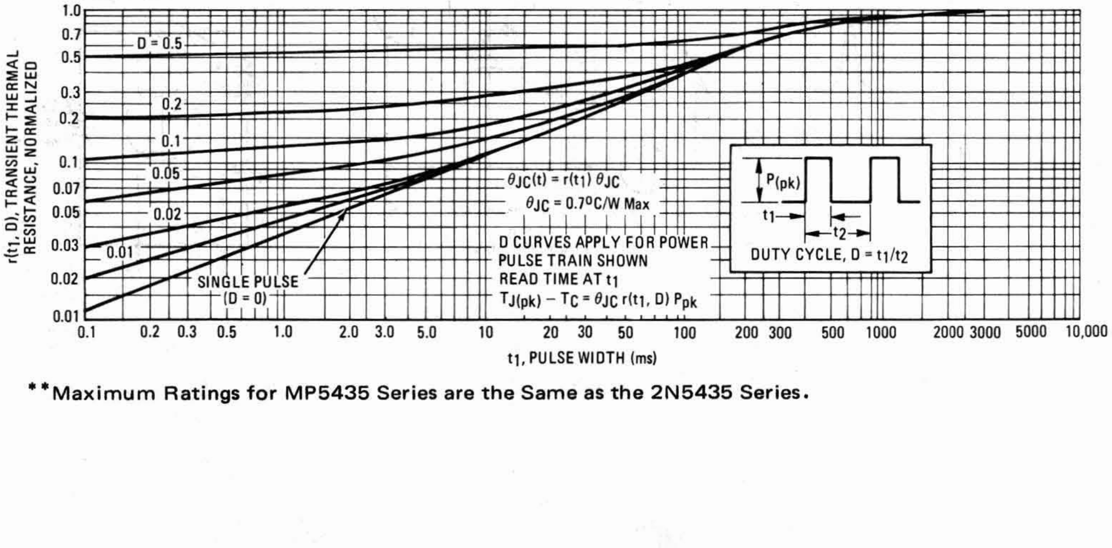
MAXIMUM RATINGS **

Rating	Symbol	2N5435 2N5438	2N5436 2N5439	2N5437 2N5440	Unit
Collector-Emitter Voltage	V_{CEO}	60	90	120	Vdc
Collector-Base Voltage	V_{CB}	80	110	140	Vdc
Emitter-Base Voltage	V_{EB}	2.5			Vdc
Collector Current — Continuous	I_C	60			Adc
Base Current — Continuous	I_B	12			Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	120 1.43			Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.7	°C/W

FIGURE 1 – THERMAL RESPONSE



**Maximum Ratings for MP5435 Series are the Same as the 2N5435 Series.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)**

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 0.1 Adc, I_B = 0)	2N5435, 2N5438 2N5436, 2N5439 2N5437, 2N5440	BV_{CEO}	60 90 120	- - -	Vdc
Collector Cutoff Current (V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc) (V_{CE} = 110 Vdc, $V_{BE(off)}$ = 0.2 Vdc) (V_{CE} = 140 Vdc, $V_{BE(off)}$ = 0.2 Vdc) (V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = +85°C) (V_{CE} = 110 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = +85°C) (V_{CE} = 140 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = +85°C)	2N5435, 2N5438 2N5436, 2N5439 2N5437, 2N5440 2N5435, 2N5438 2N5436, 2N5439 2N5437, 2N5440	I_{CEX}	- - - - - -	10 10 10 30 30 30	mAdc
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)		I_{CBO}	-	200	μAdc
Emitter Cutoff Current (V_{BE} = 2.5 Vdc, I_C = 0)		I_{EBO}	-	500	mAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 25 Adc, V_{CE} = 2.0 Vdc) (I_C = 60 Adc, V_{CE} = 2.0 Vdc)	2N5435, 2N5436, 2N5437 2N5438, 2N5439, 2N5440 2N5435, 2N5436, 2N5437 2N5438, 2N5439, 2N5440	h_{FE}*	20 40 10 15	60 120 - -	-
Collector-Emitter Saturation Voltage* (I_C = 60 Adc, I_B = 6.0 Adc)	2N5435, 2N5436, 2N5437 2N5438, 2N5439, 2N5440	$V_{CE(sat)}$*	- -	0.75 0.50	Vdc
Base-Emitter Saturation Voltage* (I_C = 60 Adc, I_B = 6.0 Adc)	2N5435, 2N5436, 2N5437 2N5438, 2N5439, 2N5440	$V_{BE(sat)}$*	- -	1.2 0.9	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain–Bandwidth Product (I_C = 5.0 Adc, V_{CE} = 5.0 Vdc, f = 100 kHz)		f_T	350	-	kHz
SWITCHING CHARACTERISTICS					
Rise Time	(I_C = 25 Adc, I_{B1} = 2.5 Adc, I_{B2} = 2.5 Adc) (See Figure 4)	t_r	-	12	μs
Storage Time		t_s	-	10	μs
Fall Time		t_f	-	8.0	μs

**Electrical Characteristics for MP5435 series are the same as the 2N5435 series.

* To avoid excessive heating of the collector junction, perform test with pulse method.

FIGURE 2 – POWER-TEMPERATURE DERATING CURVE

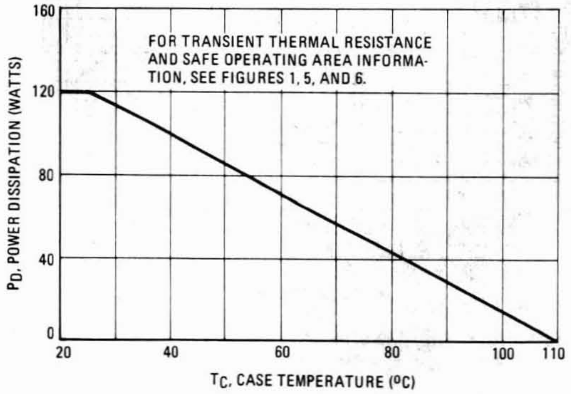


FIGURE 3 – SWITCHING TIMES

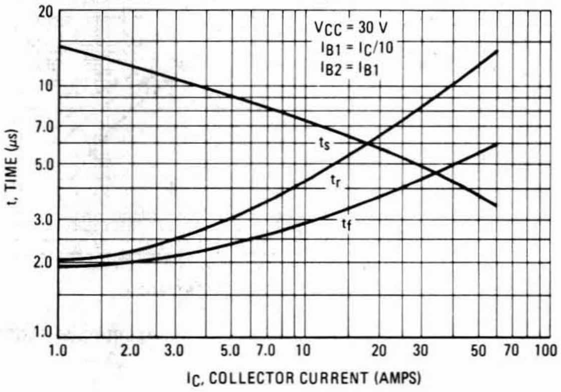


FIGURE 4 – SWITCHING TIME TEST CIRCUIT

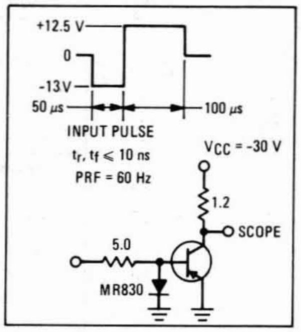
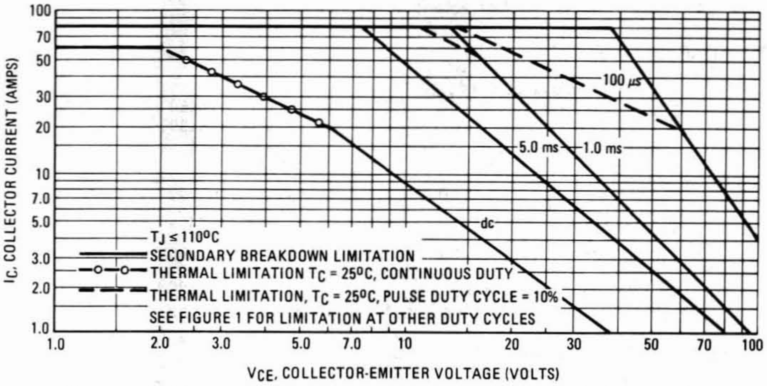

+12.5 V
0
-13 V
50 μs
100 μs
INPUT PULSE
t_r, t_f ≤ 10 ns
PRF = 60 Hz
V_{CC} = -30 V
1.2
SCOPE
5.0
MR830

FIGURE 5 – ACTIVE REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)} = 110°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles to 10% provided $T_{J(pk)} < 110°C$. $T_{J(pk)}$ may be calculated from the data in Figure 1. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 – CLAMPED INDUCTIVE SAFE OPERATING AREA

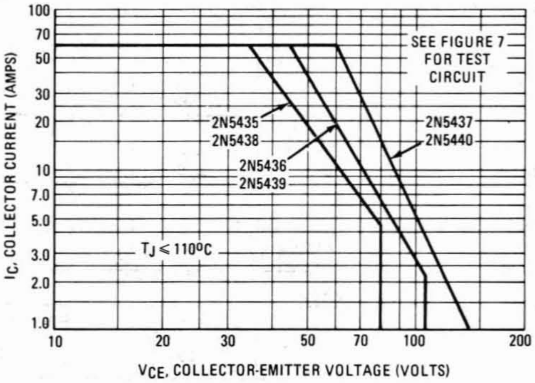
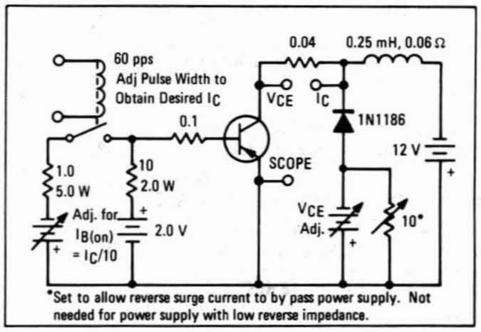


FIGURE 7 – CLAMPED INDUCTIVE SAFE OPERATING AREA TEST CIRCUIT


60 pps
Adj Pulse Width to Obtain Desired I_C
0.04
0.25 mH, 0.06 Ω
V_{CE}
I_C
1N1186
12 V
0.1
SCOPE
1.0
5.0 W
10
2.0 W
Adj. for $I_{B(on)}$ = I_C/10
2.0 V
V_{CE} Adj.
10*

*Set to allow reverse surge current to by pass power supply. Not needed for power supply with low reverse impedance.

FIGURE 8 – DC CURRENT GAIN

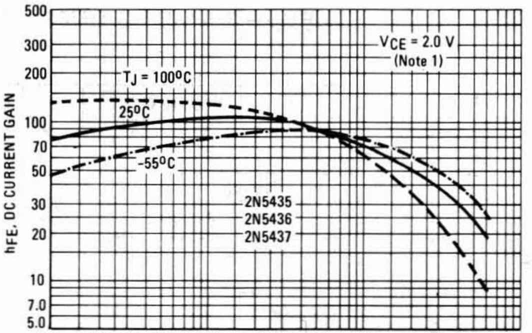
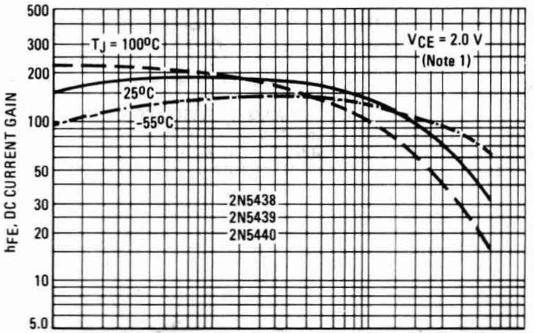


FIGURE 9 – DC CURRENT GAIN



NOTE 1: Data is obtained from pulse tests and adjusted to nullify the effect of I_{CBO}.

FIGURE 10 – COLLECTOR SATURATION REGION

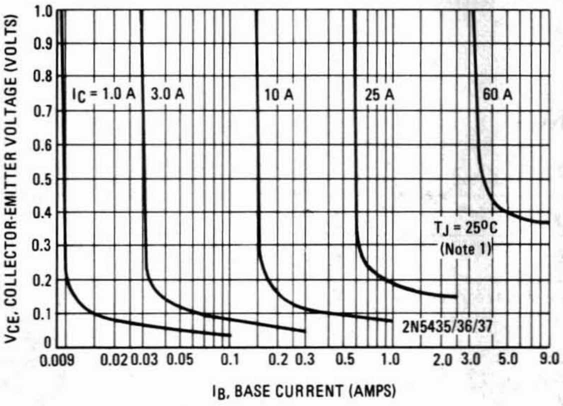


FIGURE 11 – COLLECTOR SATURATION REGION

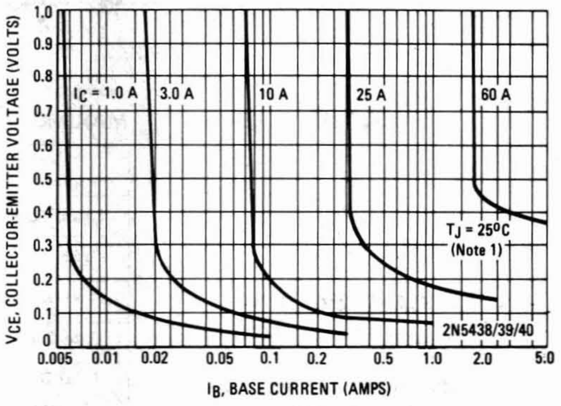


FIGURE 12 – EFFECTS OF BASE-EMITTER RESISTANCE

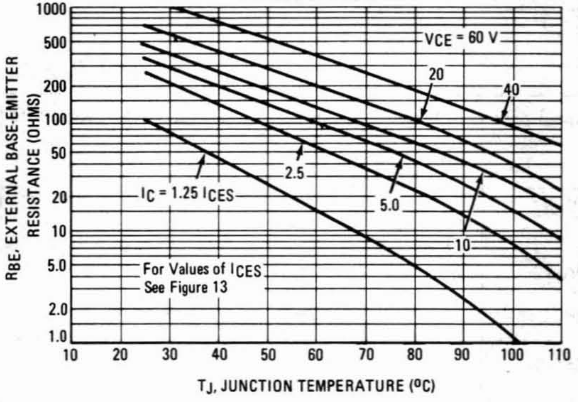


FIGURE 13 – COLLECTOR CUTOFF REGION

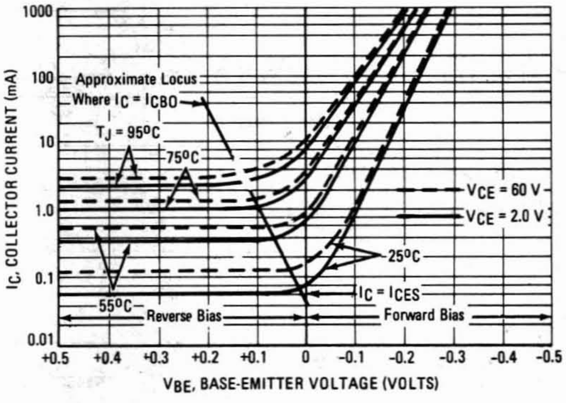


FIGURE 14 – "ON" VOLTAGES

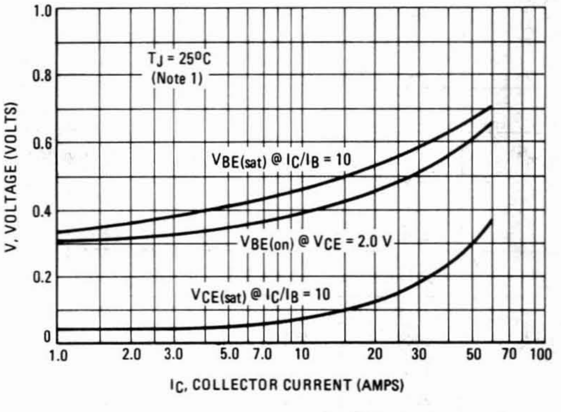
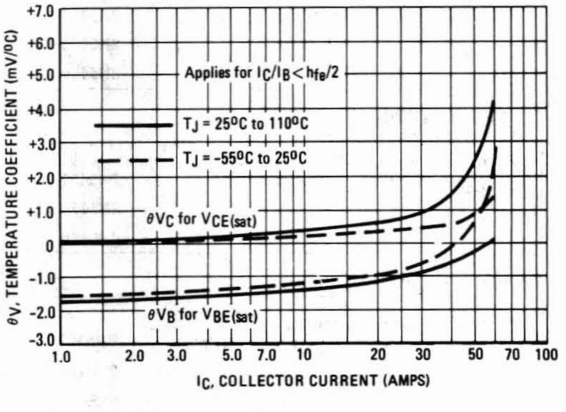
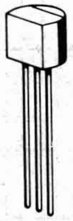


FIGURE 15 – TEMPERATURE COEFFICIENTS



2N5457 (SILICON)
2N5458
2N5459

Silicon N-channel junction field-effect transistors depletion mode (Type A) designed for general-purpose audio and switching applications.



CASE 29 (5)
(TO-92)

Drain and source may be interchanged.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	25	Vdc
Reverse Gate-Source Voltage	$V_{GS(r)}$	25	Vdc
Gate Current	I_G	10	mAdc
Total Device Dissipation @ $T_A = 25°C$	P_D	310	mW
Derate above 25°C		2.82	mW/°C
Operating Junction Temperature	T_J	135	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

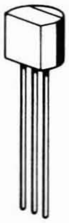
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage ($I_G = -10\mu$Adc, $V_{DS} = 0$)	BV_{GSS}	25	—	—	Vdc
Gate Reverse Current (V_{GS} = -15 Vdc, V_{DS} = 0)	I_{GSS}	—	—	1.0	nAdc
(V_{GS} = -15 Vdc, V_{DS} = 0, T_A = 100°C)		—	—	200	
Gate-Source Cutoff Voltage (V_{DS} = 15 Vdc, I_D = 10 nAdc) 2N5457	$V_{GS(off)}$	0.5	—	6.0	Vdc
2N5458		1.0	—	7.0	
2N5459		2.0	—	8.0	
Gate-Source Voltage (V_{DS} = 15 Vdc, I_D = 100 μAdc) 2N5457	V_{GS}	—	2.5	—	Vdc
(V_{DS} = 15 Vdc, I_D = 200 μAdc) 2N5458		—	3.5	—	
(V_{DS} = 15 Vdc, I_D = 400 μAdc) 2N5459		—	4.5	—	
ON CHARACTERISTICS					
Zero-Gate-Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0) 2N5457	I_{DSS}*	1.0	3.0	5.0	mAdc
2N5458		2.0	6.0	9.0	
2N5459		4.0	9.0	16	
DYNAMIC CHARACTERISTICS					
Forward Transfer Admittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 kHz) 2N5457	$\|y_{fs}\|$*	1000	3000	5000	μmhos
2N5458		1500	4000	5500	
2N5459		2000	4500	6000	
Output Admittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 kHz)	$\|y_{os}\|$*	—	10	50	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)	C_{iss}	—	4.5	7.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)	C_{rss}	—	1.5	3.0	pF

*Pulse Test: Pulse Width ≤ 630 ms; Duty Cycle ≤ 10%

2N5460 (SILICON)
thru
2N5465

P-channel depletion mode (Type A) junction field-effect transistors designed for use in general-purpose amplifier applications.



CASE 29(7)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	2N5460 2N5461 2N5462	2N5463 2N5464 2N5465	Unit
Drain-Gate Voltage	V_{DG}	40	60	Vdc
Reverse Gate-Source Voltage	$V_{GS(r)}$	40	60	Vdc
Forward Gate Current	$I_{G(f)}$	10		mAdc
Total Device Dissipation @ T_A = 25°C	P_D	310		mW
Derate above 25°C		2.82		mW/°C
Storage Temperature Range	T_{stg}	-65 to +150		°C
Operating Junction Temperature Range	T_J	-65 to +135		°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)	2N5460, 2N5461, 2N5462	$V_{(BR)GSS}$	40	-	-	Vdc
	2N5463, 2N5464, 2N5465		60	-	-	
Gate-Source Cutoff Voltage (V_{DS} = 15 Vdc, I_D = 1.0 μAdc)	2N5460, 2N5463	$V_{GS(off)}$	0.75	-	6.0	Vdc
	2N5461, 2N5464		1.0	-	7.5	
	2N5462, 2N5465		1.8	-	9.0	
Gate Reverse Current (V_{GS} = 20 Vdc, V_{DS} = 0)	2N5460, 2N5461, 2N5462	I_{GSS}	-	-	5.0	nAdc
(V_{GS} = 30 Vdc, V_{DS} = 0)	2N5463, 2N5464, 2N5465		-	-	5.0	
(V_{GS} = 20 Vdc, V_{DS} = 0, T_A = 100°C)	2N5460, 2N5461, 2N5462		-	-	1.0	μAdc
(V_{GS} = 30 Vdc, V_{DS} = 0, T_A = 100°C)	2N5463, 2N5464, 2N5465		-	-	1.0	
ON CHARACTERISTICS						
Zero-Gate Voltage Drain Current (V_{DS} = 15 Vdc, V_{GS} = 0)	2N5460, 2N5463	I_{DSS}	1.0	-	5.0	mAdc
	2N5461, 2N5464		2.0	-	9.0	
	2N5462, 2N5465		4.0	-	16	
Gate-Source Voltage (V_{DS} = 15 Vdc, I_D = 0.1 mAdc)	2N5460, 2N5463	V_{GS}	0.5	-	4.0	Vdc
(V_{DS} = 15 Vdc, I_D = 0.2 mAdc)	2N5461, 2N5464		0.8	-	4.5	
(V_{DS} = 15 Vdc, I_D = 0.4 mAdc)	2N5462, 2N5465		1.5	-	6.0	
SMALL-SIGNAL CHARACTERISTICS						
Forward Transadmittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	2N5460, 2N5463	$\|y_{fs}\|$	1000	-	4000	μmhos
	2N5461, 2N5464		1500	-	5000	
	2N5462, 2N5465		2000	-	6000	
Output Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)		$\|y_{os}\|$	-	-	75	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{iss}	-	5.0	7.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{rss}	-	1.0	2.0	pF
Common-Source Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_G = 1.0 Megohm, f = 100 Hz, BW = 1.0 Hz)		NF	-	1.0	2.5	dB
Equivalent Short-Circuit Input Noise Voltage (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 Hz, BW = 1.0 Hz)		e_n	-	60	115	nV/$\sqrt{Hz}$

DRAIN CURRENT versus GATE SOURCE VOLTAGE

FIGURE 1 – 2N5460 and 2N5463

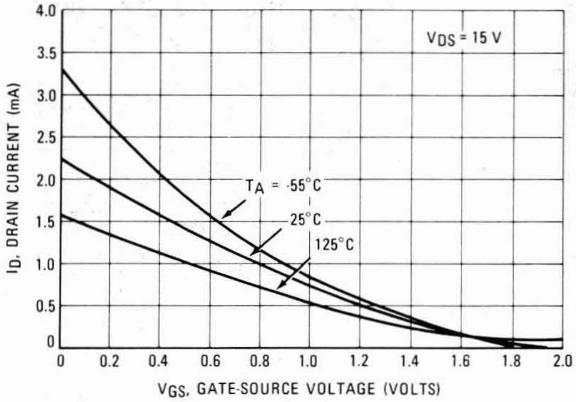


FIGURE 2 – 2N5461 and 2N5464

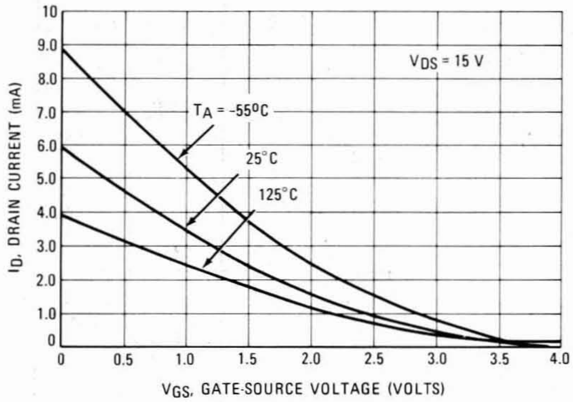
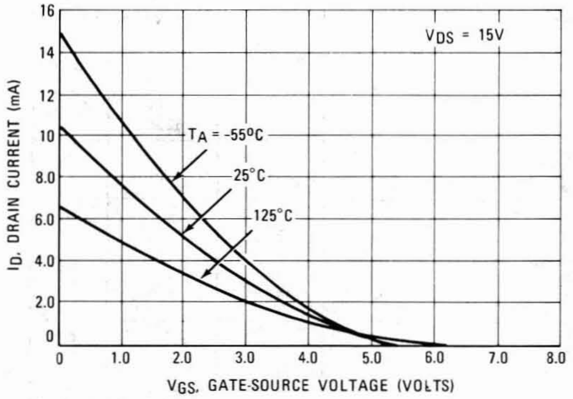


FIGURE 3 – 2N5462 and 2N5465



FORWARD TRANSFER ADMITTANCE versus DRAIN CURRENT

FIGURE 4 – 2N5460 and 2N5463

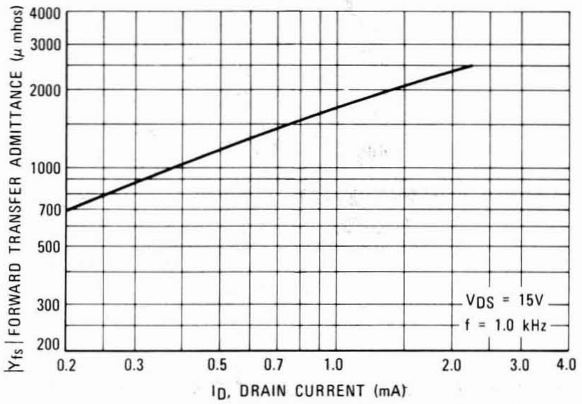


FIGURE 5 – 2N5461 and 2N5464

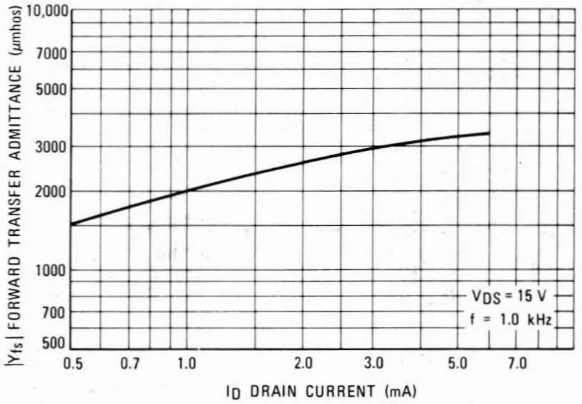


FIGURE 6 – 2N5462 and 2N5465

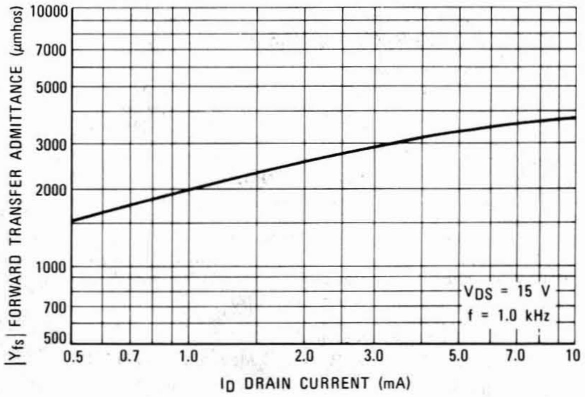


FIGURE 7 – OUTPUT RESISTANCE VERSUS DRAIN CURRENT

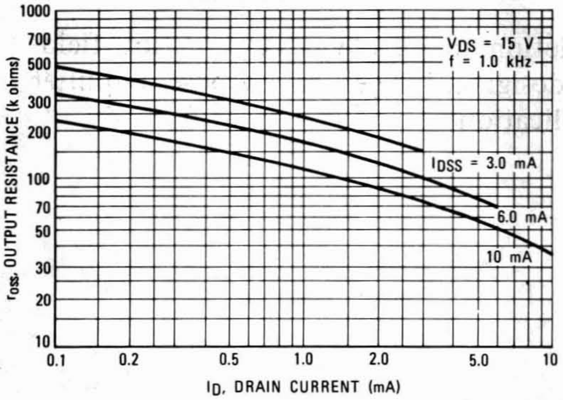


FIGURE 8 – CAPACITANCE VERSUS DRAIN-SOURCE VOLTAGE

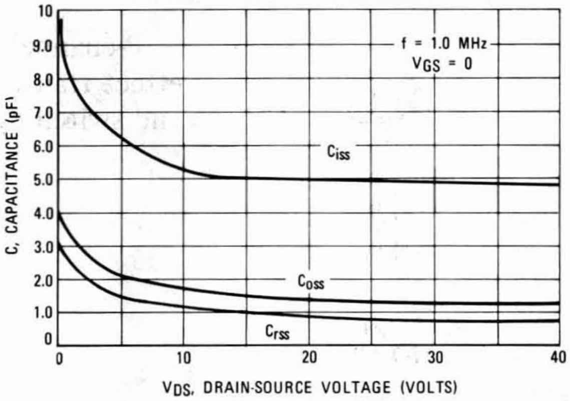


FIGURE 9 – NOISE FIGURE VERSUS FREQUENCY

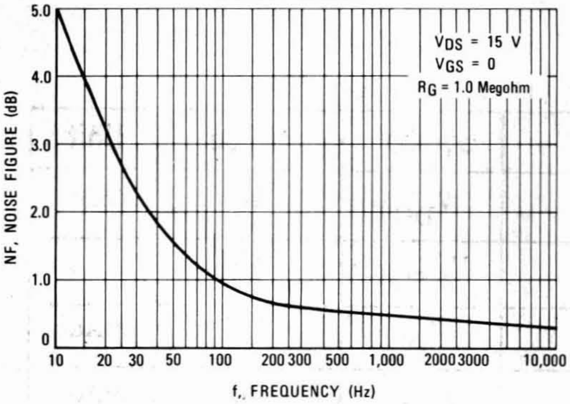


FIGURE 10 – NOISE FIGURE VERSUS SOURCE RESISTANCE

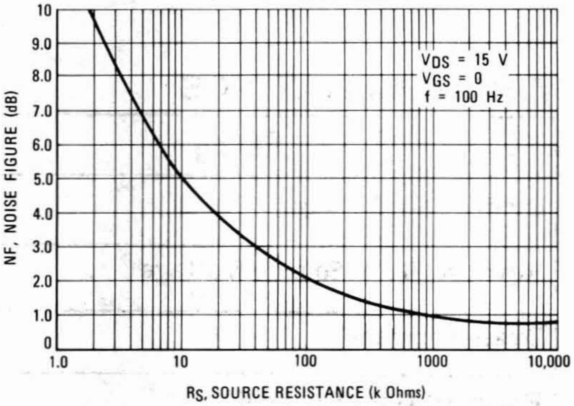
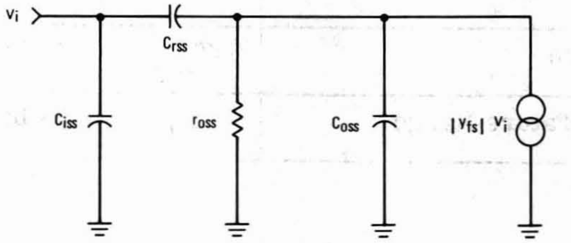


FIGURE 11 – EQUIVALENT LOW FREQUENCY CIRCUIT



Common Source
y Parameters for Frequencies
Below 30 MHz

$y_{is} = j\omega C_{iss}$

$y_{os} = j\omega C_{osp}^{*} + 1/r_{oss}$

$y_{fs} = |y_{fs}|$

$y_{rs} = -j\omega C_{rss}$

*C_{osp} is C_{oss} in parallel with Series Combination of C_{iss} and C_{rss}.

NOTE:

1. Graphical data is presented for dc conditions. Tabular data is given for pulsed conditions (Pulse Width = 630 ms, Duty Cycle = 10%).

2N5471 (SILICON)
thru
2N5476

CASE 20(5)
(TO-72)

P-channel depletion mode (Type A) junction field-effect transistors designed for general-purpose amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Gate Voltage	V_{DG}	40	Vdc
Reverse Gate-Source Voltage	$V_{GS(r)}$	40	Vdc
Drain Current	I_D	5.0	mAdc
Forward Gate Current	$I_{G(f)}$	10	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 2.0	mW mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Operating Junction Temperature Range	T_J	-65 to +175	°C

2N5471 thru 2N5476 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	40	-	Vdc
Gate-Source Cutoff Voltage (V_{DS} = -15 Vdc, I_D = -10 nAdc)	2N5471	$V_{GS(off)}$	0.5	4.0	Vdc
	2N5472		0.7	4.0	
	2N5473		0.9	6.0	
	2N5474		1.2	7.0	
	2N5475		1.5	8.0	
	2N5476		2.0	9.0	
Gate Reverse Current (V_{GS} = 10 Vdc, V_{DS} = 0)		I_{GSS}	-	0.1	nAdc
(V_{GS} = 20 Vdc, V_{DS} = 0)			-	0.5	
(V_{GS} = 20 Vdc, V_{DS} = 0, T_A = 150°C)			-	1.0	μAdc
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current* (V_{DS} = -15 Vdc, V_{GS} = 0)	2N5471	I_{DSS}*	-0.02	-0.06	mAdc
	2N5472		-0.05	-0.12	
	2N5473		-0.10	-0.25	
	2N5474		-0.20	-0.50	
	2N5475		-0.40	-1.0	
	2N5476		-0.80	-2.0	
Gate-Source Voltage (V_{DS} = -15 Vdc, I_D = 2.0 μAdc)	2N5471	V_{GS}	0.5	3.0	Vdc
(V_{DS} = -15 Vdc, I_D = 5.0 μAdc)	2N5472		0.7	3.5	
(V_{DS} = -15 Vdc, I_D = 10 μAdc)	2N5473		0.9	4.5	
(V_{DS} = -15 Vdc, I_D = 20 μAdc)	2N5474		1.2	6.0	
(V_{DS} = -15 Vdc, I_D = 40 μAdc)	2N5475		1.5	7.5	
(V_{DS} = -15 Vdc, I_D = 80 μAdc)	2N5476		2.0	8.0	
SMALL-SIGNAL CHARACTERISTICS					
Forward Transadmittance* (V_{DS} = - 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	2N5471	$\|y_{fs}\|$*	60	180	μmhos
	2N5472		90	225	
	2N5473		120	300	
	2N5474		160	400	
	2N5475		200	500	
	2N5476		260	650	
Output Admittance* (V_{DS} = -15 Vdc, V_{GS} = 0, f = 1.0 kHz)	2N5471	$\|y_{os}\|$*	-	1.0	μmhos
	2N5472		-	1.0	
	2N5473		-	2.5	
	2N5474		-	2.5	
	2N5475		-	5.0	
	2N5476			10	
Input Capacitance (V_{DS} = -15 Vdc, V_{GS} = 0, 140 kHz ≤ f ≤ 1.0 MHz)		C_{iss}	-	5.0	pF
Reverse Transfer Capacitance (V_{DS} = -15 Vdc, V_{GS} = 0, 140 kHz ≤ f ≤ 1.0 MHz)		C_{rss}	-	1.0	pF
Common-Source Noise Figure (V_{DS} = -15 Vdc, V_{GS} = 0, R_G = 1.0 Megohm, f = 1.0 kHz, BW = 1.0 Hz)		NF	-	2.5	dB
Equivalent Short-Circuit Input Noise Voltage (V_{DS} = -15 Vdc, V_{GS} = 0, f = 1.0 kHz, BW = 1.0 Hz)		e_n	-	110	nV/√Hz

*Pulse Test: Pulse Width = 630 ms, Duty Cycle = 2.0%.

2N5477 (SILICON)
thru
2N5480

MEDIUM-POWER NPN SILICON TRANSISTORS

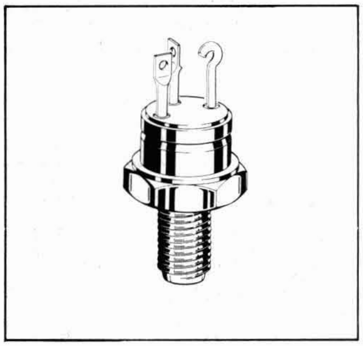
. . . designed for switching and wide-band amplifier applications.

- Low Collector Emitter Saturation Voltage — $V_{CE(sat)} = 1.2$ Vdc (Max) @ $I_C = 7.0$ Adc
- DC Current Gain Specified to 5 Amperes
- Excellent Safe Operating Area
- Packaged in the Compact, High Dissipation TO-59 Case
- Collector Common to Case

7 AMPERE
POWER TRANSISTORS

NPN SILICON

80-100 VOLTS
60 WATTS



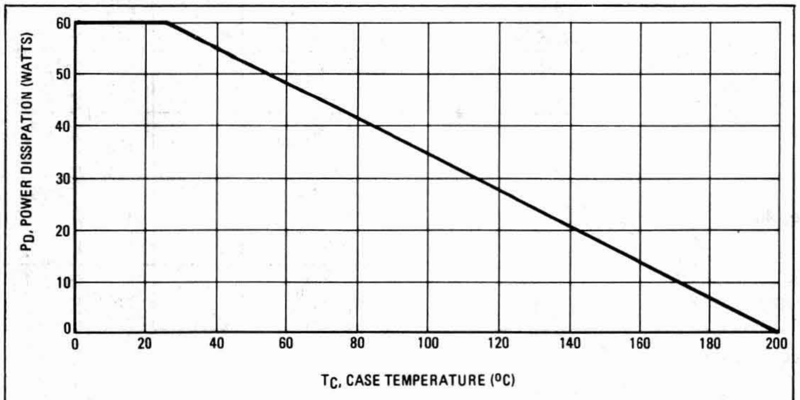
MAXIMUM RATINGS

Rating	Symbol	2N5477 2N5478	2N5479 2N5480	Unit
Collector-Emitter Voltage	V_{CEO}	80	100	Vdc
Collector-Base Voltage	V_{CB}	80	100	Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current — Continuous	I_C	7.0		Adc
Base Current - Continuous	I_B	1.0		Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	60 343		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

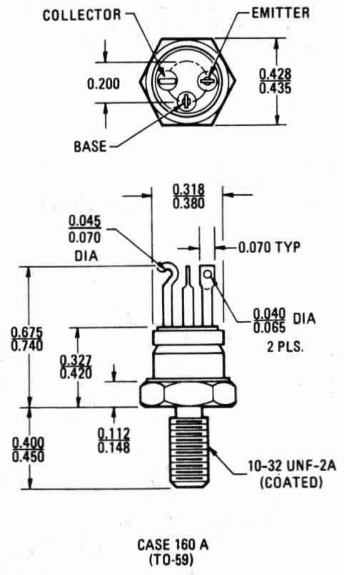
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	2.91	°C/W

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Curves are indicated by Figure 5. All limits are applicable and must be observed.



COLLECTOR
EMITTER
0.200
0.428
0.435
BASE
0.318
0.380
0.045
0.070
DIA
0.070 TYP
0.040
0.065
DIA
2 PLS.
0.675
0.740
0.327
0.420
0.400
0.450
0.112
0.148
10-32 UNF-2A
(COATED)

CASE 160 A
(TO-59)

Collector Common
To Case

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage*		-	$BV_{CEO(sus)}$*			Vdc
(I_C = 50 mAdc, I_B = 0)	2N5477, 2N5478			80	-	
	2N5479, 2N5480			100	-	
Collector Cutoff Current		-	I_{CEO}			µAdc
(V_{CE} = 75 Vdc, I_B = 0)	2N5477, 2N5478			-	100	
(V_{CE} = 90 Vdc, I_B = 0)	2N5479, 2N5480			-	100	
Collector Cutoff Current		12	I_{CEX}			µAdc
(V_{CE} = 75 Vdc, $V_{EB(off)}$ = 1.5 Vdc)	2N5477, 2N5478			-	10	
(V_{CE} = 90 Vdc, $V_{EB(off)}$ = 1.5 Vdc)	2N5479, 2N5480			-	10	
(V_{CE} = 75 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	2N5477, 2N5478			-	1.0	mAdc
(V_{CE} = 90 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	2N5479, 2N5480			-	1.0	
Collector Cutoff Current (V_{CB} = Rated V_{CB}, I_E = 0)		-	I_{CBO}	-	10	µAdc
Emitter Cutoff Current (V_{BE} = 6.0 Vdc, I_C = 0)		-	I_{EBO}	-	100	µAdc
ON CHARACTERISTICS						
DC Current Gain*		8	h_{FE}*			-
(I_C = 500 mAdc, V_{CE} = 2.0 Vdc)	2N5477, 2N5479			30	-	
	2N5478, 2N5480			60	-	
(I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	2N5477, 2N5479			30	120	
	2N5478, 2N5480			60	240	
(I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	2N5477, 2N5479			20	-	
	2N5478, 2N5480			40	-	
Collector-Emitter Saturation Voltage*		9, 11, 13	$V_{CE(sat)}$*			Vdc
(I_C = 2.0 Adc, I_B = 0.2 Adc)				-	0.7	
(I_C = 7.0 Adc, I_B = 0.7 Adc)				-	1.2	
Base-Emitter Saturation Voltage*		11, 13	$V_{BE(sat)}$*			Vdc
(I_C = 2.0 Adc, I_B = 0.2 Adc)				-	1.2	
(I_C = 7.0 Adc, I_B = 0.7 Adc)				-	2.0	
DYNAMIC CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 500 mAdc, V_{CE} = 10 Vdc, f = 10 MHz)		-	f_T	30	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		7	C_{ob}	-	250	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 100 kHz)		7	C_{ib}	-	1,000	pF
SWITCHING CHARACTERISTICS						
Delay Time	(V_{CC} = 40 Vdc, $V_{EB(off)}$ = 3.0 Vdc, I_C = 2.0 Adc, I_{B1} = 200 mAdc)	2,3	t_d	-	100	ns
Rise Time			t_r	-	100	ns
Storage Time	(V_{CC} = 40 Vdc, I_C = 2.0 Adc, I_{B1} = I_{B2} = 200 mAdc)	2,6	t_s	-	2.0	µs
Fall Time			t_f	-	200	ns

* Pulse Test: Pulse Width ≈ 300 µs, Duty Cycle ≈ 2.0%.

FIGURE 2 — SWITCHING TIME TEST CIRCUIT

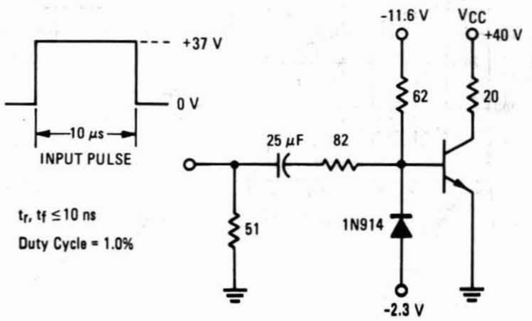


FIGURE 3 — TURN-ON TIME

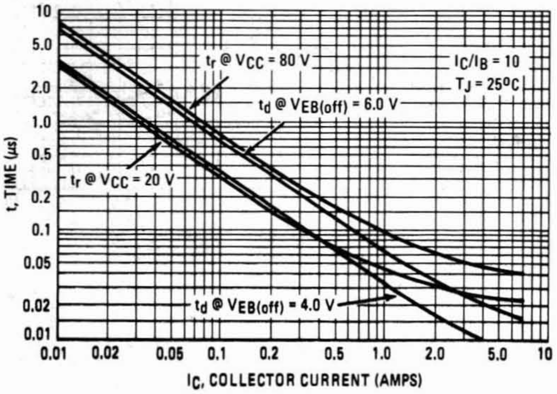


FIGURE 4 – THERMAL RESPONSE

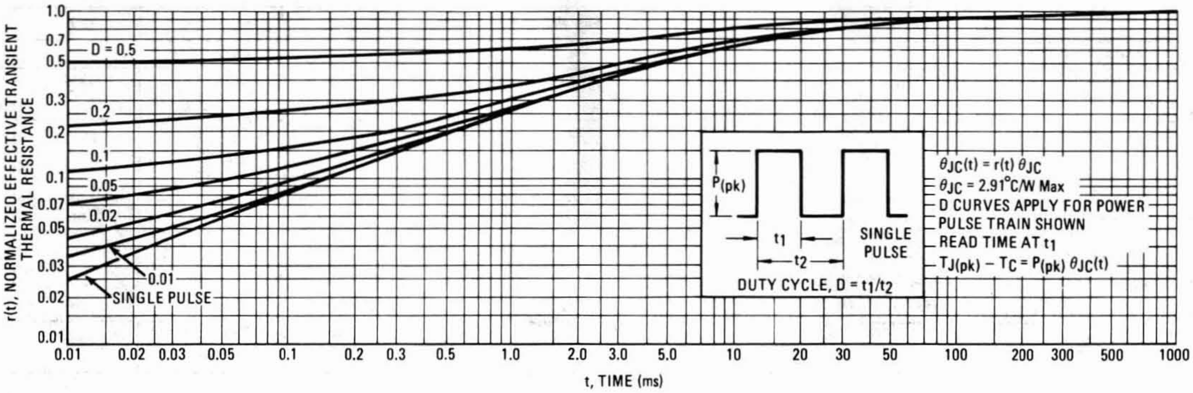
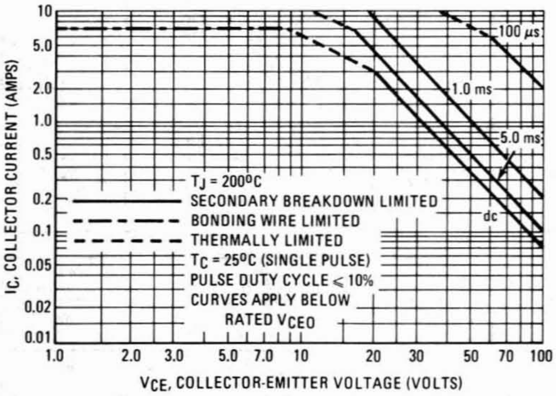


FIGURE 5 – ACTIVE-REGION SAFE OPERATING AREA



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate $I_C - V_{CE}$ limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 5 is based on $T_{J(pk)} = 200°C$; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq 200°C$. $T_{J(pk)}$ may be calculated from the data in Figure 4. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

FIGURE 6 – TURN-OFF TIME

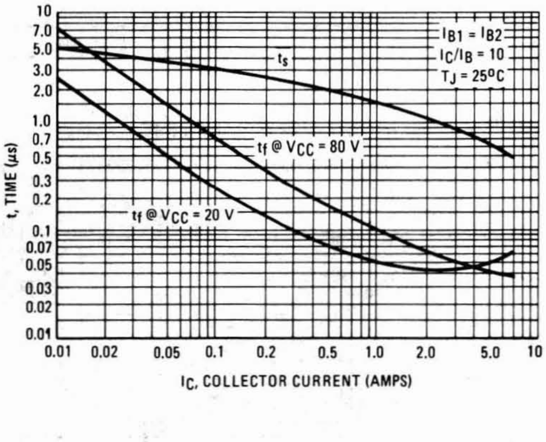


FIGURE 7 – CAPACITANCE versus VOLTAGE

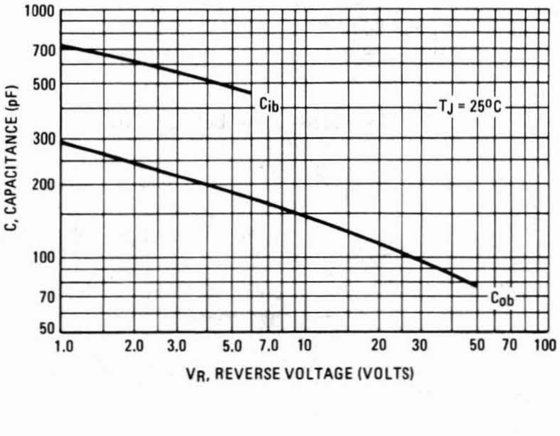


FIGURE 8 – DC CURRENT GAIN

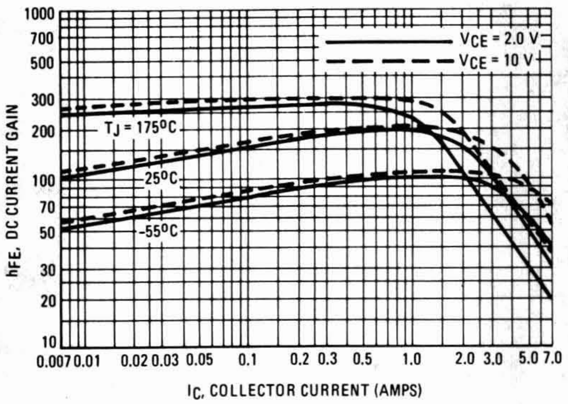


FIGURE 9 – COLLECTOR SATURATION REGION

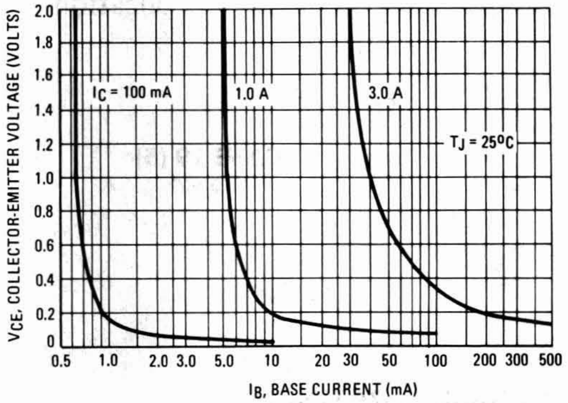


FIGURE 10 – EFFECTS OF BASE EMITTER RESISTANCE

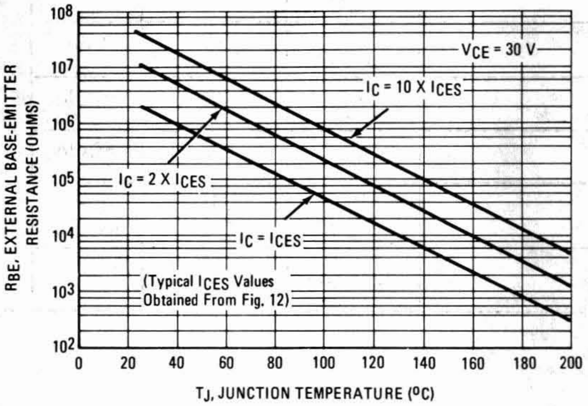


FIGURE 11 – "ON" VOLTAGES

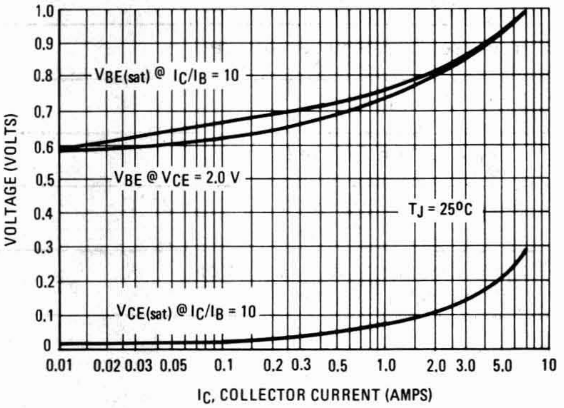


FIGURE 12 – COLLECTOR CUT-OFF REGION

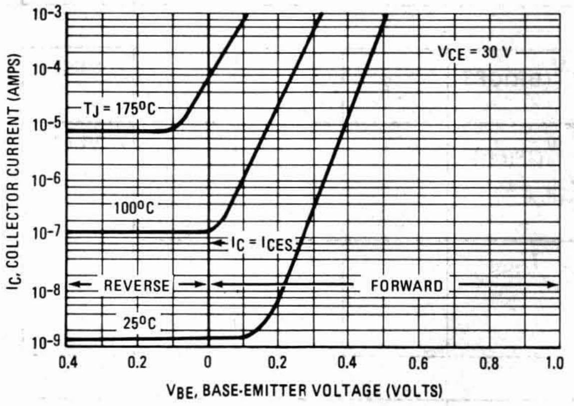
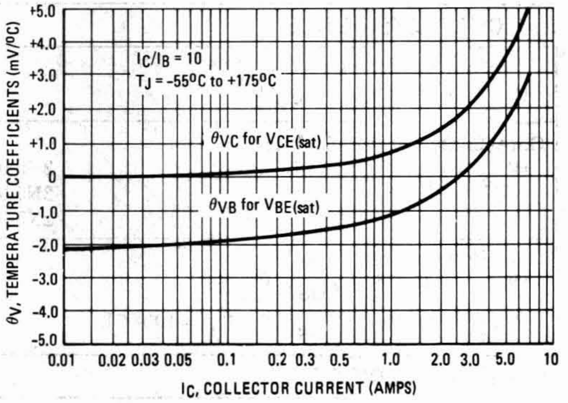


FIGURE 13 – TEMPERATURE COEFFICIENTS



2N5484 (SILICON)
thru
2N5486

N-channel depletion mode (Type A) junction field-effect transistors designed for VHF/UHF amplifier applications.

CASE 29 (5)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Gate Voltage	V_{DG}	25	Vdc
Reverse Gate-Source Voltage	$V_{GS(r)}$	25	Vdc
Drain Current	I_D	30	mAdc
Forward Gate Current	$I_{G(f)}$	10	mAdc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	310 2.82	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150	°C

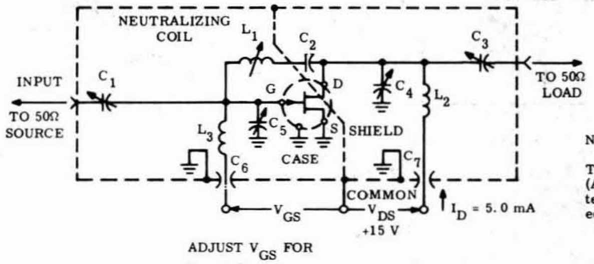
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Gate-Source Breakdown Voltage (I_G = -1.0 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	25	-	-	Vdc
Gate-Source Cutoff Voltage (V_{DS} = 15 Vdc, I_D = 10 nAdc)	2N5484	$V_{GS(off)}$	0.3	-	3.0	Vdc
	2N5485		0.5	-	4.0	
	2N5486		2.0	-	6.0	
Gate Reverse Current (V_{GS} = -20 Vdc, V_{DS} = 0)		I_{GSS}	-	-	1.0	nAdc
(V_{GS} = -20 Vdc, V_{DS} = 0, T_A = 100°C)			-	-	0.2	μAdc
ON CHARACTERISTICS						
Zero-Gate Voltage Drain Current (V_{DS} = 15 Vdc, V_{GS} = 0)	2N5484	I_{DSS}	1.0	-	5.0	mAdc
	2N5485		4.0	-	10	
	2N5486		8.0	-	20	

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Typ	Max	Unit
SMALL-SIGNAL CHARACTERISTICS						
Forward Transadmittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	2N5484 2N5485 2N5486	$\lvert y_{fs} \rvert$	3000 3500 4000	- - -	6000 7000 8000	μmhos
Forward Transconductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz) (V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)	2N5484 2N5485 2N5486	$Re(y_{fs})$	2500 3000 3500	- - -	- - -	μmhos
Output Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	2N5484 2N5485 2N5486	$\lvert y_{os} \rvert$	- - -	- - -	50 60 75	μmhos
Output Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz) (V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)	2N5484 2N5485, 2N5486	$Re(y_{os})$	- -	- -	75 100	μmhos
Input Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz) (V_{DS} = 15 Vdc, V_{GS} = 0, f = 400 MHz)	2N5484 2N5485, 2N5486	$Re(y_{is})$	- -	- -	100 1000	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{iss}	-	-	5.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{rss}	-	-	1.0	pF
Output Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{oss}	-	-	2.0	pF
Common-Source Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_G = 1.0 Megohm, f = 1.0 kHz)	All Types	NF	-	-	2.5	dB
(V_{DS} = 15 Vdc, I_D = 1.0 mAdc, R_G ≈ 1.0 k ohm, f = 100 MHz)	2N5484		-	-	3.0	
(V_{DS} = 15 Vdc, I_D = 1.0 mAdc, R_G ≈ 1.0 k ohm, f = 200 MHz)	2N5484		-	4.0	-	
(V_{DS} = 15 Vdc, I_D = 4.0 mAdc, R_G ≈ 1.0 k ohm, f = 100 MHz)	2N5485, 2N5486		-	-	2.0	
(V_{DS} = 15 Vdc, I_D = 4.0 mAdc, R_G ≈ 1.0 k ohm, f = 400 MHz)	2N5485, 2N5486		-	-	4.0	
Insertion Power Gain (V_{DS} = 15 Vdc, I_D = 1.0 mAdc, f = 100 MHz)	2N5484	G_{ps}	16	-	25	dB
(V_{DS} = 15 Vdc, I_D = 1.0 mAdc, f = 200 MHz)	2N5484		-	14	-	
(V_{DS} = 15 Vdc, I_D = 4.0 mAdc, f = 100 MHz)	2N5485, 2N5486		18	-	30	
(V_{DS} = 15 Vdc, I_D = 4.0 mAdc, f = 400 MHz)	2N5485, 2N5486		10	-	20	

FIGURE 1 — 100 MHz AND 400 MHz NEUTRALIZED AMPLIFIER



ADJUST V_{GS} FOR
I_D = 5.0 mA
V_{GS} < 0 VOLTS

NOTE:

The noise source is a hot-cold body (AIL type 70 or equivalent) with a test receiver (AIL type 136 or equivalent).

Reference Designation	VALUE	
	100 MHz	400 MHz
C_1	1-12 pF	0.8-8.0 pF
C_2	1000 pF	27 pF
C_3	1-12 pF	0.8-8.0 pF
C_4	1-12 pF	0.8-8.0 pF
C_5	1-12 pF	0.8-8.0 pF
C_6	0.0015 μF	0.001 μF
C_7	0.0015 μF	0.001 μF
L_1	3.0 μH*	0.2 μH**
L_2	0.25 μH*	0.03 μH**
L_3	0.14 μH*	0.022 μH**

* L_1 17 turns (approximately - depending upon circuit layout), AWG #28 enameled copper wire, close wound on 9/32" ceramic coil form. Tuning provided by a powdered iron slug.

L_2 4 1/2 turns, AWG #18 enameled copper wire, 5/16" long, 3/8" I. D. (AIR CORE).

L_3 3 1/2 turns, AWG #18 enameled copper wire, 1/4" long, 3/8" I. D. (AIR CORE).

** L_1 6 turns (approximately - depending upon circuit layout), AWG #24 enameled copper wire, close wound on 7/32" ceramic coil form. Tuning provided by an aluminum slug.

L_2 1 turn, AWG #16 enameled copper wire, 3/8" I. D. (AIR CORE).

L_3 1/2 turn, AWG #16 enameled copper wire, 1/4" I. D. (AIR CORE).

2N5555 (SILICON)

SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

Depletion Mode (Type A) Junction Field-Effect Transistor designed for high-speed switching applications.

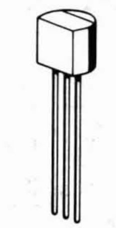
- Low Drain-Source "On" Resistance — $r_{ds(on)}$ = 150 Ohms (Max)
- Low Reverse Transfer Capacitance — C_{rss} = 1.2 pF (Max) @ f = 1.0 MHz
- Fast Turn-On Time — $t_{(on)}$ = 10 ns (Max)

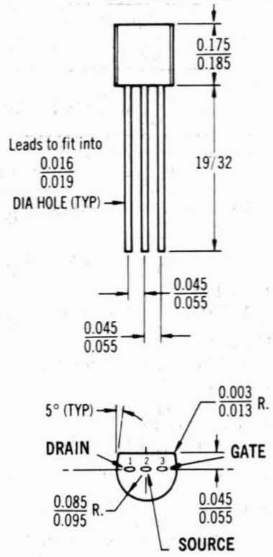
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	25	Vdc
Gate-Source Voltage	V_{GS}	25	Vdc
Forward Gate Current	$I_{G(f)}$	10	mAdc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	310 2.82	mW mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

TYPE A




0.175
0.185
Leads to fit into
0.016
0.019
DIA HOLE (TYP)
19/32
0.045
0.055
0.045
0.055
5° (TYP)
0.003
0.013 R.
DRAIN
GATE
1 2 3
0.085
0.095 R.
0.045
0.055
SOURCE

CASE 29 (5)
(TO-92)

Drain and Source may be Interchanged.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

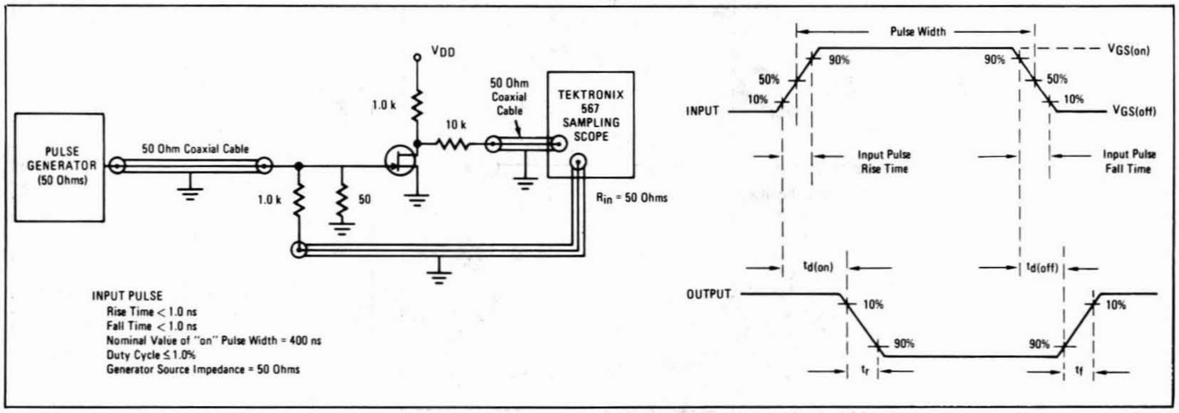
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	25	-	Vdc
Gate Reverse Current (V_{GS} = 15 Vdc, V_{DS} = 0)	I_{GSS}	-	1.0	nAdc
Drain Cutoff Current (V_{DS} = 12 Vdc, V_{GS} = 10 Vdc) (V_{DS} = 12 Vdc, V_{GS} = 10 Vdc, T_A = 100°C)	$I_{D(off)}$	- -	10 2.0	nAdc μAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0)	I_{DSS}*	15	-	mAdc
Gate-Source Forward Voltage ($I_{G(f)}$ = 1.0 mAdc, V_{DS} = 0)	$V_{GS(f)}$	-	1.0	Vdc
Drain-Source "ON" Voltage (I_D = 7.0 mAdc, V_{GS} = 0)	$V_{DS(on)}$	-	1.5	Vdc
Static Drain-Source "ON" Resistance (I_D = 0.1 mAdc, V_{GS} = 0)	$r_{DS(on)}$	-	150	Ohms
SMALL-SIGNAL CHARACTERISTICS				
Small-Signal Drain-Source "ON" Resistance (V_{GS} = 0, I_D = 0, f = 1.0 kHz)	$r_{ds(on)}$	-	150	Ohms
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	-	5.0	pF
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 10 Vdc, f = 1.0 MHz)	C_{rss}	-	1.2	pF

SWITCHING CHARACTERISTICS

Turn-On Delay Time	(V_{DD} = 10 Vdc, $I_{D(on)}$ = 7.0 mAdc, $V_{GS(on)}$ = 0, $V_{GS(off)}$ = -10 Vdc) (See Figure 1)	$t_{d(on)}$	-	5.0	ns
Rise Time		t_r	-	5.0	ns
Turn-Off Delay Time	(V_{DD} = 10 Vdc, $I_{D(on)}$ = 7.0 mAdc, $V_{GS(on)}$ = 0, $V_{GS(off)}$ = -10 Vdc) (See Figure 1)	$t_{d(off)}$	-	15	ns
Fall Time		t_f	-	10	ns

*Pulse Test: Pulse Width < 300 μs, Duty Cycle < 3.0%.

FIGURE 1 — SWITCHING TIMES TEST CIRCUIT


VDD
PULSE GENERATOR (50 Ohms)
50 Ohm Coaxial Cable
1.0 k
50
1.0 k
10 k
50 Ohm Coaxial Cable
TEKTRONIX 567 SAMPLING SCOPE
Rin = 50 Ohms
Pulse Width
VGS(on)
90%
50%
10%
INPUT
90%
50%
10%
VGS(off)
Input Pulse Rise Time
Input Pulse Fall Time
td(on)
td(off)
OUTPUT
10%
90%
90%
10%
tr
tf

INPUT PULSE
Rise Time < 1.0 ns
Fall Time < 1.0 ns
Nominal Value of "on" Pulse Width = 400 ns
Duty Cycle ≤ 1.0%
Generator Source Impedance = 50 Ohms

2N5556 (SILICON)
thru
2N5558

SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

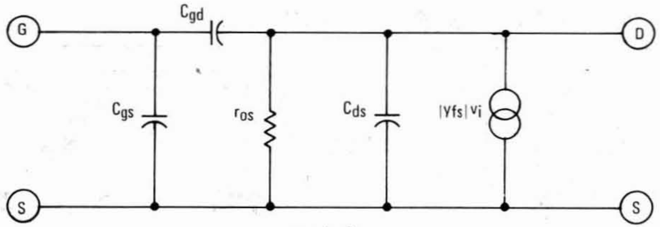
Depletion Mode (Type A) devices designed for low-noise amplifier applications.

- Low Noise Figure — NF = 1.0 dB (Max) @ 100 Hz
- Low Gate Leakage Current — I_{GSS} = 0.1 nAdc (Max)
- Low Input Capacitance — C_{iss} = 6.0 pF (Max)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	30	Vdc
Forward Gate Current	$I_{G(f)}$	10	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 2.0	mW mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 — EQUIVALENT LOW FREQUENCY CIRCUIT

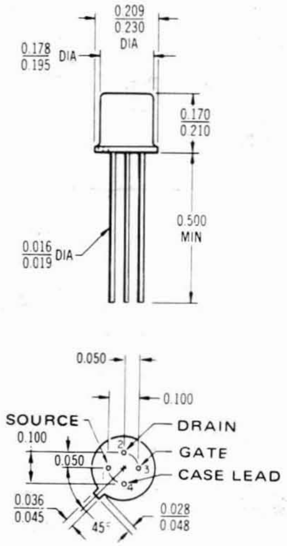

G
Cgd
D
Cgs
ros
Cds
|Yfs| vi
S
S

$y_{is} = j\omega C_{iss}$
$y_{os} = 1/r_{oss} + j\omega C_{oss}$
$y_{fs} = |y_{fs}|$
$y_{rs} = -j\omega C_{rss}$

$C_{iss} = C_{gd} + C_{gs}$
$C_{rss} = C_{gd}$
$C_{oss} = C_{gd} + C_{ds}$

SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTORS

TYPE A


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
SOURCE
0.100
0.050
DRAIN
GATE
CASE LEAD
1
2
3
4
0.036
0.045
45°
0.028
0.048

CASE 20(1)
(TO-72)

Drain and Source may be interchanged.

2N5556 thru 2N5558 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic		Symbol	Min	Typ	Max	Unit
Gate-Source Breakdown Voltage (I_G = -10 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	30	-	-	Vdc
Gate-Source Cutoff Voltage (V_{DS} = 15 Vdc, I_D = 1.0 nAdc)	2N5556	$V_{GS(off)}$	0.2	-	4.0	Vdc
	2N5557		0.8	-	5.0	
	2N5558		1.5	-	6.0	
Gate Reverse Current (V_{GS} = -15 Vdc, V_{DS} = 0)		I_{GSS}	-	-	-0.1	nAdc
(V_{GS} = -15 Vdc, V_{DS} = 0, T_A = 150°C)			-	-	-100	

ON CHARACTERISTICS

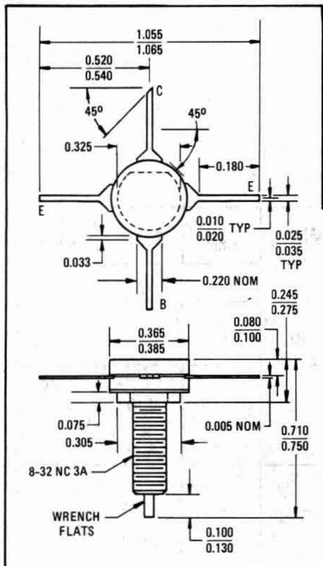
Characteristic		Symbol	Min	Typ	Max	Unit
Zero-Gate Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0)	2N5556	I_{DSS}*	0.5	-	2.5	mAdc
	2N5557		2.0	-	5.0	
	2N5558		4.0		10	

DYNAMIC CHARACTERISTICS

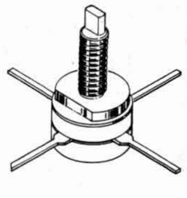
Characteristic	Symbol	Min	Typ	Max	Unit
Forward Transadmittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	$\|y_{fs}\|$*	1500	3500	6500	μmhos
Output Admittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	$\|y_{os}\|$*	-	-	20	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	-	4.5	6.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	-	1.2	3.0	pF
Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_S = 500 k ohms, f = 10 Hz, BW = 1.0 Hz)	NF	-	-	1.0	dB
(V_{DS} = 15 Vdc, V_{GS} = 0, R_S = 100 k ohms, f = 100 Hz, BW = 1.0 Hz)		-	-	1.0	
Equivalent Input Noise Voltage (V_{DS} = 15 Vdc, V_{GS} = 0, f = 10 Hz, BW = 1.0 Hz)	e_n	-	20	35	nV/√Hz
(V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 Hz, BW = 1.0 Hz)		-	10	20	

*Pulse Test: Pulse Width = 630 ms, Duty Cycle = 10%.

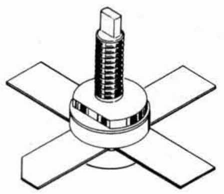
2N5589 (SILICON) (Formerly MM1601)
2N5590 (Formerly MM1602)


1.055
1.065
0.520
0.540
C
45°
45°
0.325
0.180
E
E
0.010
0.020
TYP
0.025
0.035
TYP
0.033
0.220 NOM
B
0.245
0.275
0.080
0.100
0.365
0.385
0.075
0.305
0.005 NOM
0.710
0.750
8-32 NC 3A
WRENCH
FLATS
0.100
0.130

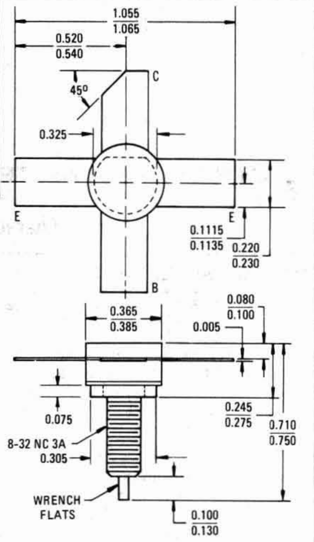
NPN SILICON
RF POWER TRANSISTORS



2N5589
CASE 144B



2N5590
CASE 145A


1.055
1.065
0.520
0.540
45°
C
0.325
E
E
0.1115
0.1135
0.220
0.230
B
0.365
0.385
0.080
0.100
0.005
0.075
8-32 NC 3A
0.305
0.245
0.275
0.710
0.750
WRENCH
FLATS
0.100
0.130

NPN SILICON RF POWER TRANSISTORS

. . . designed for power amplifier or oscillator applications in military and industrial equipment. Suitable for Class AB, B or C operation in 13.6 V applications to 240 MHz.

- Balanced Emitter Construction for Excellent Safe Operating Area. Designed to Withstand an Open or Shorted Load at Rated Power Output.
- Low Profile Stripline Package for Low Lead Inductance and Better Broadband Capability
- Choice of Power Levels at 175 MHz, 13.6 Vdc –
  2N5589 – 3.0 Watts, 8.2 dB (Min) Gain
  2N5590 – 10 Watts, 5.2 dB (Min) Gain

MAXIMUM RATINGS

Rating	Symbol	2N5589	2N5590	Unit
Collector-Emitter Voltage	V_{CEO}	18		Vdc
Collector Base Voltage	V_{CB}	36		Vdc
Emitter-Base Voltage	V_{EB}	4.0		Vdc
Collector Current	I_C	1.0	3.0	Adc
Total Device Dissipation @ $T_C = 25^{\circ}C$ Derate above 25°C	P_D	15 86	30 171	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to +200°		°C
Storage Temperature	T_{stg}	-65 to +150°		°C

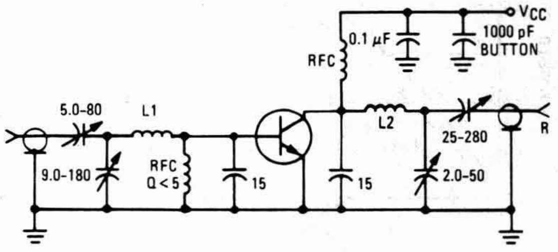
2N5589, 2N5590 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage* (I_C = 200 mAdc, I_B = 0)		BV_{CEO}*	18	-	-	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 200 mAdc, R_{BE} = 0)		BV_{CES}*	36	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 1.0 mAdc, I_C = 0)	2N5589	BV_{EBO}	4.0	-	-	Vdc
(I_E = 2.5 mAdc, I_C = 0)	2N5590		4.0	-	-	
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)		I_{CBO}	-	-	1.0	mAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 100 mAdc, V_{CE} = 5.0 Vdc)	2N5589	h_{FE}	5.0	-	-	-
(I_C = 250 mAdc, V_{CE} = 5.0 Vdc)	2N5590		5.0	-	-	
DYNAMIC CHARACTERISTICS						
Output Capacitance (V_{CB} = 15 Vdc, I_E = 0, f = 0.1 to 1.0 MHz)	2N5589	C_{ob}	-	15	30	pF
	2N5590		-	35	70	
FUNCTIONAL TESTS						
Power Input (P_{out} = 3.0 Watts, V_{CE} = 13.6 Vdc, f = 175 MHz) (Figure 1)	2N5589	P_{in}	-	-	0.45	Watts
(P_{out} = 10 Watts, V_{CE} = 13.6 Vdc, f = 175 MHz) (Figure 2)	2N5590		-	-	3.0	
Common-Emitter Amplifier Power Gain (P_{out} = 3.0 Watts, V_{CE} = 13.6 Vdc, f = 175 MHz) (Figure 1)	2N5589	G_{PE}	8.2	-	-	dB
(P_{out} = 10 Watts, V_{CE} = 13.6 Vdc, f = 175 MHz) (Figure 2)	2N5590		5.2	-	-	
Collector Efficiency (P_{out} = 3.0 Watts, V_{CE} = 13.6 Vdc, f = 175 MHz) (Figure 1)	2N5589	η	50	-	-	%
(P_{out} = 10 Watts, V_{CE} = 13.6 Vdc, f = 175 MHz) (Figure 2)	2N5590		50	-	-	

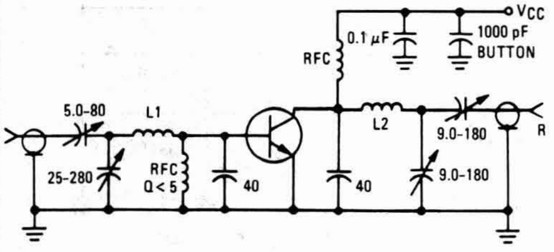
*Pulsed through 25 mH inductor.

FIGURE 1 — 175 MHz TEST CIRCUIT (2N5589)



All capacitance values in pF unless otherwise indicated
L1 – 1-3/8" length of #14 AWG Wire
L2 – 2 Turns #16 AWG Wire, 1/4" Dia. 1-1/2" Long

FIGURE 2 — 175 MHz TEST CIRCUIT (2N5590)



All capacitance values in pF unless otherwise indicated
L1 – 1-3/8" length of #14 AWG Wire
L2 – 1 Turn #14 AWG Wire, 3/8" Dia. 1-1/2" Long

POWER OUTPUT versus FREQUENCY

FIGURE 3 – 2N5589

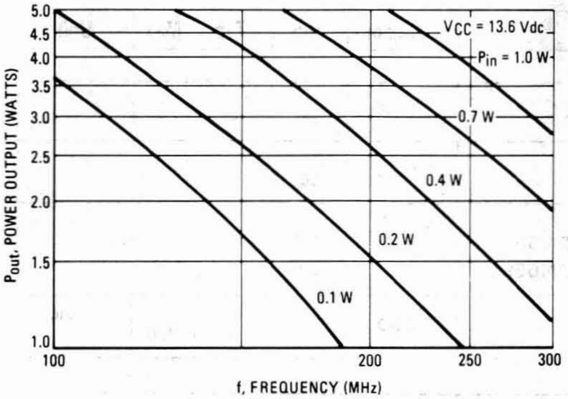


FIGURE 4 – 2N5590

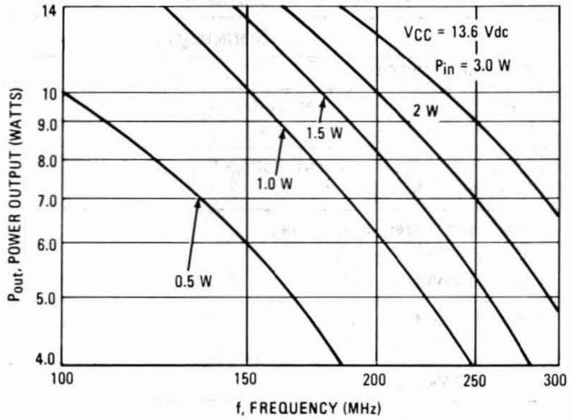


FIGURE 5 – 2N5589

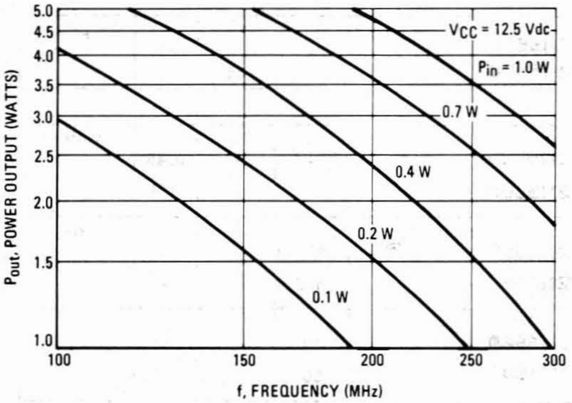
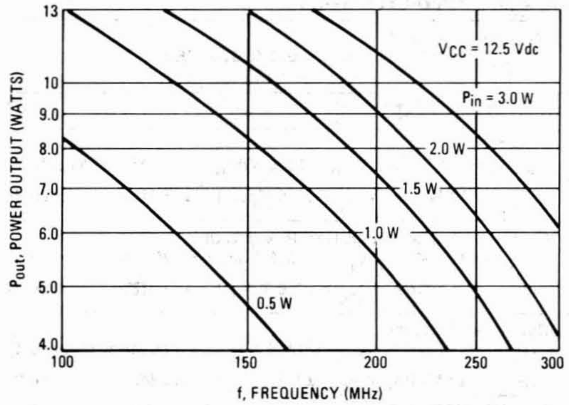


FIGURE 6 – 2N5590



POWER OUTPUT versus POWER INPUT

FIGURE 7 – 2N5589

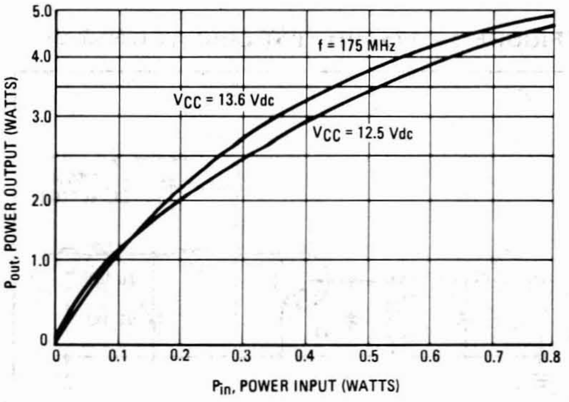
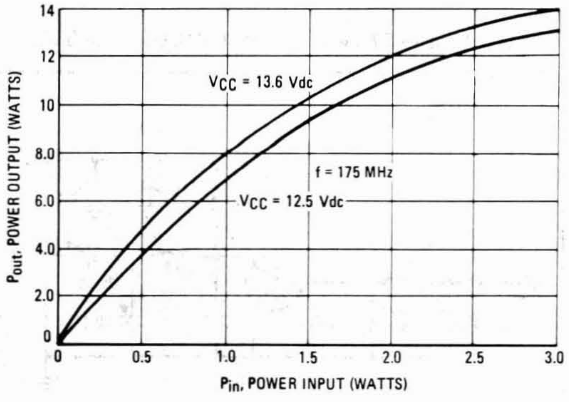


FIGURE 8 – 2N5590



PARALLEL EQUIVALENT INPUT RESISTANCE versus FREQUENCY

FIGURE 9 – 2N5589

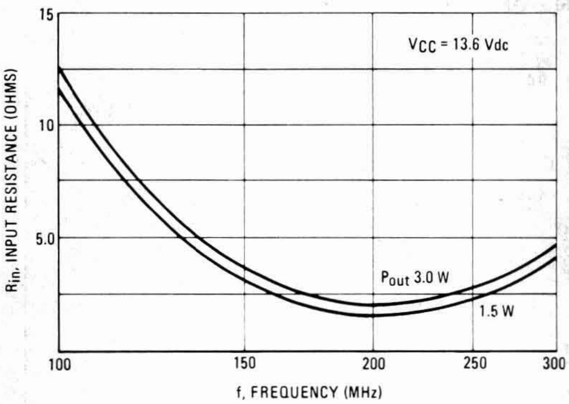
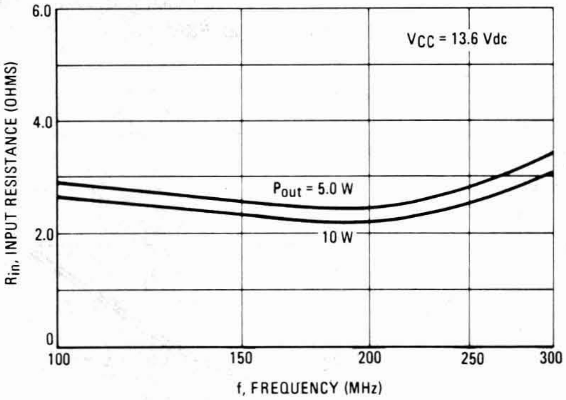


FIGURE 10 – 2N5590



PARALLEL EQUIVALENT INPUT CAPACITANCE versus FREQUENCY

FIGURE 11 – 2N5589

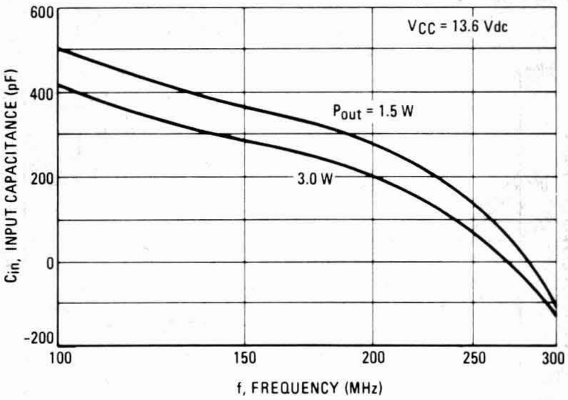
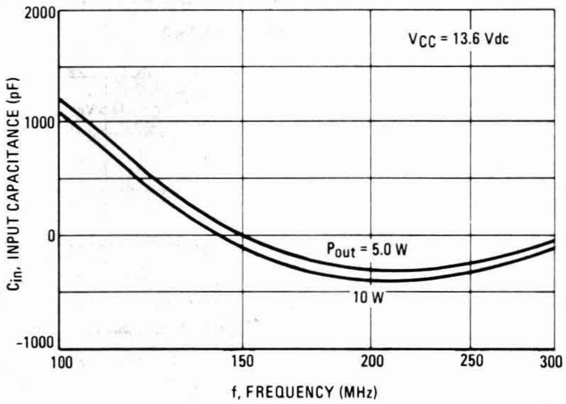


FIGURE 12 – 2N5590



PARALLEL EQUIVALENT OUTPUT CAPACITANCE versus FREQUENCY

FIGURE 13 – 2N5589

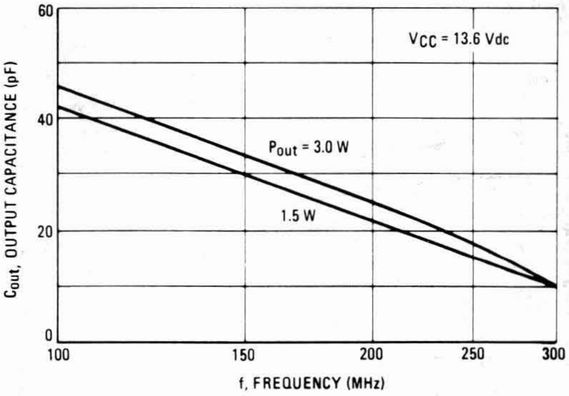
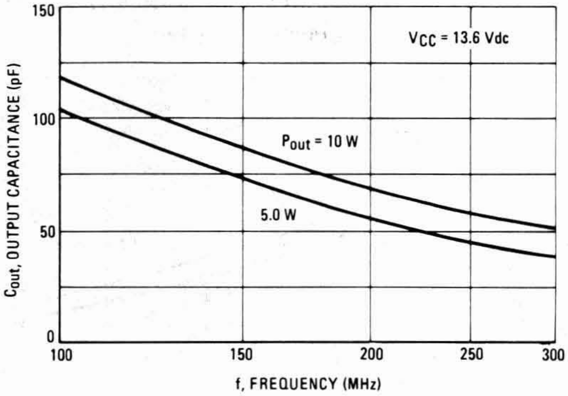


FIGURE 14 – 2N5590



PARALLEL EQUIVALENT INPUT RESISTANCE versus FREQUENCY

FIGURE 15 – 2N5589

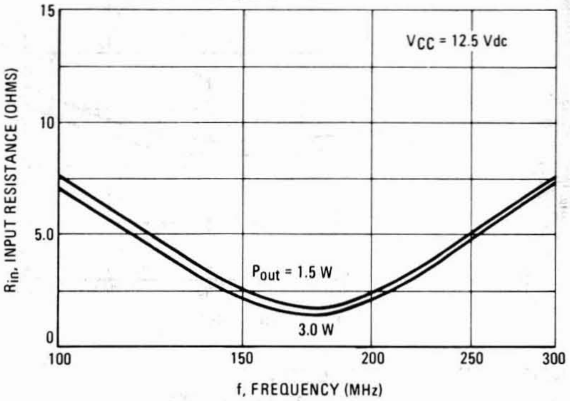
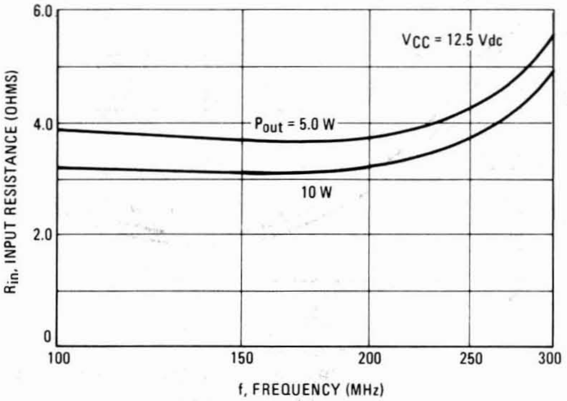


FIGURE 16 – 2N5590



PARALLEL EQUIVALENT INPUT CAPACITANCE versus FREQUENCY

FIGURE 17 – 2N5589

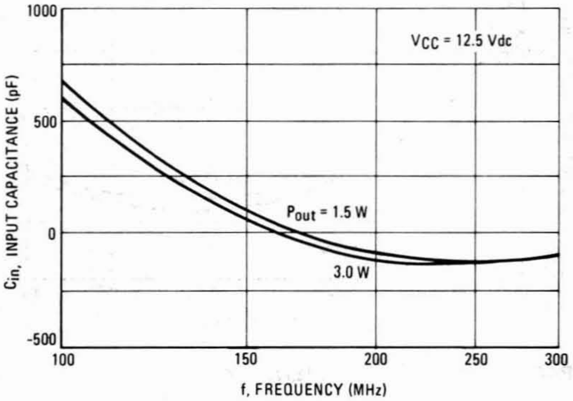
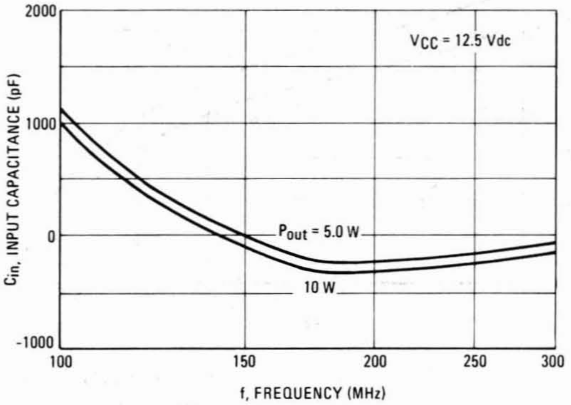


FIGURE 18 – 2N5590



PARALLEL EQUIVALENT OUTPUT CAPACITANCE versus FREQUENCY

FIGURE 19 – 2N5589

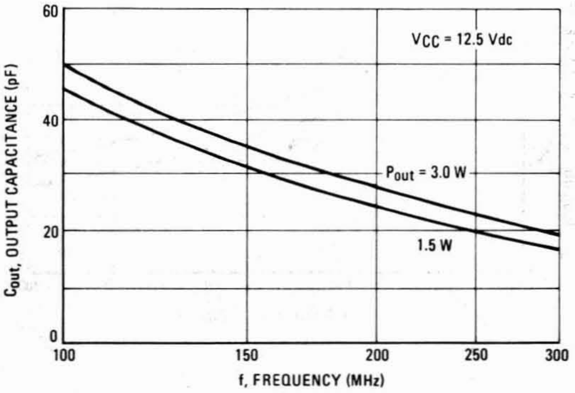
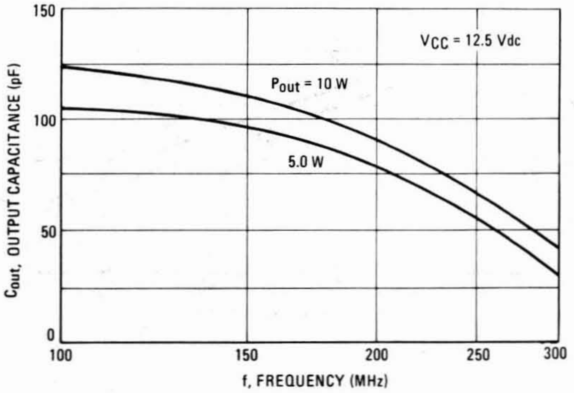


FIGURE 20 – 2N5590



SERIES INPUT RESISTANCE versus FREQUENCY

FIGURE 21 – 2N5589

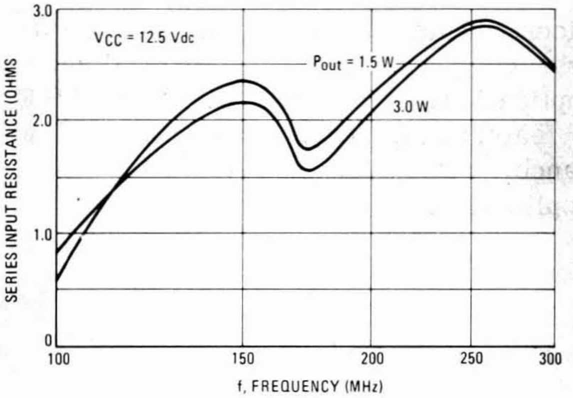
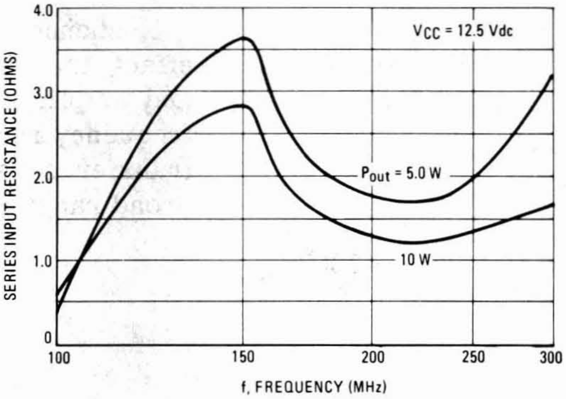


FIGURE 22 – 2N5590



SERIES INPUT REACTANCE versus FREQUENCY

FIGURE 23 – 2N5589

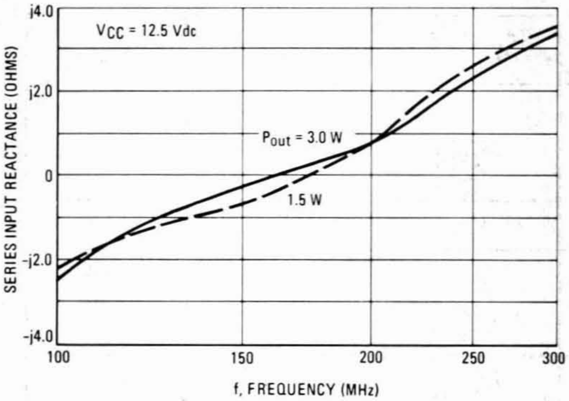
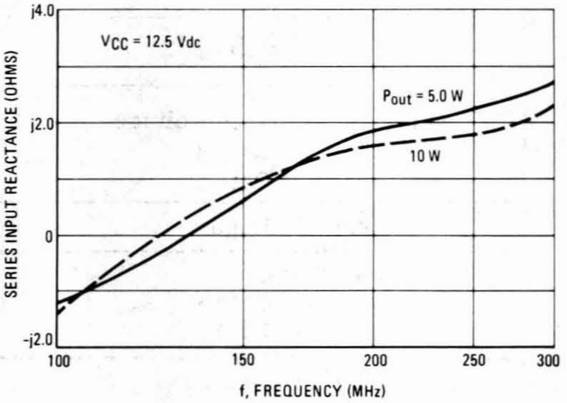


FIGURE 24 – 2N5590



LARGE SIGNAL DESIGN DATA NOTE:

The complex large signal input impedance and the reactive portion of the large signal output impedance have been plotted in Figures 9 thru 24.

It must be stressed that this data does not represent any particular two port parameter set, but rather gives the actual terminal impedances of the transistors while operating at rated power output levels in an optimized, properly tuned amplifier.

The real portion of output impedance is not included in the data. The parallel real portion of collector load impedance may normally be computed with sufficient accuracy by assuming a peak-to-peak RF voltage swing at the collector equal to 2 V_{CC} and using the resulting expression:

$$R = \frac{V_{CC}^2}{2P}$$

Where P = average RF power output.

The load resistance thus computed may be combined with the data in Figures 9 thru 24 to comprise complete complex impedance information for the input and output network designs of class C common-emitter power amplifiers.

For further information on the use of this data in power amplifier designs, refer to Application Note AN-282.

3N124 (SILICON)
3N125
3N126

CASE 20(4)
TO-72

N-channel silicon annular tetrode-connected field-effect transistors, designed for low-power switching and amplifier applications in the audio through VHF frequency range, features high breakdown voltage, low transfer capacitance, and tetrode configuration for a broad range of applications.

ABSOLUTE MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Reverse Gate-Source Voltage			Vdc
Gate 1	V_{G1S}	50	
Gate 2	V_{G2S}	50	
Drain-Source Voltage	V_{DS}	50	Vdc
Drain-Gate Voltage			Vdc
Gate 1	V_{DG1}	50	
Gate 2	V_{DG2}	50	
Gate 1-Gate 2 Current	I_{G1G2}	1.0	mAdc
Gate 2-Gate 1 Current	I_{G2G1}	1.0	mAdc
Gate Current			mAdc
Gate 1	I_{G1}	20	
Gate 2	I_{G2}	20	
Drain Current	I_D	20	mAdc
Junction Operating Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C
Total Device Dissipation @ T_A = 25°C Derate Above 25°C	P_D	300 1.71	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate Above 25°C	P_D	800 4.57	mW mW/°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise specified.)

Characteristic		Symbol	Min	Max	Unit
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0, V_{G1G2} = 0)		$V_{(BR)GSS}$	50	-	Vdc
Gate Reverse Current (V_{GS} = 25 Vdc, V_{DS} = 0, V_{G1G2} = 0)		I_{GSS}	-	0.250	nAdc
(V_{GS} = 25 Vdc, V_{DS} = 0, V_{G1G2} = 0, T_A = +150°C)			-	250	
Zero-Gate-Voltage Drain Current (V_{DS} = 15 Vdc, V_{G1G2} = 0, V_{GS} = 0)	3N124	I_{DSS}	0.2	2.0	mAdc
	3N125		1.5	4.5	
	3N126		3.0	9.0	
Gate-Source Voltage (I_D = 20 μAdc, V_{DS} = 15 Vdc, V_{G1G2} = 0)	3N124	V_{GS}	0.2	2.0	Vdc
(I_D = 150 μAdc, V_{DS} = 15 Vdc, V_{G1G2} = 0)	3N125		1.0	3.0	
(I_D = 300 μAdc, V_{DS} = 15 Vdc, V_{G1G2} = 0)	3N126		1.5	5.5	
Gate-Source Cutoff Voltage (V_{DS} = 15 Vdc, I_D = 1.0 μAdc, V_{G1G2} = 0)	3N124	$V_{GS(off)}$	-	-2.5	Vdc
	3N125		-	-4.0	
	3N126		-	-6.5	
Gate 1-Source Cutoff Voltage (V_{DS} = 15 Vdc, I_D = 1.0 μAdc, V_{G2S} = 0)	3N124	$V_{G1S(off)}$	-	-5.0	Vdc
	3N125		-	-8.0	
	3N126		-	-18	
Gate 2-Source Cutoff Voltage (V_{DS} = 15 Vdc, I_D = 1.0 μAdc, V_{G1S} = 0)	3N124	$V_{G2S(off)}$	-	-8.0	Vdc
	3N125		-	-14	
	3N126		-	-26	
Gate 1-Gate 2 Reach Through Voltage (I_{G1G2} = 10 μAdc, I_S = 0, I_D = 0)	3N124	V_{G1G2}	1.0	-	Vdc
	3N125		3.0	-	
	3N126		5.0	-	
Gate 2-Gate 1 Reach Through Voltage (I_{G2G1} = 10 μAdc, I_S = 0, I_D = 0)	3N124	V_{G2G1}	2.0	-	Vdc
	3N125		6.0	-	
	3N126		10	-	
Gate 1-Gate 2 Reach Through Drain Current (V_{DS} = 15 Vdc, I_{G1} = 10 μAdc, V_{G2S} = 0)		I_D	-	1.0	μAdc
Gate 2-Gate 1 Reach Through Drain Current (V_{DS} = 15 Vdc, I_{G2} = 10 μAdc, V_{G1S} = 0)		I_D	-	1.0	μAdc

SMALL-SIGNAL COMMON-SOURCE CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Forward Transfer Admittance (V_{DS} = 15 Vdc, V_{G1S} = V_{G2S} = 0, f = 1.0 kHz) Gate 1-Gate 2	3N124	$\|y_{fs}\|$	500	2000	μmhos
	3N125		800	2400	
	3N126		1200	3600	
Gate 1 Only	3N124	$\|y_{fs1}\|$	250	1000	
	3N125		400	1600	
	3N126		600	2700	
Gate 2 Only	3N124	$\|y_{fs2}\|$	200	800	
	3N125		250	1000	
	3N126		400	1200	
(V_{DS} = 15 Vdc, V_{G1S} = V_{G2S} = 0, f = 100 MHz) Gate 1 Only	3N124	$\|y_{fs1}\|$	250	-	
	3N125		400	-	
	3N126		600	-	
Output Admittance (V_{DS} = 15 Vdc, V_{G1S} = V_{G2S} = 0, f = 1.0 kHz)	3N124	y_{os}	-	2.0	μmhos
	3N125		-	10	
	3N126		-	20	
Input Capacitance (V_{DS} = 15 Vdc, V_{G1S} = V_{G2S} = 0, f = 1.0 kHz) Gate 1-Gate 2		C_{iss}	-	14	pF
Gate 1 Only		C_{iss1}	-	5.0	
Gate 2 Only		C_{iss2}	-	9.0	
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{G1S} = V_{G2S} = 0, f = 1.0 kHz) Gate 1-Gate 2		C_{rss}	-	2.0	pF
Gate 1 Only		C_{rss1}	-	0.5	
Gate 2 Only		C_{rss2}	-	1.5	
Spot Noise Figure (V_{DS} = 15 Vdc, V_{G1S} = V_{G2S} = 0, R_S = 1.0 megohm, f = 1.0 kHz, BW = 100 Hz)		NF	-	4.0	dB
			Typ		
Static Drain-Source "ON" Resistance (V_{GS} = 0, V_{DS} = 0)	3N124	$r_{DS(on)}$	1000		ohms
	3N125		750		
	3N126		500		

3N124, 3N125, 3N126 (continued)

FIGURE 1 — DRAIN CURRENT versus GATE SOURCE VOLTAGE

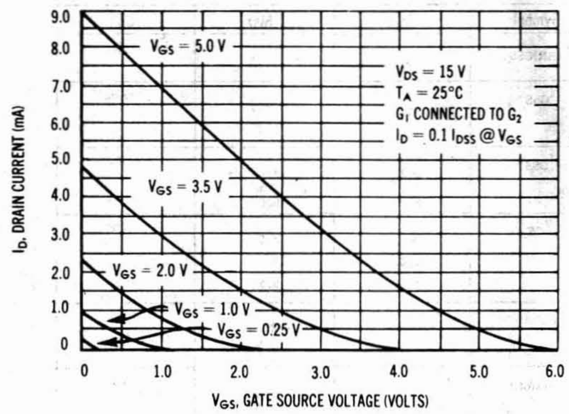


FIGURE 2 — PARAMETER INTER-RELATIONSHIPS

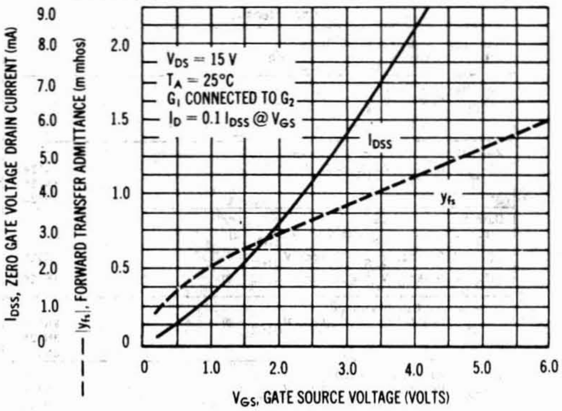


FIGURE 3 — FORWARD TRANSFER ADMITTANCE versus DRAIN CURRENT

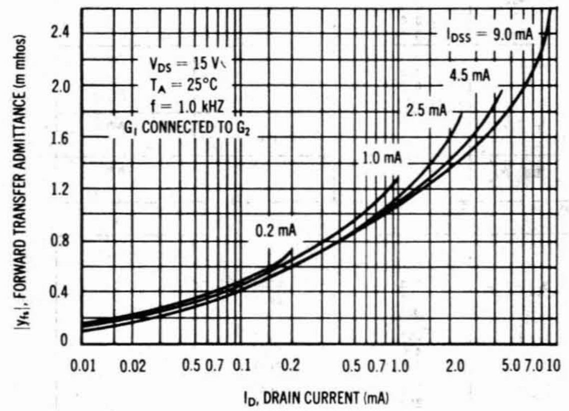
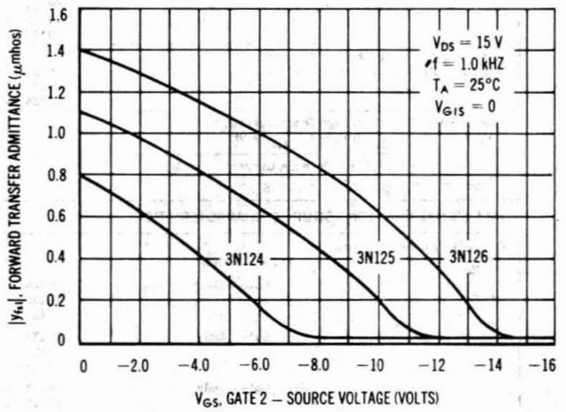


FIGURE 4 GATE 1 — FORWARD TRANSFER ADMITTANCE versus GATE 2 — SOURCE VOLTAGE



NOISE CHARACTERISTICS

$V_{DS} = 15$ Vdc, $I_D = I_{DSS}$, $T_A = 25°C$

GATE 1 CONNECTED TO GATE 2

FIGURE 5A — FREQUENCY VARIATIONS

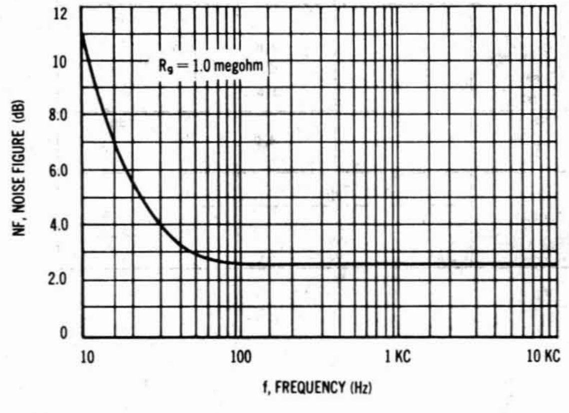
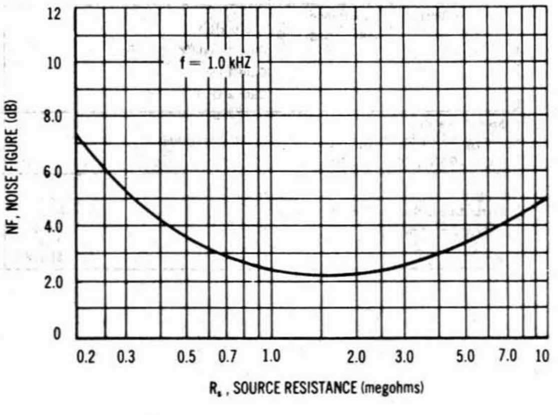


FIGURE 5B — SOURCE RESISTANCE VARIATIONS



HIGH FREQUENCY y PARAMETER CHARACTERISTICS

V_{DS} = 15 Vdc, V_{GS} = 0, T_A = 25°C – GATE 2 CONNECTED TO SOURCE

FIGURE 6 – INPUT ADMITTANCE

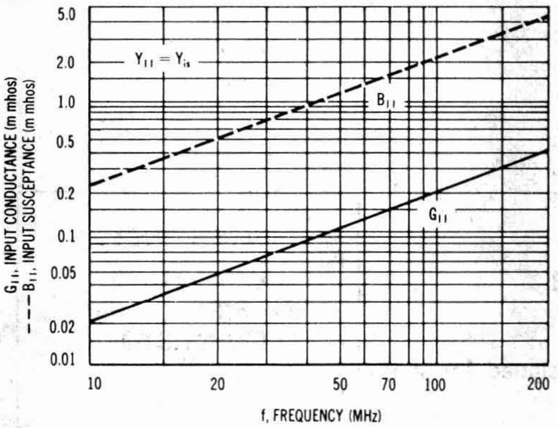


FIGURE 7 – REVERSE TRANSFER ADMITTANCE

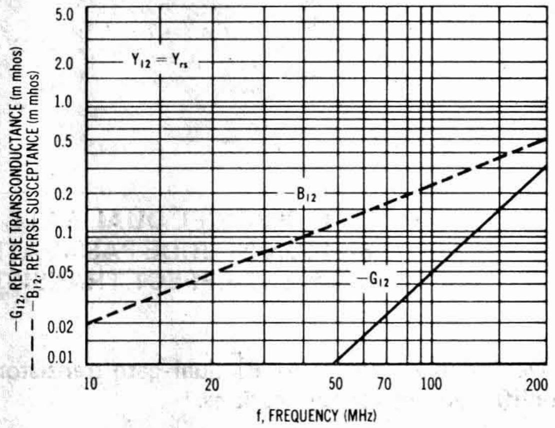


FIGURE 8 – FORWARD TRANSFER ADMITTANCE

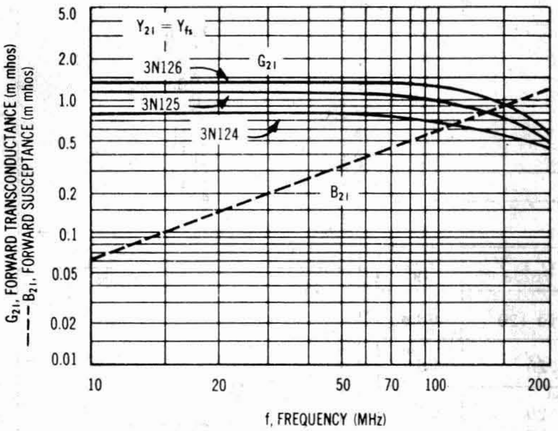
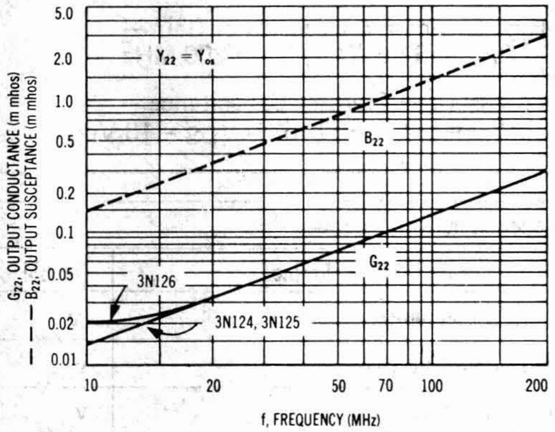
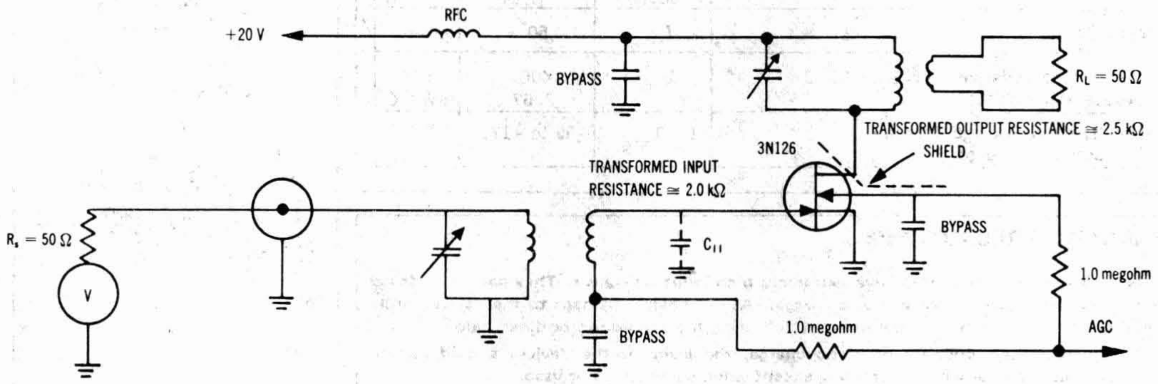


FIGURE 9 – OUTPUT ADMITTANCE



TYPICAL PERFORMANCE USING THE 3N126


+20 V
RFC
BYPASS
RL = 50 Ω
TRANSFORMED OUTPUT RESISTANCE ≅ 2.5 kΩ
3N126
SHIELD
TRANSFORMED INPUT RESISTANCE ≅ 2.0 kΩ
Rs = 50 Ω
V
C11
BYPASS
1.0 megohm
BYPASS
1.0 megohm
AGC

CIRCUIT POWER GAIN = 8.0 dB* TYPICAL AT 105 MHz (AGC = 0V)

---

*Includes circuit losses.

3N140 (SILICON)

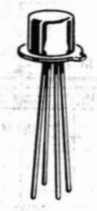
N-CHANNEL DUAL-GATE SILICON-NITRIDE PASSIVATED MOS FIELD-EFFECT TRANSISTOR

Depletion mode (Type B) dual-gate transistor designed for VHF amplifier and mixer applications.

- Silicon-Nitride Passivation for Excellent Long Term Stability
- High Common-Source Power Gain — G_{ps} = 16 dB (Min) @ f = 200 MHz
- Low Reverse Transfer Capacitance — C_{rss} = 0.02 pF (Typ) @ V_{DS} = 13 Vdc

N-CHANNEL
DUAL-GATE MOS FIELD-EFFECT TRANSISTOR

Type B



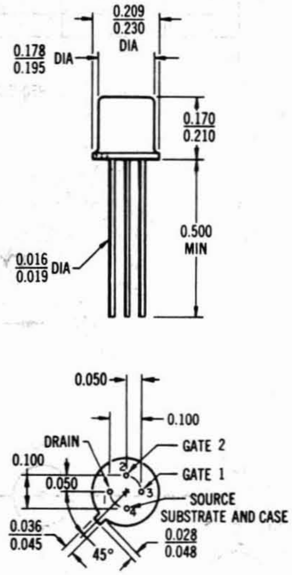
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	0 to +20	Vdc
Drain-Gate 1 Voltage	V_{DG1}	20	Vdc
Drain-Gate 2 Voltage	V_{DG2}	20	Vdc
Reverse Gate 1-Source Voltage	$V_{GS1(r)}$	-8.0	Vdc
Reverse Gate 2-Source Voltage	$V_{GS2(r)}$	-8.0 to 0.4 V_{DS}	Vdc
Forward Gate 1-Source Voltage	$V_{GS1(f)}$	+1.0	Vdc
Forward Gate 2-Source Voltage	$V_{GS2(f)}$	0.4 V_{DS}	Vdc
Drain Current	I_D	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	400 2.67	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. **To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.**
2. **Avoid unnecessary handling. Pick up devices by the case instead of the leads.**
3. **Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.**



TO-72
CASE 20 (9)

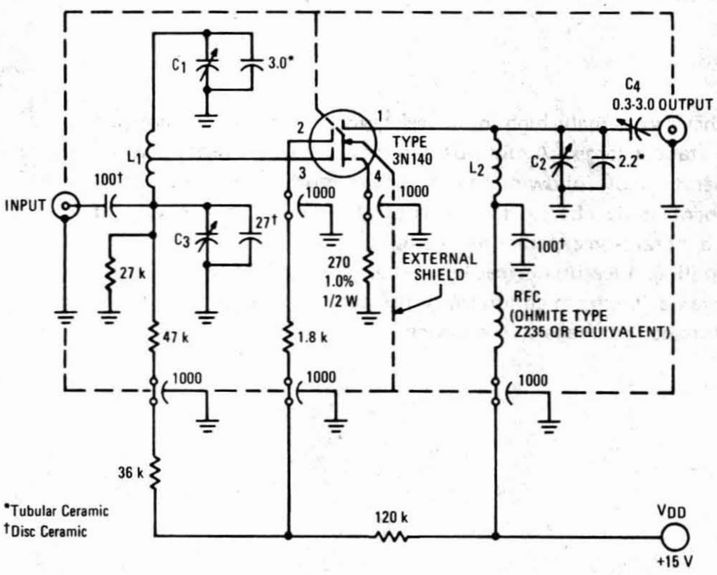
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate 1-Source Cutoff Voltage (V_{DS} = +16 Vdc, I_D = 200 μAdc, V_{G2S} = +4.0 Vdc)	$V_{G1S(off)}$	-0.5	-4.0	Vdc
Gate 2-Source Cutoff Voltage (V_{DS} = +16 Vdc, I_D = 200 μAdc, V_{G1S} = 0)	$V_{G2S(off)}$	-0.5	-4.0	Vdc
Gate 1-Reverse Current (V_{G1S} = 20 Vdc, V_{G2S} = 0, V_{DS} = 0) (V_{G1S} = 20 Vdc, V_{DS} = 0, V_{G2S} = 0, T_A = 125°C)	I_{G1SS}	- -	1.0 0.2	nAdc μAdc
Gate 2-Reverse Current (V_{G2S} = 20 Vdc, V_{G1S} = 0, V_{DS} = 0) (V_{G2S} = 20 Vdc, V_{DS} = 0, V_{G1S} = 0, T_A = 125°C)	I_{G2SS}	- -	1.0 0.2	nAdc μAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current (V_{DD} = +14 Vdc, V_{G1S} = 0, V_{G2S} = +14 Vdc)	I_{DSS}	5.0	30	mAdc
SMALL-SIGNAL CHARACTERISTICS				
Forward Transconductance (V_{DD} = +14 Vdc, I_D = 10 mAdc, V_{G2S} = +4.0 Vdc, f = 1.0 kHz)	$Re(y_{fs})$**	6000	18,000	μmhos
Input Capacitance (V_{DS} = +13 Vdc, I_D = 10 mAdc, V_{G2S} = +4.0 Vdc, f = 1.0 MHz)	C_{iss}	3.0	7.0	pF
Reverse Transfer Capacitance (V_{DS} = +13 Vdc, I_D = 10 mAdc, V_{G2S} = +4.0 Vdc, f = 1.0 MHz)	C_{rss}*	0.01	0.03	pF
Common-Source Noise Figure (See Figure 1) (V_{DD} = +15 Vdc, R_S = 275 Ohms, R_G = 50 Ohms, f = 200 MHz)	NF	-	4.5	dB
Power Gain (See Figure 1) (f = 200 MHz)	G_{ps}	16	22	dB
Bandwidth (See Figure 1) (f = 200 MHz)	BW	9.5	14.5	MHz

*Drain-to-Gate 1

**Gate 1-to-Drain

FIGURE 1 – 200 MHz POWER GAIN AND NOISE FIGURE TEST CIRCUIT



*Tubular Ceramic

†Disc Ceramic

C_1, C_2: 1.5-5.0 pF variable air capacitor: E.F. Johnson Type 160-102 or equivalent.

C_3: 1.0-10 pF piston-type variable air capacitor: JFD Type VAM-010, Johanson Type 4335, or equivalent.

C_4: 0.3-3.0 pF piston-type variable air capacitor: Roanwell Type MH-13 or equivalent.

L_1: 5 turns silver-plated 0.02" thick, 0.07" – 0.03" wide copper ribbon. Internal diameter of winding = 0.25"; winding length approx. 0.65". Tapped at 1-1/2 turns from C_1 end of winding.

L_2: Same as L_1 except winding length approx. 0.7"; no tap.

3N155,A (SILICON)
3N156,A

CASE 20 (2)
(TO-72)

P-channel silicon nitride passivated MOS field-effect enhancement mode (Type C) transistors designed for chopper and switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	35	Vdc
Drain-Gate Voltage	V_{DG}	35	Vdc
Gate-Source Voltage	V_{GS}	50	Vdc
Drain Current	I_D	30	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 1.7	mW mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Drain-Source Breakdown Voltage (I_D = -10 μAdc, $V_G = V_S = 0$)	$V_{(BR)DSS}$	35	-	-	Vdc
Gate Reverse Current (V_{GS} = +50 Vdc, V_{DS} = 0) (V_{GS} = +25 Vdc, V_{DS} = 0)	I_{GSS}	- -	- -	1000 10	pAdc
Zero-Gate Voltage Drain Current (V_{DS} = -10 Vdc, V_{GS} = 0) 3N155, 3N156 3N155A, 3N156A (V_{DS} = -10 Vdc, V_{GS} = 0, T_A = 125°C) 3N155, 3N156 3N155A, 3N156A	I_{DSS}	- - - -	- - - -	1.0 0.25 1000 250	nAdc
Resistance Drain Source (I_D = 0, V_{GS} = 0)	$R_{DS(off)}$	$1 \times 10^{+10}$	-	-	Ohms
Resistance Gate Source Input (V_{GS} = -25 Vdc)	R_{GS}	-	$1 \times 10^{+16}$	-	Ohms
ON CHARACTERISTICS					
Gate Source Threshold Voltage (V_{DS} = -10 Vdc, I_D = -10 μAdc) 3N155, 3N155A 3N156, 3N156A	$V_{GS(TH)}$	1.5 3.0	- -	3.2 5.0	Vdc
Drain Source "ON" Voltage (I_D = -2.0 mAdc, V_{GS} = -10 Vdc)	$V_{DS(on)}$	-	-	-1.0	Vdc
Gate Forward Leakage Current (V_{GS} = -50 Vdc, V_{DS} = 0) (V_{GS} = -25 Vdc, V_{DS} = 0)	$I_{G(f)}$	- -	- -	1000 10	pAdc
"ON" Drain Current (V_{DS} = -15 Vdc, V_{GS} = -10 Vdc)	$I_{D(on)}$	5.0	-	-	mAdc
Static Drain-Source "ON" Resistance (I_D = 0 mAdc, V_{GS} = -10 Vdc) 3N155, 3N156 3N155A, 3N156A	$r_{DS(on)}$	- -	- -	600 300	Ohms
SMALL-SIGNAL CHARACTERISTICS					
Drain-Source Resistance (V_{GS} = -10 Vdc, I_D = 0, f = 1.0 kHz) 3N155, 3N156 3N155A, 3N156A (V_{GS} = -15 Vdc, I_D = 0, f = 1.0 kHz) 3N155, 3N156 3N155A, 3N156A	$r_{ds(on)}$	- - - -	- - - -	600 300 500 250	Ohms
Forward Transfer Admittance (V_{DS} = -15 Vdc, I_D = -2.0 mAdc, f = 1.0 kHz)	$\|y_{fs}\|$	1000	-	4000	μmhos
Input Capacitance (V_{DS} = -15 Vdc, V_{GS} = -10 Vdc, f = 140 kHz)	C_{iss}	-	-	5.0	pF
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 0, f = 140 kHz)	C_{rss}	-	-	1.3	pF
Drain-Substrate Capacitance ($V_{D(SUB)}$ = -10 Vdc, f = 140 kHz)	$C_{d(sub)}$	4.0	-	-	pF

SWITCHING CHARACTERISTICS

Characteristic	Conditions	Symbol	Min	Typ	Max	Unit
Turn-On Delay	(V_{DD} = -10 Vdc, $I_{D(on)}$ = -2.0 mAdc, $V_{GS(on)}$ = -10 Vdc, $V_{GS(off)}$ = 0) Test Circuit given in Figure 1	t_d	-	-	45	μs
Rise Time		t_r	-	-	65	ns
Turn-Off Delay		t_s	-	-	60	ns
Fall Time		t_f	-	-	100	ns

FIGURE 1 – GATE VOLTAGE EFFECTS

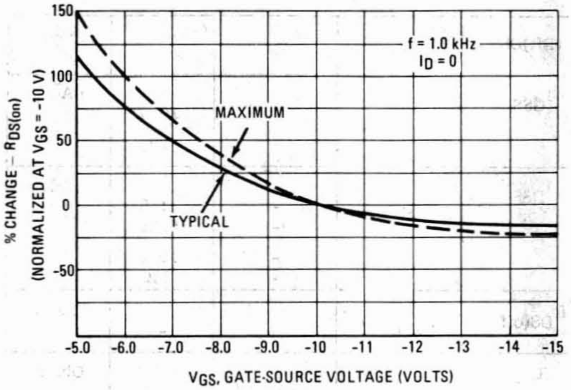


FIGURE 2 – TEMPERATURE EFFECTS

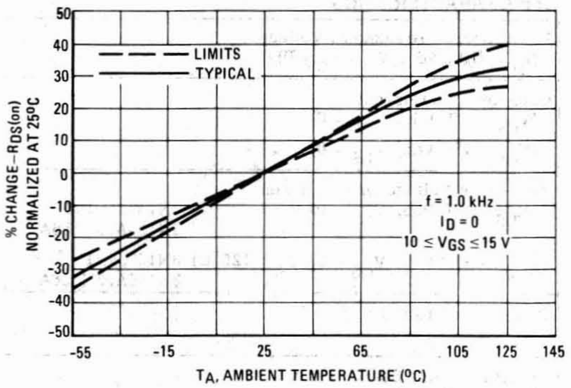


FIGURE 3 – DRAIN CURRENT versus TEMPERATURE

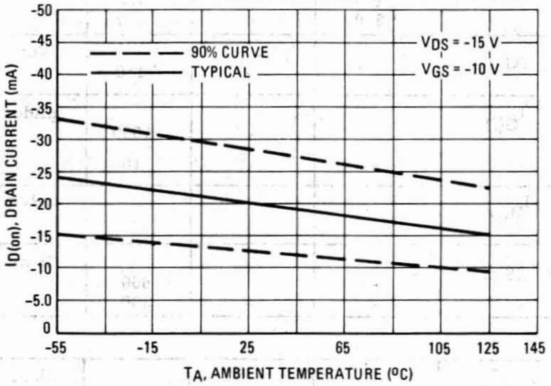


FIGURE 4 – "ON" DRAIN-SOURCE VOLTAGE

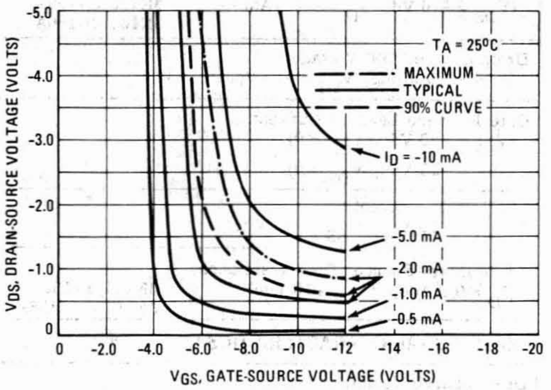


FIGURE 5 – LEAKAGE CURRENTS

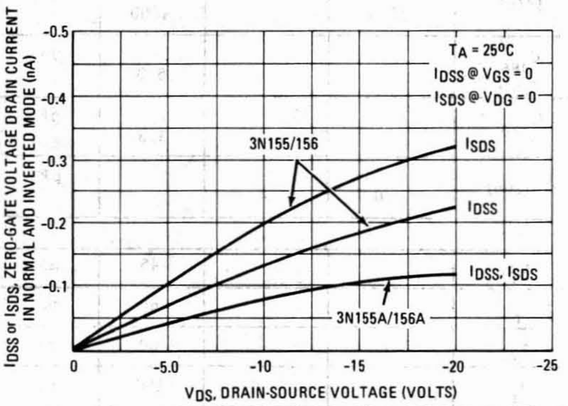
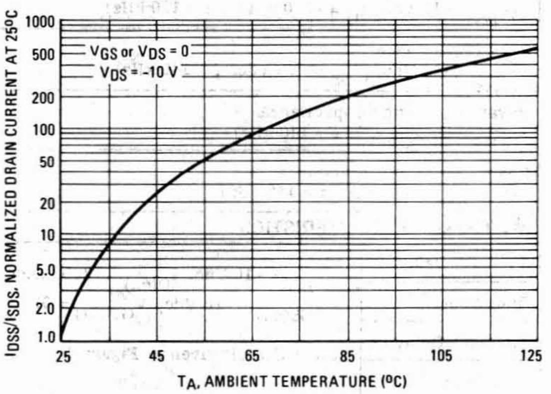


FIGURE 6 – LEAKAGE CURRENT versus TEMPERATURE



SWITCHING CHARACTERISTICS

$T_A = 25^{\circ}C$

FIGURE 7 – TURN-ON DELAY TIME

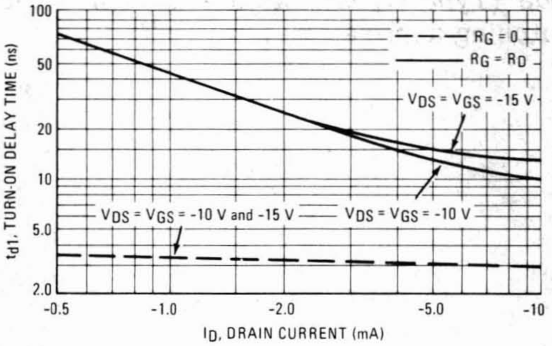


FIGURE 8 – RISE TIME

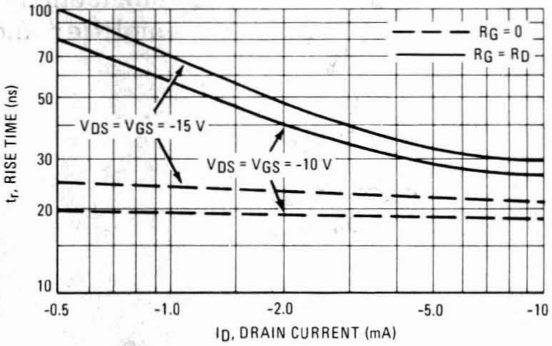


FIGURE 9 – TURN-OFF DELAY TIME

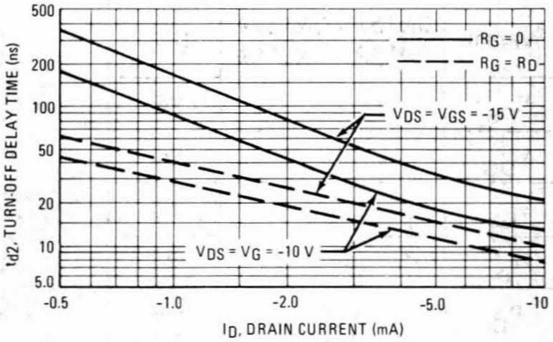


FIGURE 10 – FALL TIME

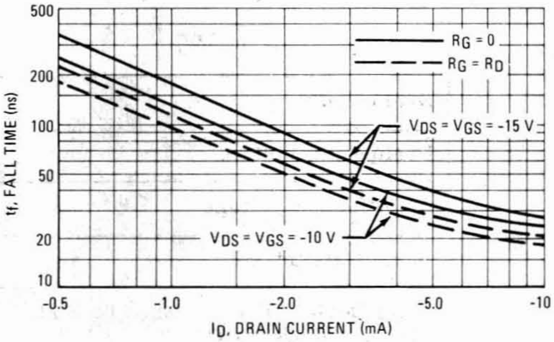
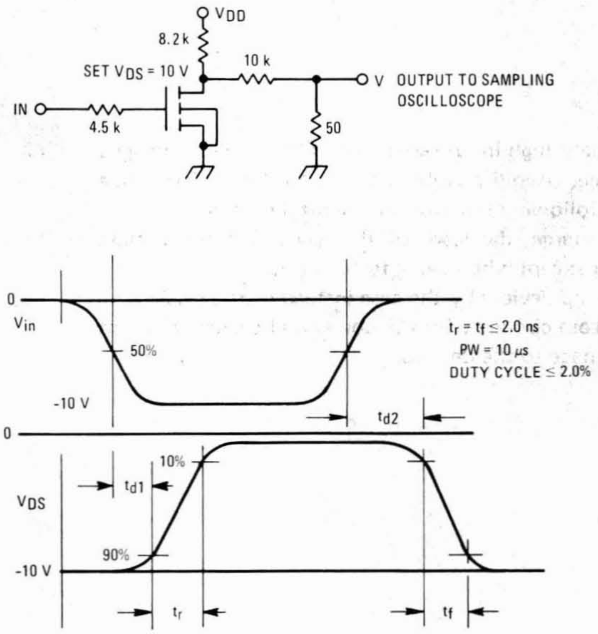


FIGURE 11 – SWITCHING CIRCUIT and WAVEFORMS



The switching characteristics shown above were measured in a test circuit similar to Figure 11. At the beginning of the switching interval, the gate voltage is at ground and the gate-source capacitance ($C_{gs} = C_{iss} - C_{rss}$) has no charge. The drain voltage is at V_{DD}, and thus the feedback capacitance (C_{rss}) is charged to V_{DD}. Similarly, the drain-substrate capacitance ($C_{d(sub)}$) is charged to V_{DD} since the substrate and source are connected to ground.

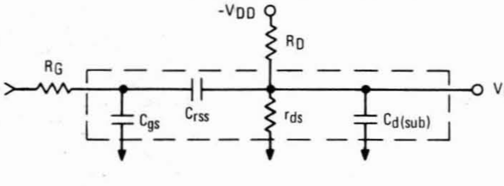
During the turn-on interval, C_{gs} is charged to V_{GS} (the input voltage) through R_G (generator impedance) (Figure 12). C_{rss} must be discharged to $V_{GS} - V_{D(on)}$ through R_G and the parallel combination of the load resistor (R_D) and the channel resistance (r_{ds}). In addition, $C_{d(sub)}$ is discharged to a low value ($V_{D(on)}$) through R_D in parallel with d_s. During turn-off this charge flow is reversed.

Predicting turn-on time proves to be somewhat difficult since the channel resistance (r_{ds}) is a function of the gate-source voltage (V_{GS}). As C_{gs} becomes charged V_{GS} is approaching V_{in} and r_{ds} decreases (see Figure 4) and since C_{rss} and $C_{d(sub)}$ are charged through r_{ds}, turn-on time is quite non-linear.

If the charging time of C_{gs} is short compared to that of C_{rss} and $C_{d(sub)}$, then r_{ds} (which is in parallel with R_D) will be low compared to R_D during the switching interval and will largely determine the turn-on time. On the other hand, during turn-off r_{ds} will be almost an open circuit requiring C_{rss} and $C_{d(sub)}$ to be charged through R_D and resulting in a turn-off time that is long compared to the turn-on time. This is especially noticeable for the curves where $R_G = 0$ and C_{gs} is charged through the pulse generator impedance only.

The switching curves shown with $R_G = R_D$ simulate the switching behavior of cascaded stages where the driving source impedance is normally the same as the load impedance. The set of curves with $R_G = 0$ simulates a low source impedance drive such as might occur in complementary logic circuits.

FIGURE 12 – SWITCHING CIRCUIT with MOSFET EQUIVALENT MODEL



3N157,A (SILICON)
3N158,A

CASE 20 (2)
(TO-72)

P-channel silicon nitride passivated MOS field-effect enhancement mode (Type C) transistors designed for amplifier and switching applications.

MAXIMUM RATINGS

Rating	Symbol	3N157 3N158	3N157A 3N158A	Unit
Drain-Source Voltage	V_{DS}	35	50	Vdc
Drain-Gate Voltage	V_{DG}	35	50	Vdc
Gate-Source Voltage	V_{GS}	50		Vdc
Drain Current	I_D	30		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 1.7		mW mW/°C
Operating Junction Temperature Range	T_J	-65 to +175		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Drain-Source Breakdown Voltage (I_D = -10 μAdc, V_G = V_S = 0)	3N157, 3N158 3N157A, 3N158A	$V_{(BR)DSS}$	35 50	- -	- -	Vdc
Gate Reverse Current (V_{GS} = +25 Vdc, V_{DS} = 0)		I_{GSS}	-	-	10	pAdc
Zero-Gate Voltage Drain Current (V_{DS} = -15 Vdc, V_{GS} = 0)	3N157, 3N158 3N157A, 3N158A	I_{DSS}	- -	- -	1.0 0.25	nAdc
(V_{DS} = -35 Vdc, V_{GS} = 0)	3N157, 3N158		-	-	10	μAdc
(V_{DS} = -50 Vdc, V_{GS} = 0)	3N157A, 3N158A		-	-	10	
Input Resistance (V_{GS} = -25 Vdc)		R_{GS}	-	$1 \times 10^{+12}$	-	Ohms
ON CHARACTERISTICS						
Gate-Source Threshold Voltage (V_{DS} = -15 Vdc, I_D = -10 μAdc)	3N157, 3N157A 3N158, 3N158A	$V_{GS(TH)}$	1.5 3.0	- -	3.2 5.0	Vdc
Gate-Source Voltage (V_{DS} = -15 Vdc, I_D = -0.5 mAdc)	3N157, 3N157A 3N158, 3N158A	V_{GS}	1.5 3.0	- -	5.5 7.0	Vdc
Gate Forward Current (V_{GS} = -25 Vdc, V_{DS} = 0)		$I_{G(f)}$	-	-	10	pAdc
(V_{GS} = -25 Vdc, V_{DS} = 0, T_A = +55°C)			-	-	10	nAdc
"ON" Drain Current (V_{DS} = -15 Vdc, V_{GS} = -10 Vdc)		$I_{D(on)}$	5.0	-	-	mAdc
SMALL-SIGNAL CHARACTERISTICS						
Forward Transfer Admittance (V_{DS} = -15 Vdc, I_D = -2.0 mAdc, f = 1.0 kHz)		$\|y_{fs}\|$	1000	-	4000	μmhos
(V_{DS} = -15 Vdc, V_{GS} = -15 Vdc, f = 1.0 kHz)			1800	-	-	
Output Admittance (V_{DS} = -15 Vdc, I_D = -2.0 mAdc, f = 1.0 kHz)		$\|y_{os}\|$	-	-	60	μmhos
Input Capacitance (V_{DS} = -15 Vdc, V_{GS} = 0, f = 140 kHz)		C_{iss}	-	-	5.0	pF
Reverse Transfer Capacitance (V_{DS} = -15 Vdc, V_{GS} = 0, f = 140 kHz)		C_{rss}	-	-	1.3	pF
Drain-Substrate Capacitance ($V_{D(sub)}$ = -10 Vdc, f = 140 kHz)		$C_{d(sub)}$	-	-	4.0	pF
Noise Voltage (R_S = 0, BW = 1.0 Hz, V_{DS} = -15 Vdc, I_D = -2.0 mAdc, f = 100 Hz)		e_n	-	300	-	NV/√Hz
(R_S = 0, BW = 1.0 Hz, V_{DS} = -15 Vdc, I_D = -2.0 mAdc, f = 1.0 kHz)			-	120	500	

3N157,A, 3N158,A (continued)

FIGURE 1 – FORWARD TRANSCONDUCTANCE

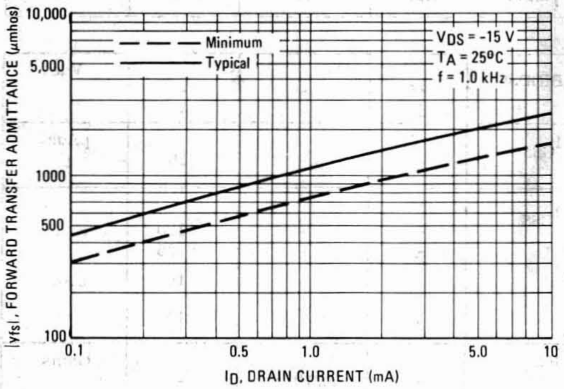


FIGURE 2 – OUTPUT TRANSCONDUCTANCE

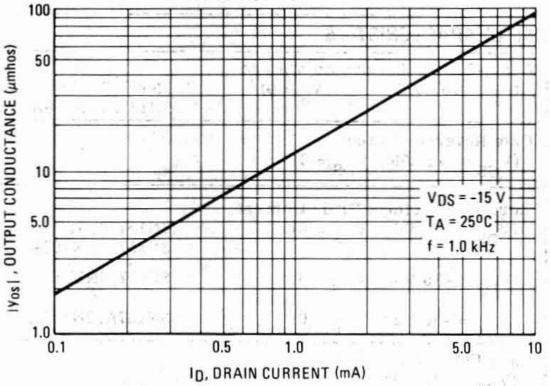


FIGURE 3 – FORWARD TRANSCONDUCTANCE versus TEMPERATURE

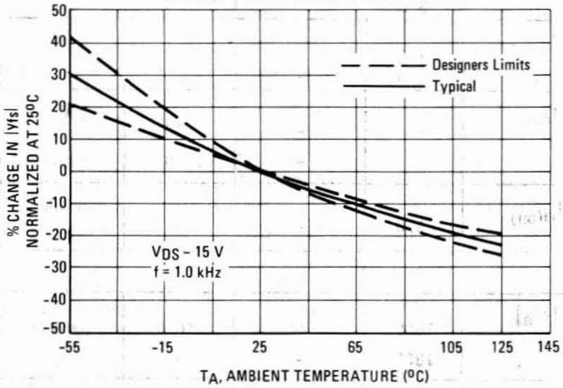


FIGURE 4 – BIAS CURVE

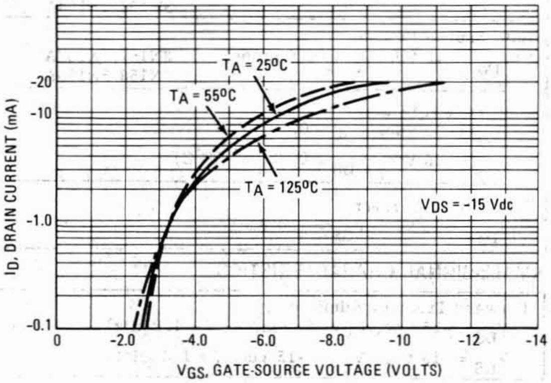


FIGURE 5 – "ON" DRAIN-SOURCE VOLTAGE

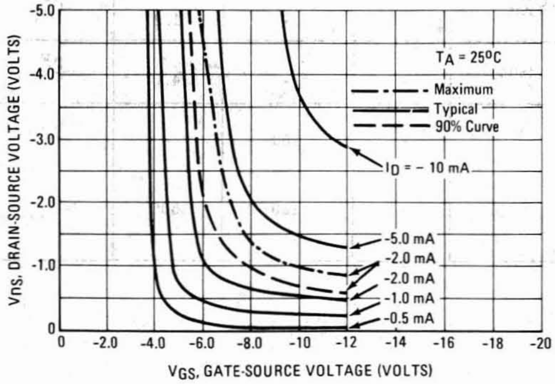
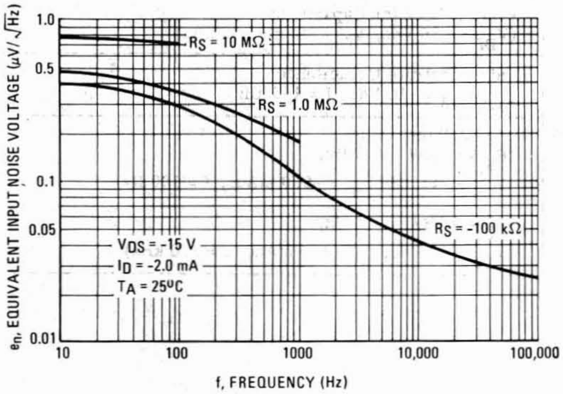


FIGURE 6 – EQUIVALENT INPUT NOISE VOLTAGE



SWITCHING CHARACTERISTICS

($T_A = 25°C$)

FIGURE 7 – TURN-ON DELAY TIME

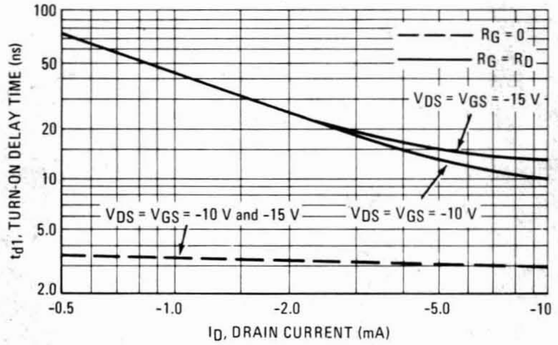


FIGURE 8 – RISE TIME

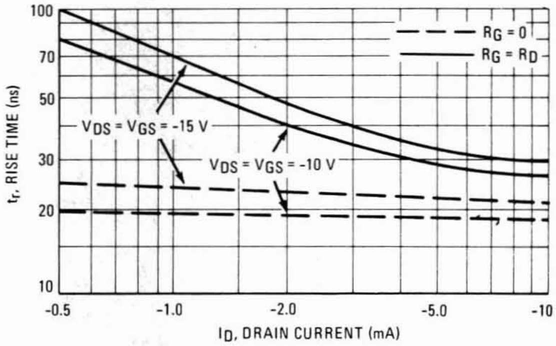


FIGURE 9 – TURN-OFF DELAY TIME

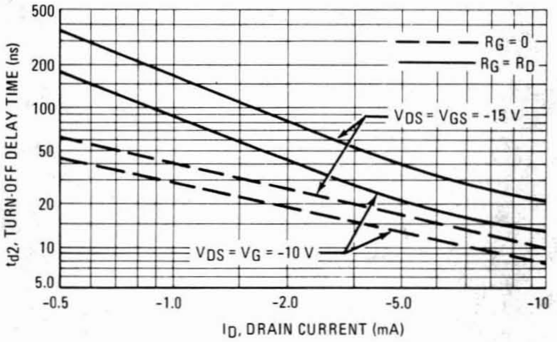


FIGURE 10 – FALL TIME

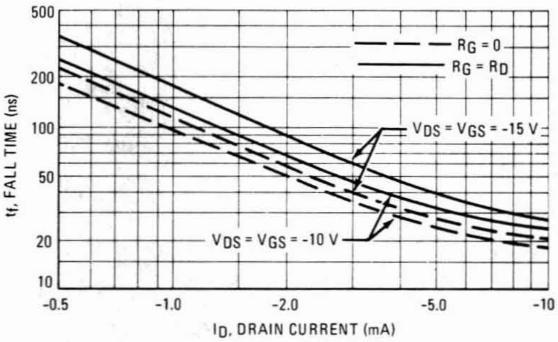
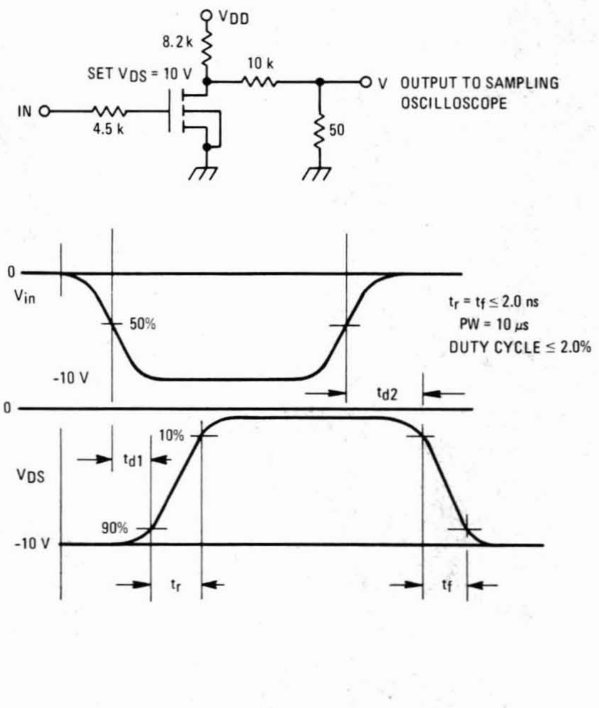


FIGURE 11 – SWITCHING CIRCUIT and WAVEFORMS



The switching characteristics shown above were measured in a test circuit similar to Figure 11 At the beginning of the switching interval, the gate voltage is at ground and the gate-source capacitance ($C_{gs} = C_{iss} - C_{rss}$) has no charge. The drain voltage is at V_{DD}, and thus the feedback capacitance (C_{rss}) is charged to V_{DD}. Similarly, the drain-substrate capacitance ($C_{d(sub)}$) is charged to V_{DD} since the substrate and source are connected to ground.

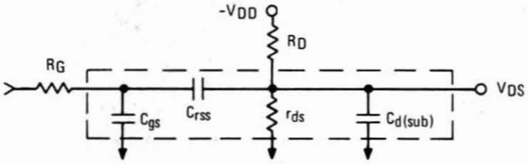
During the turn-on interval, C_{gs} is charged to V_{GS} (the input voltage) through R_G (generator impedance) (Figure 12). C_{rss} must be discharged to $V_{GS} - V_{D(on)}$ through R_G and the parallel combination of the load resistor (R_D) and the channel resistance (r_{ds}). In addition, $C_{d(sub)}$ is discharged to a low value ($V_{D(on)}$) through R_D in parallel with r_{ds}. During turn-off this charge flow is reversed.

Predicting turn-on time proves to be somewhat difficult since the channel resistance (r_{ds}) is a function of the gate-source voltage (V_{GS}). As C_{gs} becomes charged V_{GS} is approaching V_{in} and r_{ds} decreases (see Figure 5) and since C_{rss} and $C_{d(sub)}$ are charged through r_{ds}, turn-on time is quite non-linear.

If the charging time of C_{gs} is short compared to that of C_{rss} and $C_{d(sub)}$, then r_{ds} (which is in parallel with R_D) will be low compared to R_D during the switching interval and will largely determine the turn-on time. On the other hand, during turn-off r_{ds} will be almost an open circuit requiring C_{rss} and $C_{d(sub)}$ to be charged through R_D and resulting in a turn-off time that is long compared to the turn-on time. This is especially noticeable for the curves where $R_G = 0$ and C_{gs} is charged through the pulse generator impedance only.

The switching curves shown with $R_G = R_D$ simulate the switching behavior of cascaded stages where the driving source impedance is normally the same as the load impedance. The set of curves with $R_G = 0$ simulates a low source impedance drive such as might occur in complementary logic circuits.

FIGURE 12 – SWITCHING CIRCUIT with MOSFET EQUIVALENT MODEL

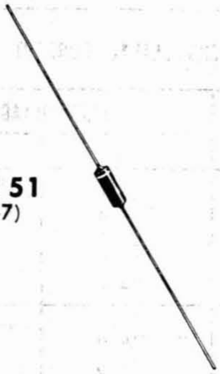


HOUSE NUMBERED DEVICE SPECIFICATIONS

- DIODES
- POWER VARACTORS
- RECTIFIERS
- RECTIFIER ASSEMBLIES
- THYRISTORS & TRIGGERS
- TRANSISTORS

1/4M2.4AZ thru 1/4M200Z (SILICON)

1/4 W
2.4 – 200 V



CASE 51
(DO-7)

Hermetically sealed, all-glass case with all external surfaces corrosion resistant. Cathode end, indicated by color band, will be positive with respect to anode end when operated in the zener region.

MAXIMUM RATINGS

Junction and Storage Temperature: -65°C to +175°C
D C Power Dissipation: 1/4 Watt (Derate 1.67 mW/°C Above 25°C)

The type numbers specified have a standard voltage (V_Z) tolerance of ±20%. For closer tolerances, add suffix "10" for ±10% or "5" for ±5%. (3%, 2%, 1% tolerances also available.)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$, $V_F = 1.5$ V max @ 100 mA)

TYPE NO.	NOMINAL ZENER VOLTAGE @ I_{ZT} (V_Z) VOLTS	TEST CURRENT (I_{ZT}) mA	MAXIMUM ZENER IMPEDANCE (Z_{ZT}) @ I_{ZT} ohms	MAXIMUM DC ZENER CURRENT (I_{ZM}) mA	REVERSE LEAKAGE CURRENT		
					I_R MAX (μA)	TEST VOLTAGE Vdc*	
						V_{R1}	V_{R2}
1/4M2.4AZ	2.4	10	60	70	75	1	1
1/4M2.7AZ	2.7	10	60	65	75	1	1
1/4M3.0AZ	3.0	10	55	60	50	1	1
1/4M3.3AZ	3.3	10	55	55	50	1	1
1/4M3.6AZ	3.6	10	50	52	50	1	1
1/4M3.9AZ	3.9	10	50	49	25	1	1
1/4M4.3AZ	4.3	10	45	46	25	1.5	1.5
1/4M4.7AZ	4.7	10	35	42	10	1.5	1.5
1/4M5.1AZ	5.1	10	25	39	5	1.5	1.5
1/4M5.6AZ	5.6	10	20	36	5	1.5	1.5
1/4M6.2AZ	6.2	10	15	33	5	3.5	3.5
1/4M6.8Z	6.8	9.2	7.0	33	150	5.2	4.9
1/4M7.5Z	7.5	8.3	8.0	30	75	5.7	5.4
1/4M8.2Z	8.2	7.6	9.0	26	50	6.2	5.9
1/4M9.1Z	9.1	6.9	10	24	25	6.9	6.6
1/4M10Z	10	6.3	11	21	10	7.6	7.2
1/4M11Z	11	5.7	13	19	5	8.4	8.0
1/4M12Z	12	5.2	15	18	5	9.1	8.6
1/4M13Z	13	4.8	18	16	5	9.9	9.4
1/4M14Z	14	4.5	20	15	5	10.6	10.1
1/4M15Z	15	4.2	22	14	5	11.4	10.8
1/4M16Z	16	3.9	24	13	5	12.2	11.5
1/4M17Z	17	3.7	26	12.5	5	13.0	12.2
1/4M18Z	18	3.5	28	11.5	5	13.7	13.0
1/4M19Z	19	3.3	30	11.0	5	14.4	13.7
1/4M20Z	20	3.1	33	10.5	5	15.2	14.4
1/4M22Z	22	2.8	40	9.5	5	16.7	15.8
1/4M24Z	24	2.6	46	9.0	5	18.2	17.3
1/4M25Z	25	2.5	50	8.0	5	19.0	18.0
1/4M27Z	27	2.3	58	7.5	5	20.6	19.4
1/4M30Z	30	2.1	70	7.0	5	22.8	21.6

*V_{R1} – Test Voltage for 5% Tolerance Device V_{R2} – Test Voltage for 10% Tolerance Device

No Leakage Specified as 20% Tolerance Device

1/4M2.4AZ thru 1/4M200Z (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C, V_F = 1.5 V max @ 100 mA) (continued)

TYPE NO.	NOMINAL ZENER VOLTAGE @ I_{ZT} (V_Z) VOLTS	TEST CURRENT (I_{ZT}) mA	MAXIMUM ZENER IMPEDANCE (Z_{ZT}) @ I_{ZT} ohms	MAXIMUM DC ZENER CURRENT (I_{ZM}) mA	REVERSE LEAKAGE CURRENT		
					I_R MAX (μA)	TEST VOLTAGE Vdc*	
						V_{R1}	V_{R2}
1/4M33Z	33	1.9	85	6.5	5	25.1	23.8
1/4M36Z	36	1.7	100	6.0	5	27.4	25.9
1/4M39Z	39	1.6	120	5.0	5	29.7	28.1
1/4M43Z	43	1.5	140	4.8	5	32.7	31.0
1/4M45Z	45	1.4	150	4.5	5	34.2	32.4
1/4M47Z	47	1.3	160	4.3	5	35.8	33.8
1/4M50Z	50	1.2	180	4.1	5	38.0	36.0
1/4M52Z	52	1.2	200	4.0	5	39.5	37.4
1/4M56Z	56	1.1	230	3.8	5	42.6	40.3
1/4M62Z	62	1.0	290	3.3	5	47.1	44.6
1/4M68Z	68	0.92	350	3.0	5	51.7	49.0
1/4M75Z	75	0.83	450	2.8	5	56.0	54.0
1/4M82Z	82	0.76	550	2.5	5	62.2	59.0
1/4M91Z	91	0.69	700	2.3	5	69.2	65.5
1/4M100Z	100	0.63	900	2.0	5	76.0	72.0
1/4M105Z	105	0.60	1000	1.9	5	79.8	75.6
1/4M110Z	110	0.57	1200	1.8	5	83.6	79.2
1/4M120Z	120	0.52	1500	1.7	5	91.2	86.4
1/4M130Z	130	0.48	1900	1.5	5	98.8	93.6
1/4M140Z	140	0.45	2200	1.4	5	106.4	100.8
1/4M150Z	150	0.42	2500	1.3	5	114.0	108.0
1/4M175Z	175	0.36	3300	1.1	5	133.0	126.0
1/4M200Z	200	0.31	4300	1.0	5	152.0	144.0

*V_{R1} – Test Voltage for 5% Tolerance Device V_{R2} – Test Voltage for 10% Tolerance Device

No Leakage Specified as 20% Tolerance Device

SPECIAL SELECTIONS AVAILABLE INCLUDE: (See Selector Guide for details)

1 — Nominal zener voltages between those shown.

2 — Matched sets: (Standard Tolerances are ±5.0%, ±3.0%, ±2.0%, ±1.0%) depending on voltage per device.
  a. Two or more units for series connection with specified tolerance on total voltage. Series matched sets make possible higher zener voltages and provide lower temperature coefficients, lower dynamic impedance and greater power handling ability.
  b. Two or more units matched to one another with any specified tolerance.

3 — Tight voltage tolerances: 1.0%, 2.0%, 3.0%.

.4M.64FR10
.4M1.36FR5
.4M1.36FR2
.4M2.04FR5
.4M2.04FR2

For Specifications, See 1N816 Data.

1M110ZS thru 1M200ZS

For Specifications, See 1N4728 Data.

AF239 (GERMANIUM)

CASE 20
(TO-72)

Active Elements Isolated From Case

PNP germanium high frequency transistor designed for use in UHF/RF amplifier and autodyne converter applications.

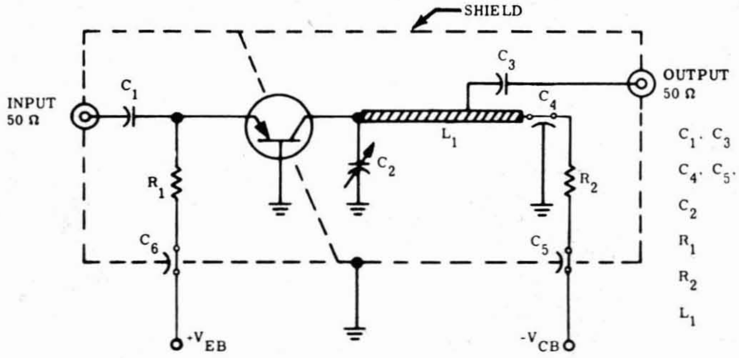
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CES}	20	Vdc
Collector-Base Voltage	V_{CB}	20	Vdc
Emitter-Base Voltage	V_{EB}	0.3	Vdc
Collector Current — Continuous	I_C	10	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25° C	P_D	60 0.8	mW mW/° C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	°C

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 8.0 μAdc, V_{BE} = 0)	BV_{CES}	20	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 8.0 μAdc, I_E = 0)	BV_{CBO}	20	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	0.3	-	-	Vdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 1.5 mAdc, V_{CE} = 12 Vdc)	h_{FE}	15	50	-	-
DYNAMIC CHARACTERISTICS					
Current-Gain – Bandwidth Product (I_C = 1.5 mAdc, V_{CE} = 12 Vdc, f = 100 MHz)	f_T	600	720	-	MHz
Common-Emitter Reverse Transfer Capacitance (V_{CE} = 12 Vdc, I_E = 0, f = 1.0 MHz)	C_{re}	-	0.23	0.30	pF
Collector-Base Time Constant (I_E = 1.5 mAdc, V_{CB} = 12 Vdc, f = 31.8 MHz)	$r_b'C_c$	-	2.0	5.0	ps
Noise Figure (Figure 1) (I_C = 1.5 mAdc, V_{CE} = 12 Vdc, R_S = 50 ohms, f = 800 MHz)	NF	-	5.0	6.0	dB
Noise Figure (Figure 1) (I_C = 1.5 mAdc, V_{CE} = 12 Vdc, R_S = 50 ohms, f = 860 MHz)	NF	-	-	6.7	dB
FUNCTIONAL TEST					
Common-Base Amplifier Power Gain (I_C = 1.5 mAdc, V_{CE} = 12 Vdc, f = 800 MHz) (Figure 1)	G_{pb}	11.2	14	-	dB
Common-Base Amplifier Power Gain (I_C = 1.5 mAdc, V_{CE} = 12 Vdc, f = 860 MHz) (Figure 1)	G_{pb}	-	13.2	-	dB

FIGURE 1 — 800 MHz POWER GAIN AND NOISE FIGURE TEST CIRCUIT



C_1, C_3	10 pF DUR-MICA
C_4, C_5, C_6	240 pF FEEDTHROUGH ERIE
C_2	0.4 - 6.0 pF JOHANSEN
R_1	2.2 k Ω, 0.25 W
R_2	100 Ω, 0.25 W
L_1	SILVER PLATED BRASS STRIP 0.08" WIDE, 0.025" THICK. APPROX. LENGTH 1" – TAP @ 1/3 LENGTH

COMMON-BASE y PARAMETERS

$T_A = 25°C$

FIGURE 2 — INPUT ADMITTANCE

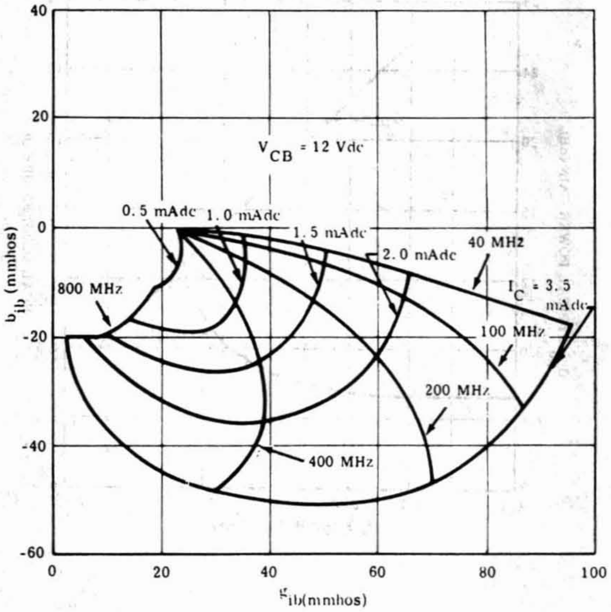


FIGURE 3 — REVERSE TRANSFER ADMITTANCE

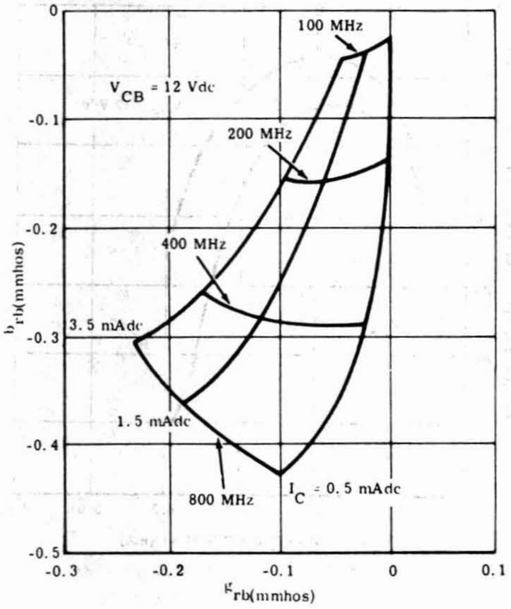


FIGURE 4 — FORWARD TRANSFER ADMITTANCE

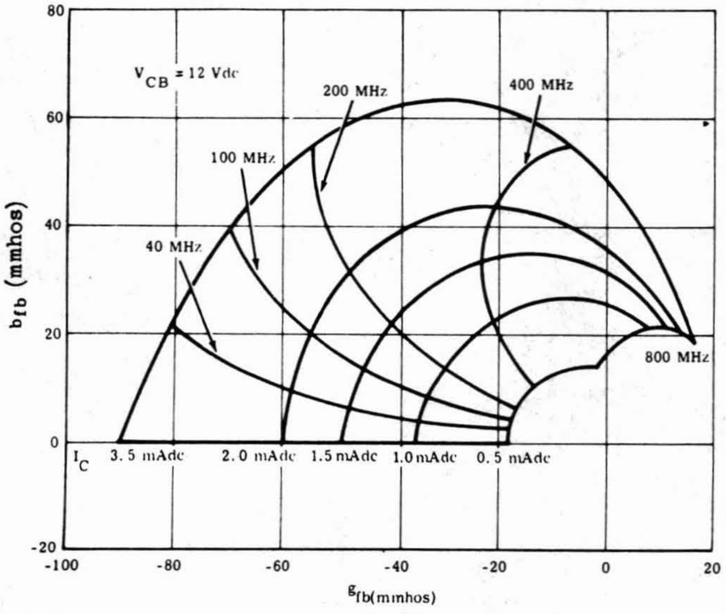


FIGURE 5 — OUTPUT ADMITTANCE

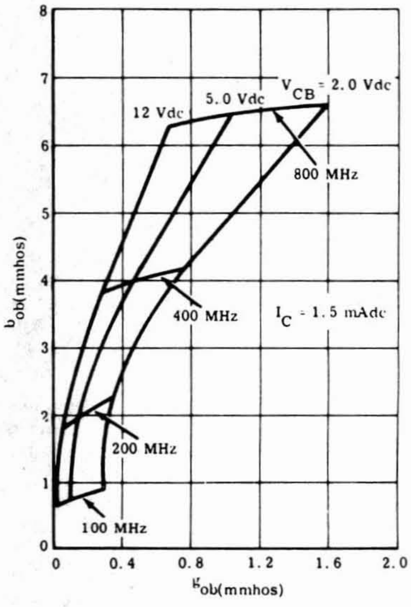


FIGURE 6 — CURRENT-GAIN-BANDWIDTH PRODUCT

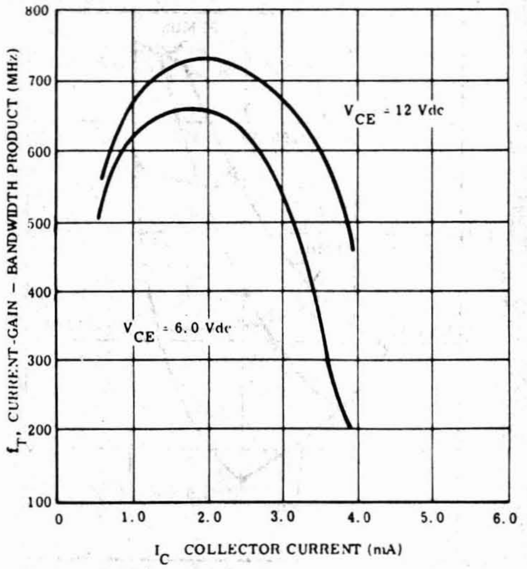
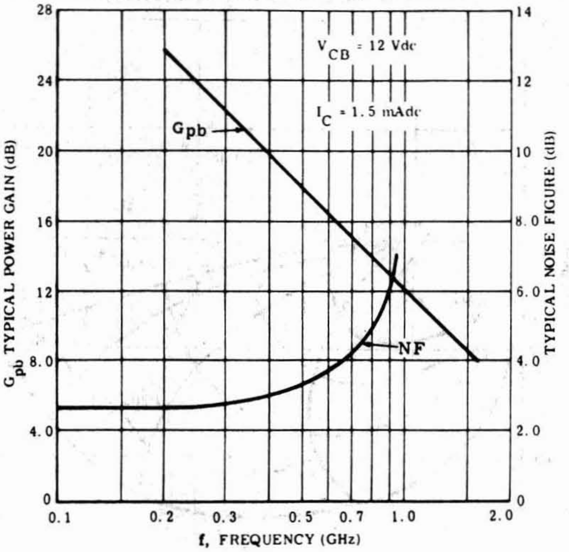


FIGURE 7 — TYPICAL POWER GAIN AND NOISE FIGURE



MA100 (GERMANIUM)

CASE 31(1)
(TO-5)

All leads isolated from case

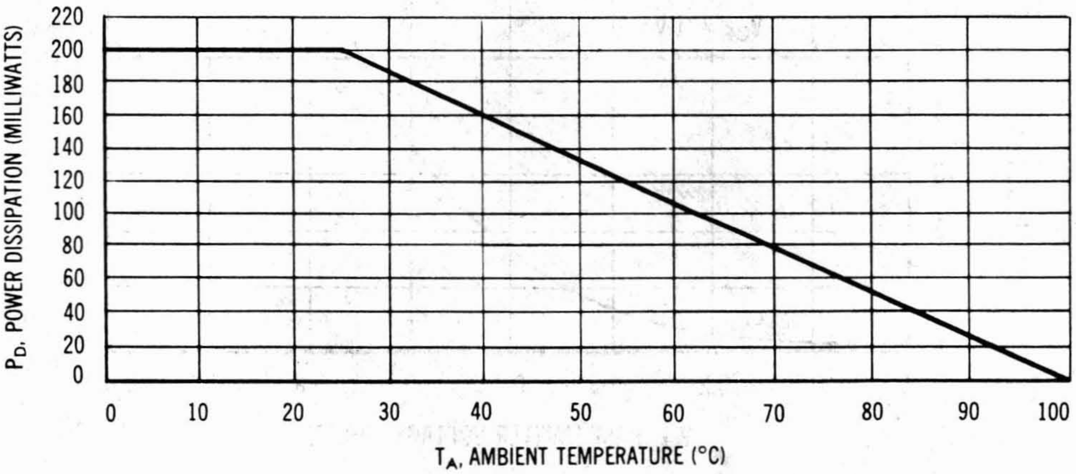
Low noise germanium transistor, designed for audio amplifier applications, feature stabilization bake for greater gain stability, and rugged quad-mount construction.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CES}	60	Vdc
Emitter-Base Voltage	V_{EB}	15	Vdc
Collector Current (Continuous)*	I_C*	500	mAdc
Collector Dissipation at T_A = 25°C Derate above 25°C	P_D	200 2.67	mW mW/°C
Junction Temperature Range	T_J	-65 to +100	°C
Storage Temperature Range	T_{stg}	-65 to +100	°C

*Limited by power dissipation.

POWER-TEMPERATURE DERATING CURVE

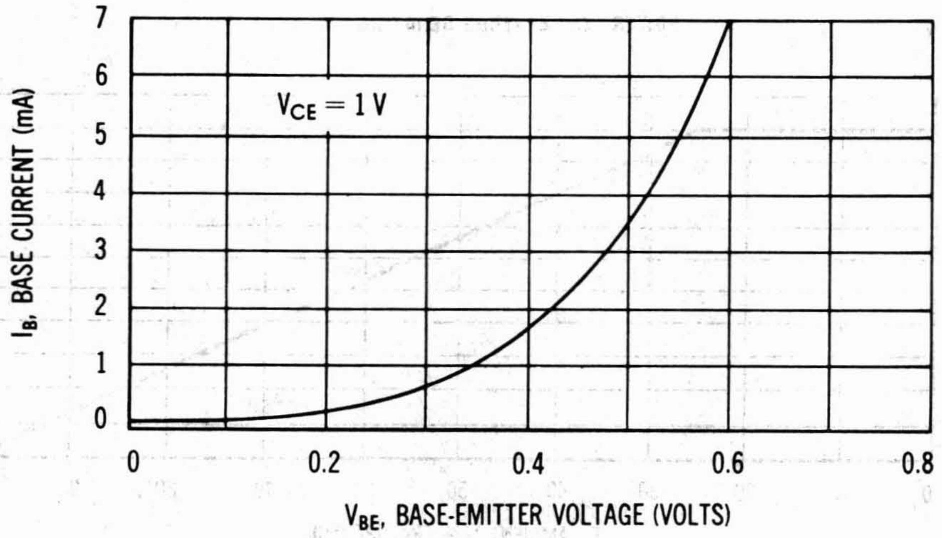


MA100 (continued)

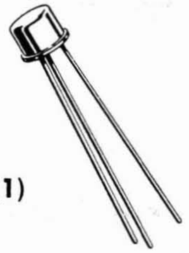
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 0)	I_{CBO}	— —	100 10	μAdc
Emitter-Base Cutoff Current (V_{EB} = 15 Vdc, I_C = 0)	I_{EBO}	—	10	μAdc
Collector-Emitter Leakage Current (V_{CE} = 60 Vdc, R_{BE} = 0)	I_{CES}	—	100	μAdc
Output Capacitance (V_{CB} = 6 Vdc, I_E = 0, f = 1 MHz)	C_{ob}	—	25	pF
Input Impedance (V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	h_{ib}	26	40	ohms
Output Admittance (V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	h_{ob}	0.1	1.0	μmhos
DC Current Gain (V_{CE} = 1 Vdc, I_C = 10 mAdc)	h_{FE}	30	—	—
Small-Signal Current Gain (V_{CE} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	h_{fe}	50	190	—
Small-Signal Current Gain Cutoff Frequency (V_{CB} = 6 Vdc, I_E = 1 mAdc)	$f_{\alpha b}$	1.0	—	MHz
Noise Figure (V_{CE} = 5 Vdc, I_C = 100 μAdc, R_s = 1 K ohms, f = 100 Hz)	NF	—	8.0	dB

BASE INPUT CURRENT versus BASE DRIVE VOLTAGE



MA112 thru MA117 (GERMANIUM)



CASE 31(1)
(TO-5)

All leads isolated from case

PNP Germanium transistors for economical circuit applications. Available with a wide variety of gain ranges.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	V
Collector-Base Voltage	V_{CB}	15	V
Emitter-Base Voltage	V_{EB}	15	V
Collector Current	I_C	200	mA
Storage Temperature Limits	T_{stg}	-55 to +85	°C
Power Dissipation @ $T_A = +25°C$	P_D	175	mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Emitter Current ($V_{CE} = 15$ V, $R_{BE} = 10$ KΩ)	I_{CER}	-	600	μA
Collector-Base Current ($V_{CB} = 15$ V, $I_E = 0$)	I_{CBO}	-	15	μA
Small Signal Current Gain ($V_{CE} = 6$ V, $I_C = 1$ mA)	h_{fe}			-
MA112		30	70	
MA113		50	125	
MA114		100	250	
MA115		30	125	
MA116		50	250	
MA117		30	250	

MA200 thru MA206 (GERMANIUM)

CASE 31(1)
(TO-5)

Germanium PNP transistor designed for high-voltage applications in the audio frequency range, such as neon driver, solenoid or relay driver applications.

All leads isolated from case

MAXIMUM RATINGS ($T_A = 25°C$)

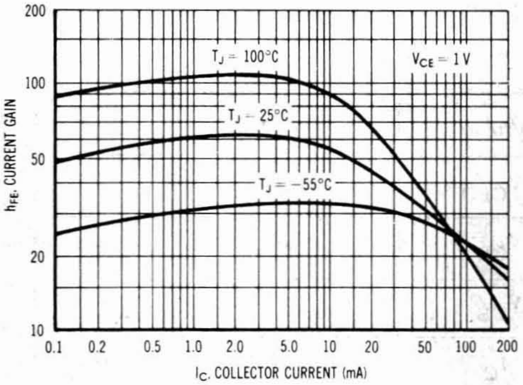
Rating	Symbol	MA200 MA202	MA201 MA203	MA204	MA205	MA206	Unit
Collector-Base Voltage	V_{CB}	105	105	90	75	60	Vdc
Collector-Emitter Voltage	V_{CE}	105	105	90	75	60	Vdc
Emitter-Base Voltage	V_{EB}	10	20	20	20	10	Vdc
Collector Current	I_C	200					mAdc
Emitter Current	I_E	200					mAdc
Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +100					^oC
Thermal Resistance	θ_{JA}	0.5					$^oC/mW$
Collector Dissipation at $T_A = 25^oC$ Derate above 25^oC	P_D	150 2.0					mW $mW/^oC$

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

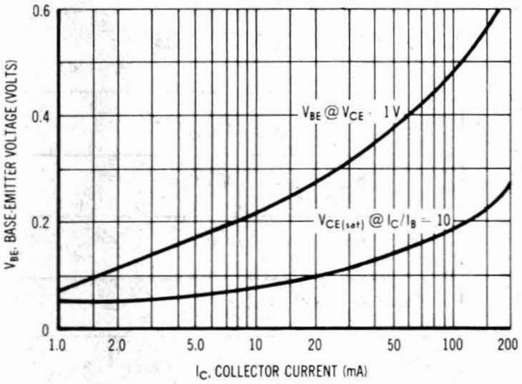
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current		I_{CBO}				μA
(V_{CB} = 105 V, I_E = 0)	MA 200 thru MA203					
(V_{CB} = 90 V, I_E = 0)	MA204		—	12.0	50	
(V_{CB} = 75 V, I_E = 0)	MA205					
(V_{CB} = 60 V, I_E = 0)	MA206					
Collector-Base Cutoff Current (V_{CB} = 2.5 V, I_E = 0)		I_{CBO}	—	5.0	14	μA
Emitter-Base Cutoff Current		I_{EBO}				μA
(V_{EB} = 10 V, I_C = 0)	MA200, MA202, MA206		—	3.0	50	
(V_{EB} = 20 V, I_C = 0)	MA201, MA203, MA204, MA205		—	3.0	50	
Collector-Emitter Saturation Voltage (I_C = 5 mAdc, I_B = 0.25 mAdc)		$V_{CE(sat)}$	—	0.11	0.35	Vdc
Base-Emitter Saturation Voltage (I_C = 5 mAdc, I_B = 0.25 mAdc)		$V_{BE(sat)}$	—	0.22	0.40	Vdc
DC Current Gain		h_{FE}				—
(I_C = 5 mAdc, V_{CE} = 0.35 Vdc)	MA200, MA201, MA204, MA205, MA206		20	—	—	
	MA202, MA203		40	—	—	
DC Collector-Emitter Punch-Through Voltage (V_{CB} necessary to obtain V_{EB} of -1 V max, using instrument with Z_{in} > 11 megohm to measure V_{BE})		V_{PT}				Vdc
	MA200, MA201, MA202, MA203		105	—	—	
	MA204		90	—	—	
	MA205		75	—	—	
	MA206		60	—	—	
Small-Signal Short-Circuit Forward Current Transfer Ratio Cutoff Frequency (V_{CB} = 6 Vdc, I_E = 1 mAdc)		$f_{\alpha b}$	—	1.0	—	MHz

DC CHARACTERISTICS

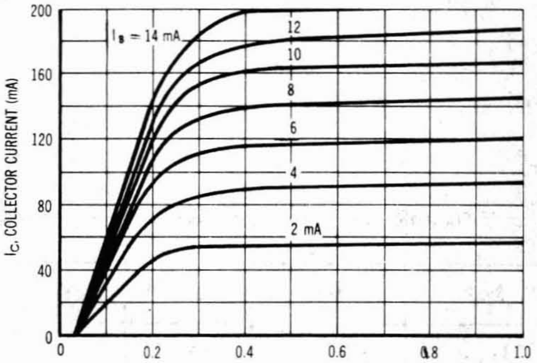
($T_J = 25°C$ unless otherwise noted)



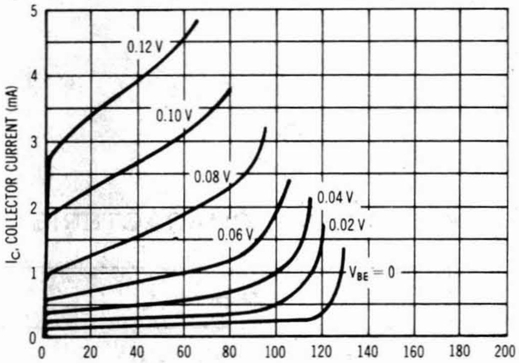
CURRENT GAIN



"ON" VOLTAGES

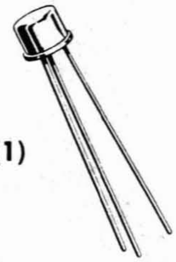


COLLECTOR SATURATION REGION



COLLECTOR HIGH VOLTAGE REGION

MA286 thru MA288 (GERMANIUM)



CASE 31(1)
(TO-5)

PNP germanium transistors for very economical circuit applications. Available with a wide variety of gain ranges.

All leads isolated from case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	10	V
Collector-Base Voltage	V_{CB}	10	V
Emitter-Base Voltage	V_{EB}	10	V
Collector Current	I_C	200	mA
Storage Temperature Limits	T_{stg}	-55 to +85	°C
Power Dissipation @ T_A = +25°C	P_D	175	mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Current (V_{CE} = 10 V R_{BE} = 10 KΩ)		I_{CER}	-	600	μA
Small Signal Current Gain (V_{CE} = 6 V, I_C = 1 mA)	MA286	h_{fe}	14	40	-
	MA287		30	250	
	MA288		180	-	

MA881 thru MA889 (GERMANIUM)

CASE 31(1)
(TO-5)

All leads isolated from case

PNP germanium transistors for audio amplifier and medium-speed switching applications. Recommended as driver transistors for 50-60 Volt power transistors.

MAXIMUM RATINGS

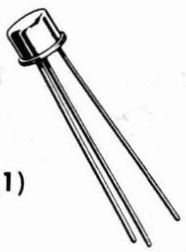
Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}		Vdc
MA881 thru MA884		60	
MA885 thru MA889		50	
Collector-Emitter Voltage	V_{CES}		Vdc
MA881 thru MA884		60	
MA885 thru MA889		50	
Emitter-Base Voltage	V_{EB}	15	Vdc
Collector Current (Continuous)*	I_{C*}	500	mAdc
Collector Dissipation at T_A = 25°C	P_D	200	mW
Derate above 25°C		2.67	mW/°C
Storage and Operating Temperature Range	T_{stg}, T_J	-50 to +100	°C

*Limited by power dissipation

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO}			μAdc
(V_{CB} = 30 Vdc, I_E = 0)	MA881 thru MA884		---	10	
(V_{CB} = 60 Vdc, I_E = 0)	MA881 thru MA884		---	100	
(V_{CB} = 25 Vdc, I_E = 0)	MA885 thru MA889		---	15	
(V_{CB} = 50 Vdc, I_E = 0)	MA885 thru MA889		---	100	
Emitter-Base Cutoff Current		I_{EBO}			μAdc
(V_{EB} = 15 Vdc, I_C = 0)	MA881 thru MA884		---	10	
	MA885 thru MA889		---	15	
Collector-Emitter Leakage Current		I_{CES}			μAdc
(V_{CE} = 60 Vdc, R_{BE} = 0)	MA881 thru MA884		---	100	
(V_{CE} = 50 Vdc, R_{BE} = 0)	MA885 thru MA889		---	100	
Output Capacitance		C_{ob}			pF
(V_{CB} = 6 Vdc, I_E = 0, f = 1 MHz)			---	25	
Input Impedance		h_{ib}			ohms
(V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)			26	40	
Output Admittance		h_{ob}			μmhos
(V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)			0.1	1.0	
DC Current Gain		h_{FE}			----
(V_{CE} = 1 Vdc, I_C = 10 mAdc)	MA881		30	---	
	MA882		40	---	
	MA883		75	---	
	MA884		125	---	
Small-Signal Current Gain		h_{fe}			----
(V_{CE} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	MA881, MA886		30	70	
	MA882, MA887		50	120	
	MA883, MA888		100	225	
	MA884, MA889		190	400	
	MA885		15	40	
Small-Signal Current Gain Cutoff Frequency		$f_{\alpha b}$			MHz
(V_{CB} = 6 Vdc, I_E = 1 mAdc)	MA881, MA886		0.75	---	
	MA882, MA887		1.0	---	
	MA883, MA888		1.25	---	
	MA884, MA889		1.75	---	
	MA885		0.5	---	

MA909, MA910 (GERMANIUM)



CASE 31(1)
(TO-5)

All leads isolated from case

PNP Germanium transistors for high-voltage neon driver, solenoid and relay driver circuits.

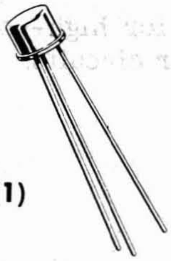
MAXIMUM RATINGS

Rating	Symbol	MA909	MA910	Unit
Collector-Base Voltage	V_{CB}	75	90	Volts
Collector-Emitter Voltage	V_{CEO}	75	90	Volts
Emitter-Base Voltage	V_{EB}	35	45	Volts
Collector Current	I_C	200		mA
Collector Dissipation at $T_C = 25°C$	P_D	150		mW
Junction and Storage Temperature	T_J, T_{stg}	100		°C

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO}			Adc
($V_{CB} = 2.5$ Vdc, $I_E = 0$)	Both Types		-	14	
($V_{CB} = 75$ Vdc, $I_E = 0$)	MA909		-	50	
($V_{CB} = 90$ Vdc, $I_E = 0$)	MA910		-	50	
Emitter-Base Cutoff Current		I_{EBO}			Adc
($V_{EB} = 35$ Vdc, $I_C = 0$)	MA909		-	50	
($V_{EB} = 45$ Vdc, $I_C = 0$)	MA910		-	50	
Collector-Emitter Leakage Current		I_{CES}			Adc
($V_{CE} = 75$ Vdc, $R_{BE} = 0$)	MA909		-	100	
($V_{CE} = 90$ Vdc, $R_{BE} = 0$)	MA910		-	100	
Collector-Emitter Saturation Voltage ($I_C = 5$ mAdc, $I_B = 0.25$ mAdc)		$V_{CE(sat)}$	-	0.35	Vdc
Base-Emitter Saturation Voltage ($I_C = 5$ mAdc, $I_B = 0.25$ mAdc)		$V_{BE(sat)}$	-	0.40	Vdc
DC Current Gain ($I_C = 5$ mAdc, $V_{CE} = 0.35$ Vdc)		h_{FE}	20	-	-
Collector-Emitter Punch-Thru Voltage ($V_{fl} = 1.0$ Vdc, R_{in} of VTVM - 10 to 12 Megohms)	MA909	V_{pt}	75	-	Vdc
	MA910		90	-	

MA1702 thru MA1708 (GERMANIUM)



CASE 31(1)
(TO-5)

All leads isolated from case

PNP germanium transistors for audio amplifier and medium speed switching applications requiring high ac gain at low collector current or high dc gain at high collector current.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage MA1702 MA1703 thru MA1705 MA1706 thru MA1708	V_{CB}	 45 25 15	Vdc
Collector-Emitter Voltage MA1702 MA1703 thru MA1705 MA1706 thru MA1708	V_{CER}	 30 25 15	Vdc
Emitter-Base Voltage MA1702 MA1703 thru MA1705 MA1706 thru MA1708	V_{EB}	 30 25 4.5	Vdc
Collector Current (Continuous)*	I_C	500*	mAdc
Base Current (Continuous)*	I_B	50*	mAdc
Maximum Junction Temperature	T_J	100	°C
Storage Temperature Range	T_{stg}	-65 to +100	°C
Collector Dissipation, Ambient Derate Above 25° C	P_D	200 2.67	mW mW/° C

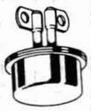
*Limited by power dissipation

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

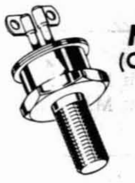
Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 1.5 Vdc, I_E = 0)	MA1702 thru MA1705		-	3.0	5.0	
(V_{CB} = 10 Vdc, I_E = 0, T_A = +71° C)	MA1702		-	-	100	
(V_{CB} = 15 Vdc, I_E = 0)	MA1706 thru MA1708		-	-	15	
(V_{CB} = 25 Vdc, I_E = 0)	MA1703 thru MA1705		-	-	15	
(V_{CB} = 30 Vdc, I_E = 0)	MA1702		-	-	10	
(V_{CB} = 45 Vdc, I_E = 0)	MA1702		-	-	50	
Emitter-Base Cutoff Current		I_{EBO}				μAdc
(V_{EB} = 4.5 Vdc, I_C = 0)	MA1706 thru MA1708		-	-	15	
(V_{EB} = 25 Vdc, I_C = 0)	MA1703 thru MA1705		-	-	15	
(V_{EB} = 30 Vdc, I_C = 0)	MA1702		-	3.0	10	
Collector-Emitter Leakage Current		I_{CER}				μAdc
(V_{CE} = 15 Vdc, R_{BE} = 10 K ohms)	MA1706 thru MA1708		-	-	600	
(V_{CE} = 25 Vdc, R_{BE} = 10 K ohms)	MA1703 thru MA1705		-	-	600	
(V_{CE} = 30 Vdc, R_{BE} = 10 K ohms)	MA1702		-	-	600	
Collector-Emitter Punch-Thru Voltage		V_{pt}				Vdc
(V_{fl} = 1.0 Vdc, VTVM impedance ≥ 1 megohm)	MA1702		30	-	-	
Output Capacitance		C_{ob}				pF
(V_{CB} = 6 Vdc, I_E - 0, f = 1 MHz)			-	10	20	
Noise Figure		NF				dB
(V_{CE} = 4.5 Vdc, I_E = 0.5 mA, R_g = 1 K, f = 1 kHz, Δf = 1 Hz)	MA1702		-	5.0	10	
Small-Signal Current Gain Cutoff Frequency		$f_{\alpha b}$				MHz
(V_{CB} = 6 Vdc, I_E = 1 mAdc)	MA1702		7.0	-	-	
	MA1703		3.0	-	-	
	MA1704		5.0	-	-	
	MA1705		6.0	-	-	
	MA1706		3.0			
	MA1707		4.0			
	MA1708		5.0			
Input Impedance		h_{ib}				Ohms
(V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	MA1702 thru MA1705		25	-	35	
	MA1706 thru MA1708		25	-	37	
Output Admittance		h_{ob}				μmho
(V_{CB} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	MA1702		0.05	-	0.50	
Small Signal Current Gain		h_{fe}				-
(V_{CE} = 6 Vdc, I_E = 1 mAdc, f = 1 kHz)	MA1702, MA1705, MA1708		500	-	-	
	MA1703, MA1706		200	-	500	
	MA1704, MA1707		350	-	800	
DC Current Gain		h_{FE}				-
(I_C = 20 mAdc, V_{CE} = 1 Vdc)	MA1702		350	-	-	
(I_C = 100 mAdc, V_{CE} = 1 Vdc)	MA1702, MA1705, MA1708		200	-	-	
	MA1703, MA1706		100	-	350	
	MA1704, MA1707		150	-	400	
(I_C = 200 mAdc, V_{CE} = 1 Vdc)	MA1702		135	-	-	
	MA1703		70	-	-	
	MA1704		110	-	-	
	MA1705		125	-	-	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$				Vdc
(I_C = 200 mAdc, I_B = 4.0 mAdc)	MA1702		-	-	0.260	

MAC1 (SILICON)
MAC2
MAC3

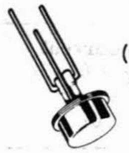
Silicon bi-directional thyristors designed primarily for full-wave ac control applications, such as heating and lighting; these TRIAC type thyristors switch from a blocking to a conducting state for either polarity of applied anode voltage with positive or negative gate triggering.



MAC1
(CASE 85)



MAC2
(CASE 86)



MAC3
(CASE 87L)

MAXIMUM RATINGS (T_J = 100°C unless otherwise noted)
Applies to all case types

Rating	Symbol	Value	Unit
Peak Blocking Voltage* MAC1 -2 MAC2 -4 MAC3 -6	V_{BOM}*	 50 200 400	Volts
RMS Conduction Current (T_C = 75°C)	I_A	8.0	Amp
Peak Surge Current (One-half cycle, 60 Hz) (T_J = -42 to +100°C)	$I_{M(surge)}$	100	Amp
Circuit Fusing Considerations (T_J = -40 to +100°C, t = 1.0 to 8.3 ms)	I^2t	40	A^2s
Peak Gate Power	P_{GM}	10	Watts
Average Gate Power	$P_{G(av)}$	0.5	Watt
Peak Gate Current	I_{GM}	2.0	Amp
Operating Junction Temperature Range	T_J	-40 to +100	°C
Storage Temperature Range	T_{stg}	-40 to +150	°C
Stud Torque (MAC2 Series)	-	15	in. lb.

* For either direction of blocking voltage. V_{BOM} for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for open or shorted gate conditions. Thyristor devices shall not be tested with a constant current source for blocking capability such that the voltage applied exceeds the rated blocking voltage.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Applies to all case types unless otherwise noted.

Characteristics	Symbol	Min	Typ	Max	Unit
Peak Blocking Current (Either direction) (Rated V_{BOM} @ T_J = 100°C, gate open)	I_{BOM}	-	-	2.0	mA
"On" Voltage (Either direction) (I_A = 5.0 Amp Peak)	$V_{(on)}$	-	1.0	1.4	Volts
Gate Trigger Current (Continuous dc, all modes) (Anode Voltage = 7.0 Vdc, R_L = 100 Ω)	I_{GT}	-	-	30	mA
Gate Trigger Voltage (Continuous dc, all modes) (Anode Voltage = 7.0 Vdc, R_L = 100 Ω)	V_{GT}	-	0.9	2.0	Volts
(Anode Voltage = Rated V_{BOM}, R_L = 100 Ω, T_J = 100°C)	V_{GNT}	0.2	-	-	
Holding Current (Either direction) (Anode Voltage = 7.0 Vdc, gate open)	I_{HO}	-	-	30	mA
Turn-On Time (I_A = 5.0 Adc, I_{GT} = 100 mAdc)	t_{on}	-	1.0	-	µs
Blocking Voltage Application Rate at Commutation (T_C = 75°C)	dv/dt	-	5.0	-	V/µs
Thermal Resistance, Junction to Case (Either direction)	θ_{JC}	-	-	2.0	°C/W
Thermal Resistance, Case to Ambient (MAC1, MAC3)	θ_{CA}	-	50	-	°C/W

FIGURE 1 — CURRENT DERATING

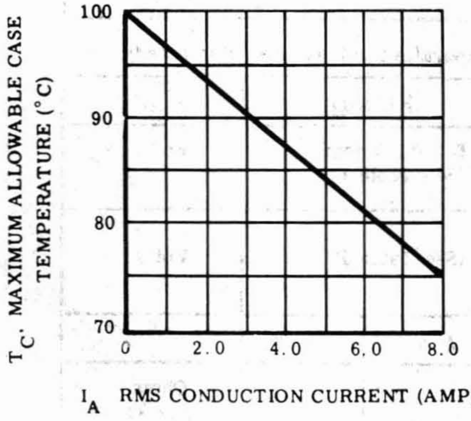
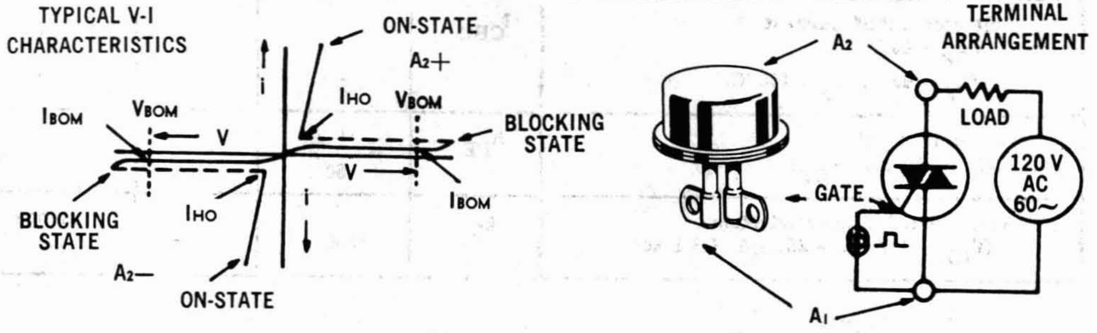


FIGURE 2 — TYPICAL COMPARISON OF PARAMETERS FOR VARIOUS MODES OF OPERATION*

Parameter	Mode Voltage Polarity (Relative to A_1)			
	A_2(+), G(+)	A_2(+), G(-)	A_2(-), G(-)	A_2(-), G(+)
I_{GT}	0.7	0.8	0.9	1.0
V_{GT}	0.9	0.8	0.9	1.0
I_{HO}	0.8	-	1.0	-
$V_{(on)}$	0.9	-	1.0	-

* Values shown are normalized to the values obtained in the mode where highest values occur.

FIGURE 3 — CHARACTERISTICS AND SYMBOLS

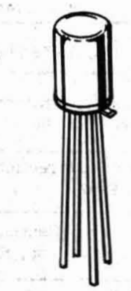


TYPICAL V-I CHARACTERISTICS
ON-STATE
A_2+
i
I_{HO}
V_{BOM}
I_{BOM}
V_{BOM}
V
BLOCKING STATE
V
i
I_{BOM}
BLOCKING STATE
I_{HO}
A_2-
ON-STATE
TERMINAL ARRANGEMENT
A_2
LOAD
120 V AC 60~
GATE
A_1

SILICON

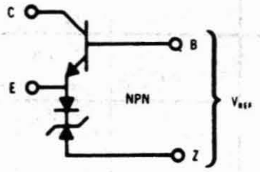
MCA1911 SERIES 6.8 V
MCA2011 SERIES 8.6 V
MCA2111 SERIES 9.5 V
MCA2211 SERIES 11.0 V

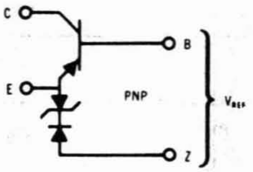
Reference amplifiers for use in regulated power supplies as a combination reference element and error voltage amplifier. Available with either PNP or NPN transistors.



CASE 181

*MCA1911 series used only zener diode and transistors





ABSOLUTE MAXIMUM RATINGS (at 25°C ambient temperature unless otherwise noted)

Rating	Symbol	Value	Unit
Zener Current	I_Z	20	mA
Collector Current	I_C	20	mA
Collector-Emitter Voltage	V_{CEO}	30	V
Junction and Storage Temperature Range	T_J T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS (at 25°C ambient temperature unless otherwise noted)

Characteristic	Symbol	Rating		Unit
Nominal Reference Voltage (I_Z = 5 mA, V_{CE} = 3 V, I_C = 250 μA)	V_{REF}	6.8-11.0 nom (See Table 1)		Volts
Maximum Reference Voltage Change with Temperature (I_Z = 5 mA, V_{CE} = 3 V, I_C = 250 μA)	ΔV_{REF}	(See Table 1)		Volts
		Min	Max	
Zener Impedance (I_{ZT} = 5 mA, I_{ac} = 10% I_Z)	Z_{ZT}	-	40	Ohms
Collector-Emitter Breakdown Voltage (I_C = 250 μA)	BV_{CEO}	30	-	Volts
Collector Cutoff Current (V_{CB} = 45 V) (V_{CB} = 45 V, T_A = 150°C)	I_{CBO}	- -	0.05 10	μA μA
DC Current Gain (I_C = 250 μA, V_{CE})	h_{FE}	50	100	-
Small-Signal Transconductance (V_{CE} = 3 V, I_C - 250 μA, f = 1 kc)	g_{fe}	6500	-	μmhos

TABLE 1 ELECTRICAL CHARACTERISTICS

(at I_{ZT} = 7.5 mA & T_A = 25°C unless otherwise specified)

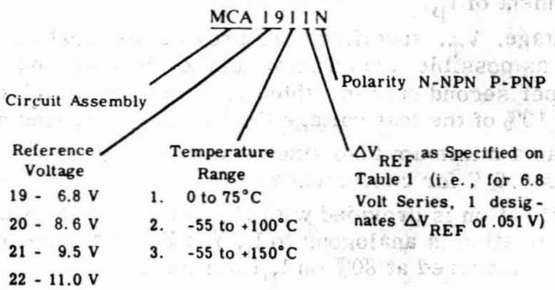
Type Number (Note 1)	Max Voltage Change (Note 2) ΔV_{REF} (Volts)	Test @ Temperature (°C)	Reference Voltage V_{REF} (Volts)
6.8 Volt Series (I_{ZT} = 5 mA)			
MCA1911N	.051	0, +25, +75	6.8 ± 10%
MCA1912N	.025		
MCA1913N	.010		
MCA1914N	.005		
MCA1921N	.105	-55, 0, +25, +75, +100	6.8 ± 5%
MCA1922N	.052		
MCA1923N	.020		
MCA1924N	.010		
MCA1931N	.139	-55, 0, +25, +75, +100, +150	6.8 ± 5%
MCA1932N	.069		
MCA1933N	.026		
MCA1934N	.013		
9.5 Volt Series (I_{ZT} = 5 mA)			
MCA2111N	.071	0, +25, +75	9.5 ± 10%
MCA2112N	.035		
MCA2113N	.014		
MCA2114N	.007		
MCA2121N	.147	-55, 0, +25, +75, +100	9.5 ± 5%
MCA2122N	.073		
MCA2123N	.028		
MCA2124N	.014		
MCA2131N	.194	-55, 0, +25, +75, +100, +150	9.5 ± 5%
MCA2132N	.097		
MCA2133N	.038		
MCA2134N	.019		

Type Number (Note 1)	Max Voltage Change (Note 2) ΔV_{REF} (Volts)	Test @ Temperature (°C)	Reference Voltage V_{REF} (Volts)
8.6 Volt Series (I_{ZT} = 5 mA)			
MCA2011N	.060	0, +25, +75	8.6 ± 10%
MCA2012N	.030		
MCA2013N	.012		
MCA2014N	.006		
MCA2021N	.124	-55, 0, +25, +75, +100	8.6 ± 5%
MCA2022N	.062		
MCA2023N	.024		
MCA2024N	.012		
MCA2031N	.164	-55, 0, +25, +75, +100, +150	8.6 ± 5%
MCA2032N	.082		
MCA2033N	.032		
MCA2034N	.016		
11.0 Volt Series (I_{ZT} = 5 mA)			
MCA2211N	.082	0, +25, +75	11.0 ± 10%
MCA2212N	.041		
MCA2213N	.016		
MCA2214N	.008		
MCA2221N	.170	-55, 0, +25, +75, +100	11.0 ± 5%
MCA2222N	.085		
MCA2223N	.034		
MCA2224N	.017		
MCA2231N	.225	-55, 0, +25, +75, +100, +150	11.0 ± 5%
MCA2232N	.112		
MCA2233N	.044		
MCA2234N	.022		

NOTES:

1. Type numbers shown are for devices containing NPN transistors; for devices with PNP transistors substitute a "P" suffix for the "N" suffix in the type number.
2. ΔV_{REF} is the maximum voltage variation over the specified temperature range, verified by tests at specified points within the range.

NOMENCLATURE

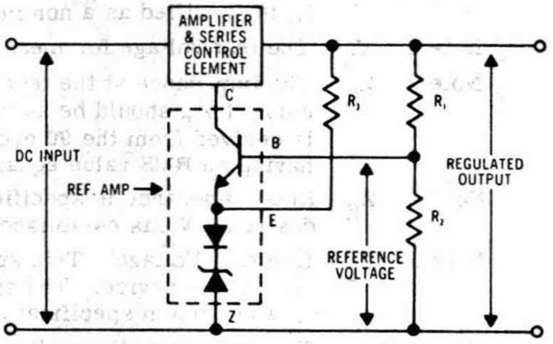


Reference Voltage
19 - 6.8 V
20 - 8.6 V
21 - 9.5 V
22 - 11.0 V

Temperature Range
1. 0 to 75°C
2. -55 to +100°C
3. -55 to +150°C

ΔV_{REF} as Specified on Table 1 (i.e., for 6.8 Volt Series, 1 designates ΔV_{REF} of .051 V)

TYPICAL APPLICATION IN REGULATED POWER SUPPLIES

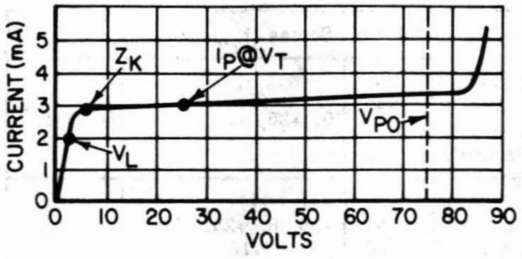


MCL1300 thru MCL1304 (SILICON)

Field-effect current limiting diodes designed for applications requiring a current reference or a constant current over a specified voltage range.

CASE 51
(DO-7)

CURRENT-LIMITER CHARACTERISTICS AND SYMBOL IDENTIFICATION
(See Notes 1 thru 6)



MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Junction and Storage Temperature: -65°C to +200°C

Peak Operating Voltage: See Table

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Type Number	Nominal Pinch-Off Current Note 1 I_P (mA)	Tol. (mA)	Test Volt. Note 2 V_T (volts)	Limiter Imped. Note 3 Z_T (min) (megohms)	Knee Imped. at 6 V Note 4 Z_K (min) (megohms)	Limiting Voltage Note 5 V_L (max) (volts)	Peak Operating Voltage Note 6 V_{PO} (volts)
MCL1300	0.5	±0.3	25	4.000	0.500	1.0	75
MCL1301	1.0	±0.6	25	0.800	0.200	1.5	75
MCL1302	2.0	±0.6	25	0.400	0.100	2.0	75
MCL1303	3.0	±0.6	25	0.300	0.050	2.0	75
MCL1304	4.0	±0.6	25	0.250	0.025	2.5	75

These specifications are preliminary. Selections may be made to obtain nominal currents between those shown, as well as tighter tolerance units.

SYMBOL DEFINITIONS:

Note 1 I_P - The pinch-off current is the guaranteed current at a specified V_T. I_P is specified as a nominal with a tolerance.

Note 2 V_T - The test voltage for measurement of I_P.

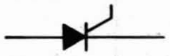
Note 3 Z_T - The impedance at the test voltage, V_T, specified. To provide the most constant current Z_T should be as high as possible; thus a minimum Z_T is specified. Z_T is derived from the 90 cycle per second current which results when an AC voltage having an RMS value equal to 10% of the test voltage (V_T) is superimposed on V_T.

Note 4 Z_K - Knee impedance is specified as a minimum also since again the highest value is desired. V_K is established as 6.0 V for convenience.

Note 5 V_L - Limiting Voltage. This specification is provided with Z_K to indicate the sharp knee of the device. The specification is analogous to I_R and Z_K of a zener diode. V_L a maximum specification is measured at 80% on I_P tolerance.

Note 6 V_{PO} - The peak-operating voltage is provided and indicates the maximum voltage to be applied to the device. The specification is necessary since the device is either power limited or breakdown limited beyond this specified voltage.

MCR406-1
thru
MCR406-4



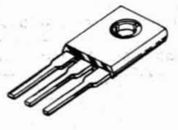
PLASTIC THYRISTORS

. . . Annular PNPN devices designed for high volume consumer applications, such as temperature, light, and speed control, process and remote control, and warning systems where reliability of operation is important. Sensitive gate trigger permits operation as a switch directly from low level sensors.

- Annular Passivated Surface for Reliability and Uniformity
- True Power Rated – 4.0 Amp @ $T_C = 97^oC$
- Low Level Gate Characteristics – $I_{GT} = 200\ \mu A$ @ $T_A = 25^oC$
- Higher Surge Current Rating – $I_{FM(surge)} = 30$ Amp
- Flat, Rugged, Thermopad Construction – for Low Thermal Resistance, High Heat Dissipation, and Durability

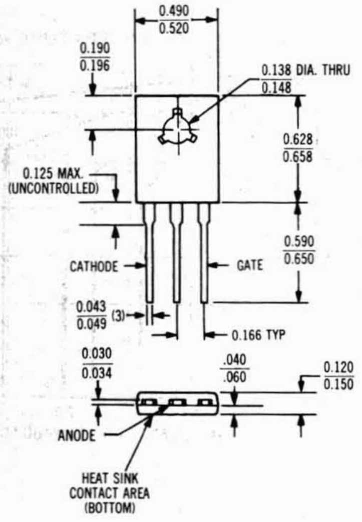
PLASTIC SILICON CONTROLLED RECTIFIERS

4.0 AMPERES RMS
30 thru 200 VOLTS



MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage (Note 1)	$V_{RXM(rep)}$		Volts
MCR406-1		30	
MCR406-2		60	
MCR406-3		100	
MCR406-4		200	
Forward Current RMS (All Conduction Angles)	I_f	4.0	Amp
Peak Forward Surge Current (1/2 cycle, 60 Hz, T_J = -40 to +110°C)	$I_{FM(surge)}$	30	Amp
Circuit Fusing Considerations (T_J = -40 to 110°C, t = 1.0 to 8.3 ms)	I^2t	3.6	A^2s
Peak Gate Power – Forward	P_{GFM}	0.5	Watt
Average Gate Power – Forward	$P_{GF(AV)}$	0.1	Watt
Peak Gate Current – Forward	I_{GFM}	0.2	Amp
Peak Gate Voltage – Reverse	V_{GRM}	6.0	Volts
Operating Junction Temperature Range	T_J	-40 to +110	°C
Storage Temperature Range	T_{stg}	-40 to +150	°C
Mounting Torque (6-32 screw) (Note 2)	–	12	in. lb.


0.490
0.520
0.190
0.196
0.138 DIA. THRU
0.148
0.628
0.658
0.125 MAX.
(UNCONTROLLED)
0.590
0.650
CATHODE
GATE
0.043
0.049
(3)
0.166 TYP
0.030
0.034
.040
.060
0.120
0.150
ANODE
HEAT SINK
CONTACT AREA
(BOTTOM)

CASE 90

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted, R_{GK} = 1000 Ohms)

Characteristic		Symbol	Min	Typ	Max	Unit
Peak Forward Blocking Voltage (T_J = 110°C) Note 1	MCR406-1	V_{FXM}	30	–	–	Volts
	MCR406-2		60	–	–	
	MCR406-3		100	–	–	
	MCR406-4		200	–	–	
Peak Forward Blocking Current (Rated V_{FXM} @ T_J = 110°C)		I_{FXM}	–	–	100	μA
Peak Reverse Blocking Current (Rated V_{RXM} @ T_J = 110°C)		I_{RXM}	–	–	100	μA
Forward "On" Voltage (I_F = 4.0 A peak)		V_F	–	–	2.2	Volts
Gate Trigger Current (Continuous dc) (Anode Voltage = 7.0 Vdc, R_L = 100 Ohms)		I_{GT}	–	–	200	μA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7.0 Vdc, R_L = 100 Ohms)		V_{GT}	–	–	0.8	Volts
(Anode Voltage = Rated V_{FXM}, R_L = 100 Ohms, T_J = 110°C)		V_{GNT}	0.2	–	–	
Holding Current (Anode Voltage = 7.0 Vdc)		I_{HXM}	–	–	3.0	mA
Turn-On Time		t_{on}	Circuit Dependent. Consult Manufacturer.			
Turn-Off Time		t_{off}				
Forward Voltage Application Rate (T_J = 110°C)		dv/dt	–	10	–	V/μs
Thermal Resistance, Junction to Case		θ_{JC}	–	–	2.0	°C/W
Thermal Resistance, Junction to Ambient		θ_{JA}	–	–	50	°C/W

NOTES:

1. V_{FXM} and V_{RXM} for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for zero or negative gate voltage but positive gate voltage shall not be applied concurrently with a negative potential on the anode. When checking forward or reverse blocking capability, thyristor devices should not be tested with a constant current source in a manner that the voltage applied exceeds the rated blocking voltage.
2. Torque rating applies with use of torque washer (Shakeproof WD19522 #6 or equivalent). Mounting torque in excess of 8 in. lbs. does not appreciably lower case-to-sink thermal resistance. Anode lead and heatsink contact pad are common.

   For soldering purposes (either terminal connection or device mounting), soldering temperatures shall not exceed +225°C. For optimum results, an activated flux (oxide removing) is recommended.

FIGURE 1 – CASE TEMPERATURE versus CURRENT

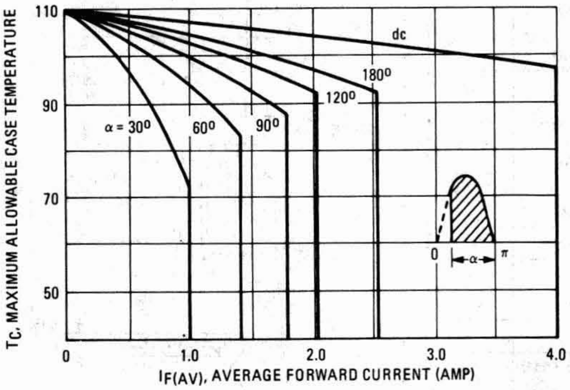


FIGURE 2 – AMBIENT TEMPERATURE versus CURRENT

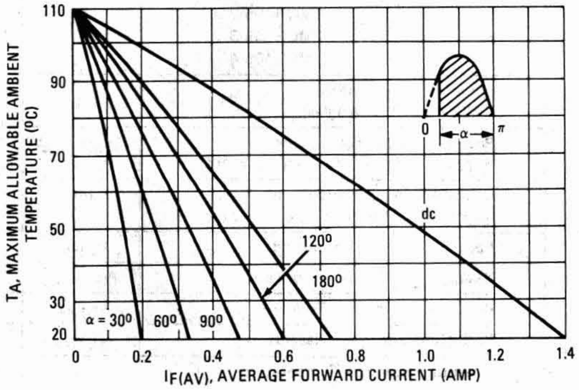


FIGURE 3 – FORWARD CONDUCTION CHARACTERISTICS

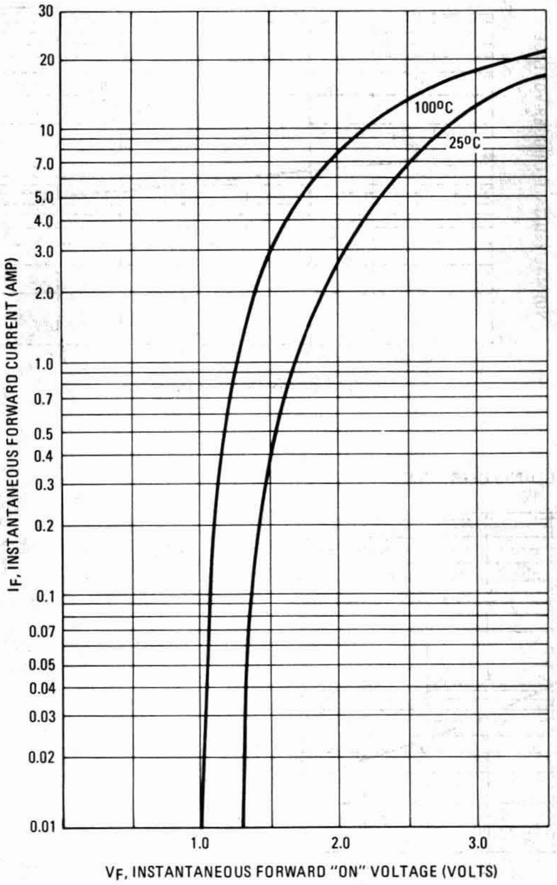


FIGURE 4 – P_D, POWER DISSIPATION

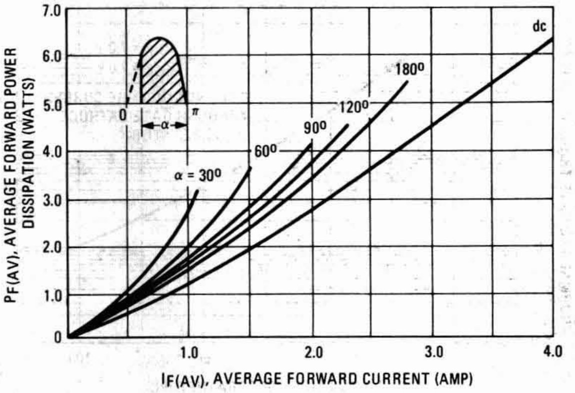


FIGURE 5 – 60 Hz SURGES

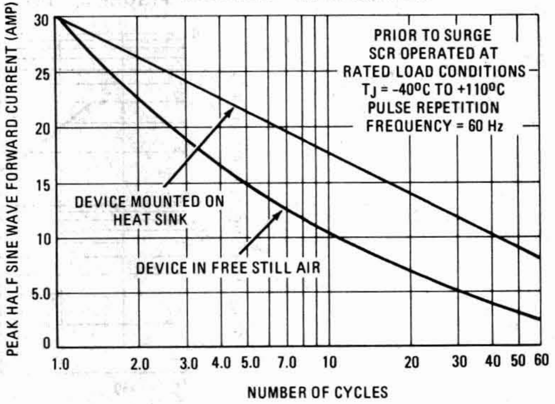


FIGURE 6 – THERMAL RESPONSE

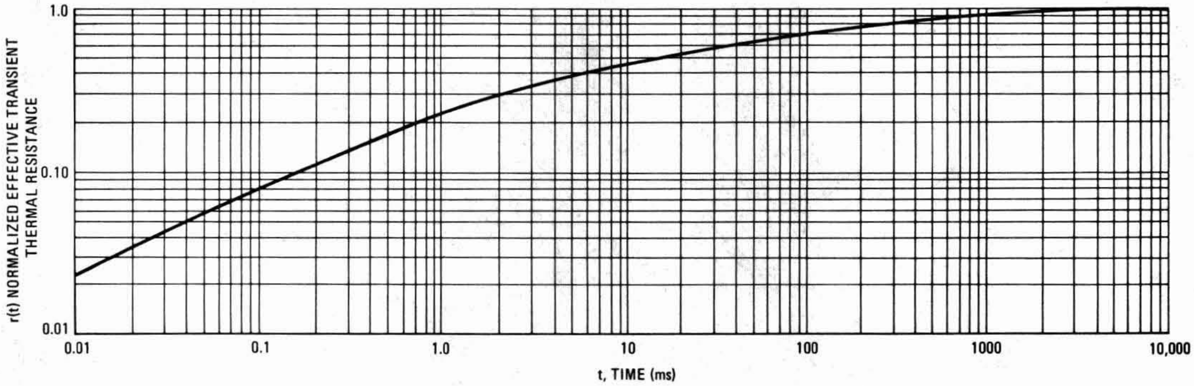


FIGURE 7 – TYPICAL GATE TRIGGER CURRENT

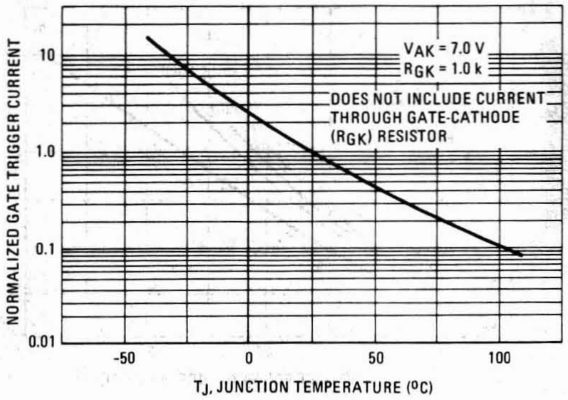


FIGURE 8 – TYPICAL GATE TRIGGER VOLTAGE

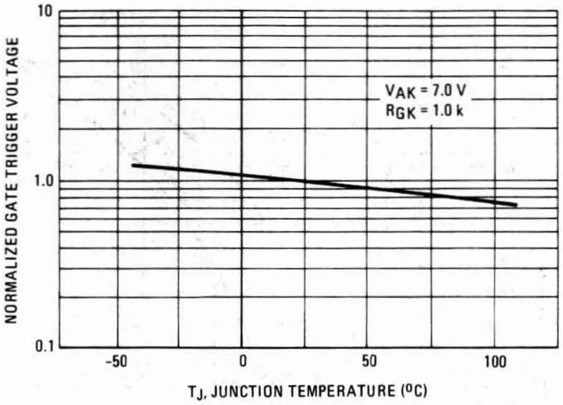
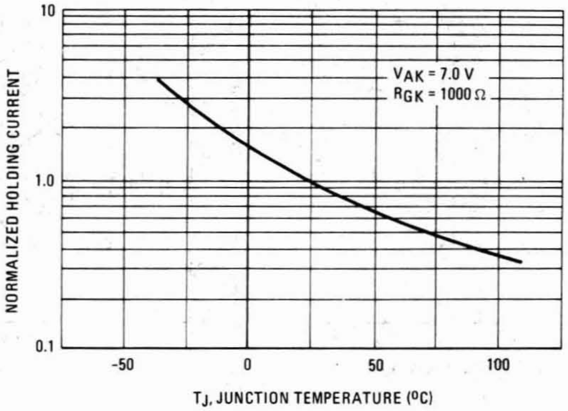
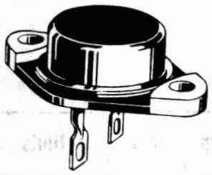


FIGURE 9 – TYPICAL HOLDING CURRENT



MCR649-1 thru MCR649-7 (SILICON)



CASE 61 (TO-41) **CASE 54** (TO-3 Modified)

Industrial-type, silicon controlled rectifiers in a "diamond" package for applications requiring a high surge-current rating or low thermal resistance. For units with pins (TO-3) specify devices MCR649P-1 thru MCR649P-7.

MAXIMUM RATINGS (T_J = 100°C unless otherwise noted)

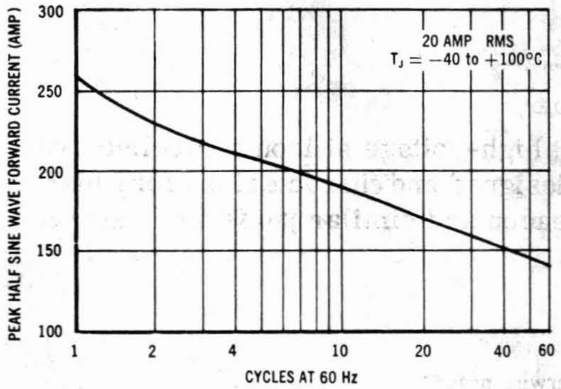
Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*	V_{ROM}*		Volts
MCR649-1		25	
-2		50	
-3		100	
-4		200	
-5		300	
-6		400	
-7		500	
Forward Current RMS (All Conduction Angles)	I_f	20	Amp
Circuit Fusing Considerations (T_J = -40 to +100°C; $t \leq 8.3$ ms)	I^2t	275	A^2s
Peak Forward Surge Current (One Cycle, 60 Hz, T_J = -40 to +100°C)	$I_{FM(surge)}$	260	Amp
Peak Gate Power - Forward	P_{GFM}	5.0	Watts
Average Gate Power - Forward	$P_{GF(AV)}$	0.5	Watt
Peak Gate Current - Forward	I_{GFM}	2.0	Amp
Peak Gate Voltage - Forward	V_{GFM}	10	Volts
Reverse	V_{GRM}	5.0	
Operating Junction Temperature Range	T_J	-40 to +100	°C
Storage Temperature Range	T_{stg}	-40 to +150	°C

*V_{ROM} for all types can be applied on a continuous dc basis without incurring damage. V_{ROM} ratings apply for zero or negative gate voltage.

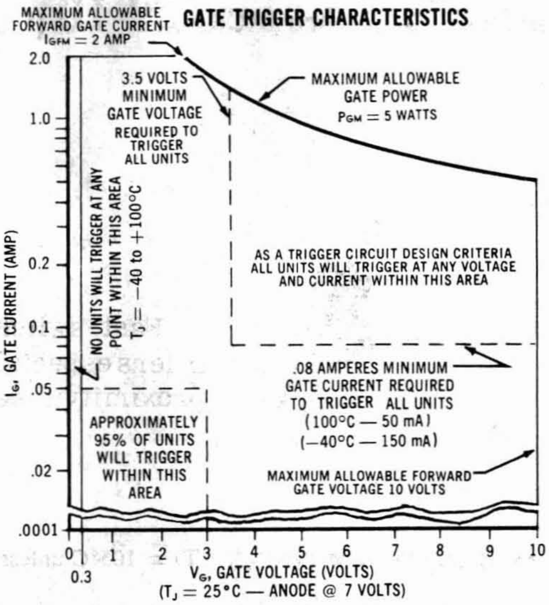
ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage ($T_J = 100^oC$) MCR649-1	V_{FOM}	25	—	—	Volts
-2		50	—	—	
-3		100	—	—	
-4		200	—	—	
-5		300	—	—	
-6		400	—	—	
-7		500	—	—	
Peak Forward Blocking Current (Rated V_{FOM} with gate open, $T_J = 100^oC$)	I_{FOM}	—	—	5.0	mA
Peak Reverse Blocking Current (Rated V_{FOM} with gate open, $T_J = 100^oC$)	I_{ROM}	—	—	5.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, $R_L = 50\ \Omega$)	I_{GT}	—	30	80	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, $R_L = 50\ \Omega$)	V_{GT}	—	1.0	3.5	Volts
(Anode Voltage = Rated V_{FOM}, $R_L = 50\Omega$, $T_J = 100^oC$)	V_{GNT}	0.3	—	—	
Holding Current (Anode Voltage = 7 Vdc, Gate Open)	I_{HO}	—	20	—	mA
Forward On Voltage (I_F = 20 Adc)	V_F	—	1.1	1.5	Volts
Turn-On Time ($t_d + t_r$) (I_G = 50 mA, I_F = 10 A)	t_{on}	—	1.0	—	μs
Turn-Off Time (I_F = 10 A, I_R = 10 A, dv/dt = 20 V/ μs min, $T_J = 100^oC$) (V_{FXM} = rated voltage) (V_{RXM} = rated voltage)	t_{off}	—	25	—	μs
Forward Voltage Application Rate (Gate open, $T_J = 100^oC$)	dv/dt				V/ μs
MCR649-1 thru MCR649-4		—	20	—	
MCR649-5 thru MCR649-7		—	30	—	
Thermal Resistance (Junction to Case)	θ_{JC}	—	1.0	1.5	$^oC/W$

MAXIMUM ALLOWABLE NON-RECURRENT SURGE CURRENT



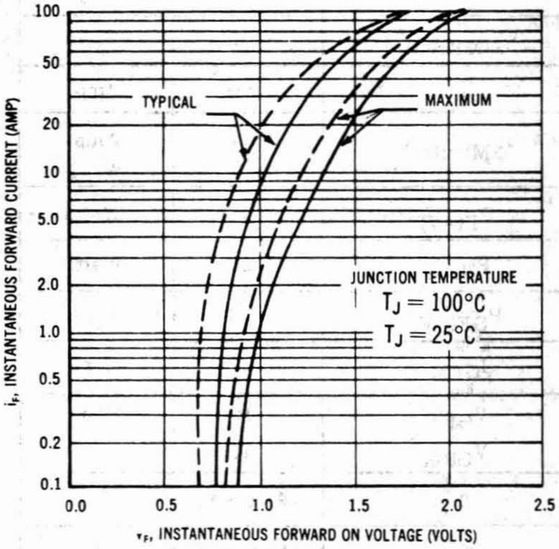
GATE TRIGGER CHARACTERISTICS



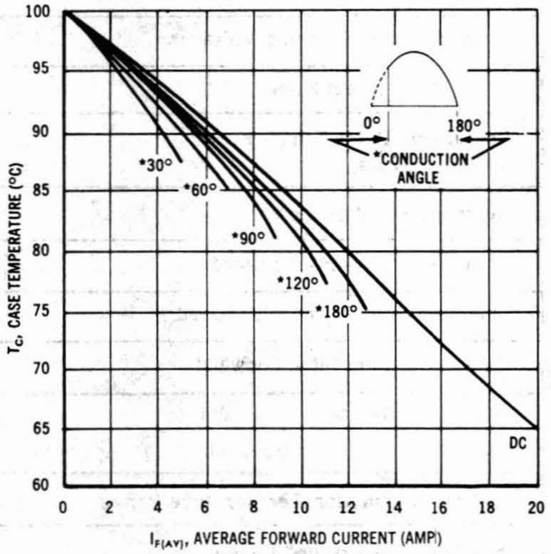
AS A TRIGGER CIRCUIT DESIGN CRITERIA ALL UNITS WILL TRIGGER AT ANY VOLTAGE AND CURRENT WITHIN THIS AREA

APPROXIMATELY 95% OF UNITS WILL TRIGGER WITHIN THIS AREA

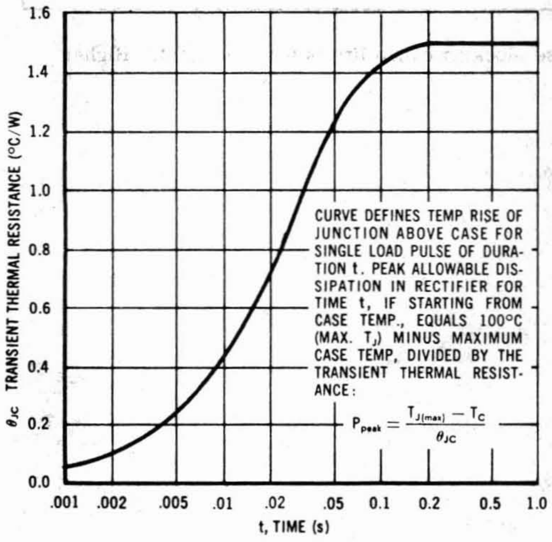
LOW CURRENT LEVEL



MAXIMUM ALLOWABLE CASE TEMPERATURE



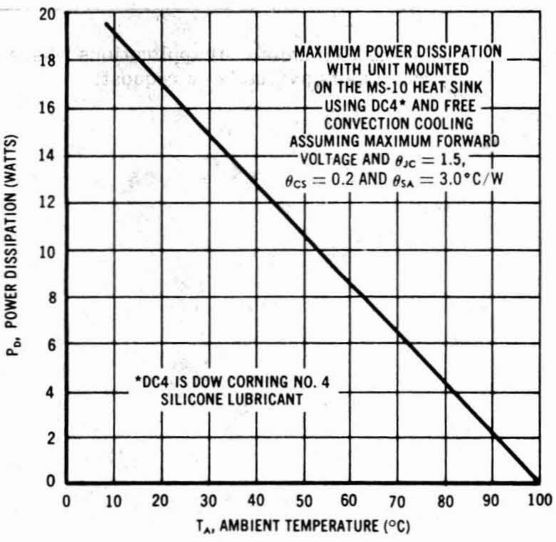
MAXIMUM TRANSIENT THERMAL RESISTANCE JUNCTION TO CASE



CURVE DEFINES TEMP RISE OF JUNCTION ABOVE CASE FOR SINGLE LOAD PULSE OF DURATION t. PEAK ALLOWABLE DISSIPATION IN RECTIFIER FOR TIME t, IF STARTING FROM CASE TEMP., EQUALS 100°C (MAX. T_J) MINUS MAXIMUM CASE TEMP, DIVIDED BY THE TRANSIENT THERMAL RESISTANCE:

$$P_{peak} = \frac{T_{J(max)} - T_C}{\theta_{JC}}$$

POWER DERATING CURVE



MAXIMUM POWER DISSIPATION WITH UNIT MOUNTED ON THE MS-10 HEAT SINK USING DC4* AND FREE CONVECTION COOLING ASSUMING MAXIMUM FORWARD VOLTAGE AND $\theta_{JC} = 1.5$, $\theta_{CS} = 0.2$ AND $\theta_{SA} = 3.0°C/W$

*DC4 IS DOW CORNING NO. 4 SILICONE LUBRICANT

MCR729-5 thru MCR729-10 (SILICON)

CASE 63

Fast-switching, high-voltage silicon controlled rectifiers especially designed and characterized for radar, proximity fuse, beacon and similar pulse applications.

MAXIMUM RATINGS (T_J = 105°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*	$V_{ROM(rep)}{}^*$	50	Volts
Forward Current RMS	I_f	2.0	Amp
Repetitive Pulse Current (PW = 10 μs)	$I_{FM(pulse)}$	100	Amp
Average Forward Power	$P_{F(AV)}$	5.0	Watts
Peak Gate Power - Forward	P_{GFM}	20	Watts
Average Gate Power - Forward	$P_{GF(AV)}$	1.0	Watt
Peak Gate Current - Forward	I_{GFM}	5.0	Amp
Peak Gate Voltage - Forward	V_{GFM}	10	Volts
Reverse	V_{GRM}	10	
Operating Junction Temperature Range	T_J	-65 to + 105	°C
Storage Temperature Range	T_{stg}	-65 to + 150	°C
Stud Torque	—	15	in. lb.

*Characterized for unilateral applications where reverse blocking capability is not important. Higher V_{ROM} rated units available on request.

MCR729-5 thru MCR729-10 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage* (T_J = 105°C) MCR729-5	V_{FOM}*	300	—	—	Volts
-6		400	—	—	
-7		500	—	—	
-8		600	—	—	
-9		700	—	—	
-10		800	—	—	
Peak Forward Blocking Current (Rated V_{FOM}, T_J = 105°C, gate open)	I_{FOM}	—	0.2	2.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 100 ohms)	I_{GT}	—	10	50	mAdc
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 100 ohms)	V_{GT}	—	0.8	1.5	Volts
Holding Current (Anode Voltage = 7 Vdc, gate open)	I_{HO}	5.0	15	—	mA
Forward On Voltage (I_f = 2 Adc)	V_F	—	1.1	1.5	Volts
Dynamic Forward On Voltage (0.5 µs after 50% pt, I_G = 200 mA, I_{pulse} = 30 Amps)	$V_{F(on)}$	—	15	25	Volts
Turn-On Time ($t_d + t_r$) (I_G = 200 mA)	t_{on}				ns
(I_{pulse} = 30 Amps peak)	—	—	200	—	
(I_{pulse} = 100 Amps peak)		—	400	—	
Turn-On Time Variation (T_J = +25°C to +105°C and -65°C to +25°C)	Δt_{on}	—	±50	—	ns
Pulse Turn-Off Time	$t_{off(pulse)}$	—	15	—	µs
Test Conditions: PFN discharge; Forward Current = 30 A pulse; Reverse Current = 5 A; Rep. Rate = 100 pps; Duty cycle = 0.05%; Forward Voltage = rated V_{FOM}; T_C = 85°C; dv/dt = 250 V/µs; Reverse anode voltage applied during turn-off interval = rated V_{FOM}; Reverse gate bias during turn-off interval = -6 V; Gate Trigger Pulse: 200 mA, 1 µs wide, 2 ns rise time. Turn-off time measured from 90% pt. of forward, current decay to 10% pt. of reapplied forward voltage.					
Forward Voltage Application Rate (T_J = 105°C, gate open)	dv/dt	50	—	—	V/µs
Thermal Resistance (Junction to Case)	θ_{JC}	—	—	3.0	°C/W

*Other voltage units available upon request.

MCR846 series (SILICON)

CASE 63

Silicon controlled rectifiers for low-power switching and control applications requiring blocking to 200 volts and load currents to 2 amp.

MAXIMUM RATINGS ($T_J = 105°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage MCR846-1 -2 -3 -4	$V_{ROM(rep)}$	 25 50 100 200	Volts
Forward Current RMS (all conduction angles)	I_f	2.0	Amp
Circuit Fusing Considerations (T_J = -65 to +105°C; t ≦ 8.3 ms)	I^2t	35	A^2s
Peak Forward Surge Current (One Cycle, 60 Hz, T_J = -65 to +105°C)	$I_{FM(surge)}$	30	Amp
Peak Gate Power - Forward	P_{GFM}	5.0	Watts
Average Gate Power - Forward	$P_{GF(AV)}$	0.5	Watt
Peak Gate Current - Forward	I_{GFM}	2.0	Amp
Peak Gate Voltage - Forward Reverse	V_{GFM} V_{GRM}	10 10	Volts
Operating Junction Temperature Range	T_J	-65 to +105	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C
Stud Torque	—	15	in. lb.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Peak Forward Blocking Voltage* (T_C = 105°C)	V_{FOM}*				Volts
MCR1336 -5		300	-	-	
MCR1336 -6		400	-	-	
MCR1336 -7		500	-	-	
MCR1336 -8		600	-	-	
MCR1336 -9		700	-	-	
MCR1336 -10		800	-	-	
Peak Forward and Reverse Blocking Current (Rated V_{FOM} and V_{ROM}, T_C = 105°C, gate open)	I_{FOM}	-	-	2.0	mA
	I_{ROM}	-	-	2.0	
Gate Trigger Current (Continuous dc)	I_{GT}				mA
(Anode Voltage = 7.0 Vdc, R_L = 100 ohms, T_C = 25°C)		-	-	40	
(Anode Voltage = 7.0 Vdc, R_L = 100 ohms, T_C = -65°C)		-	-	100	
Gate Trigger Voltage (Continuous dc)	V_{GT}				Volts
(Anode Voltage = rated V_{FOM}, R_L = 100 ohms, T_C = 105°C)		0.2	-	-	
(Anode Voltage = 7.0 Vdc, R_L = 100 ohms, T_C = 25°C)		-	-	1.25	
(Anode Voltage = 7.0 Vdc, R_L = 100 ohms, T_C = -65°C)		-	-	2.0	
Holding Current	I_{HO}				mA
(Anode Voltage = 7.0 Vdc, gate open, T_C = 105°C)		1.0	-	-	
(Anode Voltage = 7.0 Vdc, gate open, T_C = 25°C)		-	-	50	
Forward "On" Voltage (I_f = 1.0 Adc, PW = 1.0 ms max, Duty cycle ≤ 1.0%)	V_F	-	-	2.0	Volts
Dynamic Forward "On" Voltage (0.5 μs after 50% decay point on dynamic forward voltage waveform) Forward Current: 100 A pulse (PFN discharge circuit) Gate Pulse: at 500 mA, PW = 1.0 μs, t_r = 20 ns	$V_{F(on)}$	-	45	-	Volts
Turn-On Time					ns
Delay Time	t_d	-	75	-	
Rise Time	t_r	-	75	-	
Forward Current: 100 A Pulse (Capacitor discharge circuit) Gate Pulse: at 500 mA, PW = 1.0 μs, t_r = 20 ns					
Pulse Turn-Off Time Test Conditions: PFN discharge; Forward Current = 100 A pulse; Reverse Current = 5.0 A, T_C = 85°C, dv/dt = 250 V/μs to Rated V_{FOM}; Reverse anode voltage during turn-off interval = 0 V; Reverse gate bias during turn-off interval = 6.0 V.	$t_{off(pulse)}$	-	7.0	-	μs
Forward Voltage Application Rate (Linear Rise of Voltage) (T_C = 105°C, gate shorted)	dv/dt	250	-	-	V/μs
Thermal Resistance (Junction to Case)	θ_{JC}	-	-	2.5	°C/W

*V_{FOM} for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for zero or negative gate voltage. When checking forward or reverse blocking capability, these devices should not be tested with a constant current source in a manner that the voltage applied exceeds the rated blocking voltage. Other voltage units available upon request.

MCR1906-1 thru MCR1906-4 (SILICON)

CASE 31(2)
(TO-5)

Thyristors (silicon controlled rectifiers) designed for applications in control systems and sensing circuits where low level gating and holding characteristics are necessary.

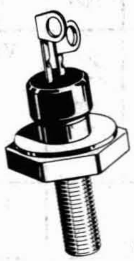
MAXIMUM RATINGS (T_J = 100° C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage (Note 1) MCR1906-1 MCR1906-2 MCR1906-3 MCR1906-4	$V_{RXM(rep)}$	 25 50 100 200	Volt
Forward Current RMS (All Conduction Angles)	I_f	1.6	Amp
Peak Forward Surge Current (One Cycle, 60 Hz, T_J = -40 to +100° C) No Repetition Until Thermal Equilibrium is Restored	$I_{FM(surge)}$	15	Amp
Peak Gate Power Forward	P_{GFM}	0.1	Watt
Average Gate Power Forward	$P_{GF(AV)}$	0.01	Watt
Peak Gate Current Forward	I_{GFM}	0.1	Amp
Peak Gate Voltage - Forward Reverse	V_{GFM} V_{GRM}	6.0 6.0	Volt
Operating Junction Temperature Range	T_J	-65 to +100	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C
Lead Solder Temperature (>1/16" From Case, 10 sec. max.)	-	+230	°C

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage (T_J = 105°C) MCR846-1 -2 -3 -4	V_{FOM}	 25 50 100 200	 — — — —	 — — — —	Volts
Peak Forward Blocking Current (Rated V_{FOM} with gate open, T_J = 105°C)	I_{FOM}	—	—	2.0	mA
Peak Reverse Blocking Current (Rated V_{ROM} with gate open, T_J = 105°C)	I_{ROM}	—	—	2.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 100Ω)	I_{GT}	—	10	50	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 100Ω)	V_{GT}	—	0.8	1.5	Volts
Holding Current (Anode Voltage = 7 Vdc, Gate Open)	I_{HO}	—	15	—	mA
Forward On Voltage (I_F = 2 Adc)	V_F	—	1.3	1.6	Volts
Turn-On Time ($t_d + t_r$) (I_G = 50 mA, I_F = 2 A)	t_{on}	—	0.5	—	μs
Turn-Off Time (I_F = 2 A, I_R = 10 A, dv/dt = 50 V/μs) (V_{FXM} = rated voltage) (V_{RXM} = rated voltage)	t_{off}	—	6.0	—	μs
Forward Voltage Application Rate (T_J = 105°C, gate open)	dv/dt	50	—	—	V/μs
Thermal Resistance (Junction to Case)	θ_{JC}	—	—	3.0	°C/W

MCR1336-5 (SILICON)
thru
MCR1336-10



CASE 63

Fast switching, high-voltage thyristors especially designed for pulse modulator applications in radar and other similar equipment.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage* (T_J = 105°C)	$V_{ROM(rep)}$*	50	Volts
Repetitive Peak Forward Current (PW = 3.0 μs, Duty Cycle = 0.6%, T_C = 85°C max)	$I_{FM(rep)}$	300	Amp
Current Application Rate**	di/dt**	1000	A/μs
Peak Gate Power-Forward	P_{GFM}	20	Watts
Average Gate Power-Forward	$P_{GF(AV)}$	1.0	Watt
Peak Gate Current-Forward	I_{GFM}	5.0	Amp
Peak Gate Voltage-Forward Reverse***	V_{GFM} V_{GRM}***	7.0 7.0	Volts
Operating Junction Temperature Range	T_J	-65 to +105	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Stud Torque	-	15	in. lb.

*Characterized for unilateral applications where reverse blocking capability is not important. Higher voltage units available upon request. $V_{ROM(rep)}$ may be applied as a continuous dc voltage for zero or negative gate voltage but positive gate voltage must not be applied concurrently with a negative potential on the anode. When checking blocking capability, do not permit the applied voltage to exceed the rated voltage.

**Minimum Gate Trigger Pulse: i_G = 500 mA, PW = 1.0 μs, t_r = 20 ns.

***Do not reverse bias gate during forward conduction if anode current exceeds 10 amperes.

MCR1906-1 thru MCR1906-4 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted, R_{GK} = 1000 ohms)

Characteristic	Symbol	Min	Max	Unit
Peak Forward Blocking Voltage (Note 1)	V_{FXM}			Volt
MCR1906-1		25	-	
MCR1906-2		50	-	
MCR1906-3		100	-	
MCR1906-4		200	-	
Peak Reverse Blocking Current (Note 3) (Rated V_{RXM}, T_J = 100° C)	I_{RXM}	-	500	μA
Peak Forward Blocking Current (Rated V_{FXM}, T_J = 100° C)	I_{FXM}	-	500	μA
Forward "On" Voltage (Pulsed, 1.0 ms max, Duty Cycle ≤ 1.0%) (I_F = 1.0 Adc peak)	V_F	-	1.75	Volt
Gate Trigger Current (Note 2) (Continuous dc) (Anode Voltage = 7.0 V, R_L = 100 ohms)	I_{GT}	-	1.0	mAdc
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7.0 V, R_L = 100 ohms)	V_{GT}	-	1.0	Volt
(Anode Voltage = Rated V_{FXM}, R_L = 100 ohms, T_J = 100° C)	V_{GNT}	0.1	-	
Holding Current (Anode Voltage = 7.0 V)	I_{HX}	-	5.0	mA
Turn-On Time	t_{on}	Circuit dependent, consult manufacturer		
Turn-Off Time	t_{off}			

NOTES: 1. V_{RXM} and V_{FXM} can be applied for all types on a continuous dc basis without incurring damage. Thyristor devices shall not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

2. R_{GK} current is not included in measurement.

3. Thyristor devices shall not have a positive bias applied to the gate concurrently with a negative potential applied to the anode.

FIGURE 1 – CASE TEMPERATURE versus CURRENT

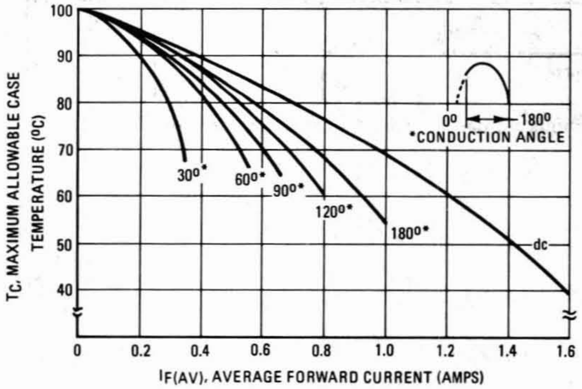
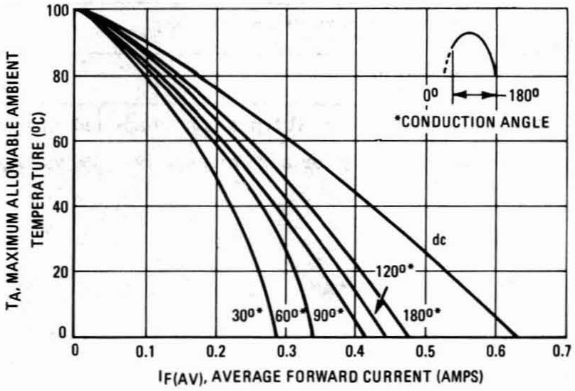
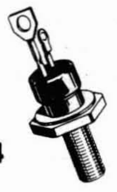


FIGURE 2 – AMBIENT TEMPERATURE versus CURRENT



MCR1907-1 thru MCR1907-6 (SILICON)



CASE 64
(TO-48)

Fast turn-on, fast turn-off silicon controlled rectifiers for high-frequency applications requiring blocking to 400 volts and load currents to 25 amp.

MAXIMUM RATINGS ($T_J = 125°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Reverse Blocking Voltage*	$V_{ROM(rep)}$*		Volts
MCR1907-1		25	
-2		50	
-3		100	
-4		200	
-5		300	
-6		400	
Peak Reverse Blocking Voltage (Non-Recurrent 5 ms (max.)	$V_{ROM(non-rep)}$		Volts
MCR1907-1		35	
-2		75	
-3		150	
-4		300	
-5		400	
-6		500	
Forward Current RMS (All Conduction Angles)	I_f	25	Amp
Circuit Fusing Considerations (T_J = -65 to +125°C; t ≦ 8.3 ms)	I^2t	75	A^2s
Peak Forward Surge Current (One Cycle, 60 Hz, T_J = -65 to +125°C)	$I_{FM(surge)}$	150	Amp
Peak Gate Power - Forward	P_{GFM}	5.0	Watts
Average Gate Power - Forward	$P_{GF(AV)}$	0.5	Watt
Peak Gate Current – Forward	I_{GFM}	2.0	Amp
Peak Gate Voltage - Forward	V_{GFM}	10	Volts
Reverse	V_{GRM}	5.0	
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C
Stud Torque	—	30	in. lb.

*$V_{ROM(rep)}$ for all types can be applied on a continuous dc basis without incurring damage.
Ratings apply for zero or negative gate voltage.

MCR1907-1 thru MCR1907-6 (continued)

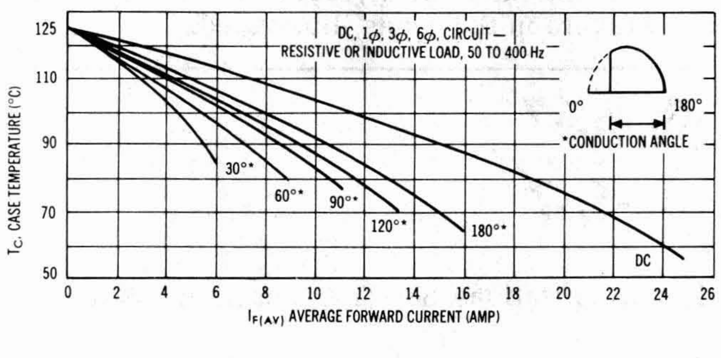
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Units
Peak Forward Blocking Voltage*	V_{FOM}*				Volts
(T_J = 125°C) MCR1907-1		25	—	—	
-2		50	—	—	
-3		100	—	—	
-4		200	—	—	
-5		300	—	—	
-6		400	—	—	
Peak Forward Blocking Current (Rated V_{FOM} with gate open, T_J = 125°C)	I_{FOM}	—	—	4.0	mA
Peak Reverse Blocking Current (Rated V_{ROM} with gate open, T_J = 125°C)	I_{ROM}	—	—	4.0	mA
Gate Trigger Current (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50Ω)	I_{GT}	—	15	30	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7 Vdc, R_L = 50 Ω)	V_{GT}	—	—	1.5	Volts
(Anode Voltage = Rated V_{FOM}, R_L = 50Ω, T_J = 125°C)	V_{GNT}	0.25	—	—	
Holding Current (Anode Voltage = 7 Vdc, Gate Open)	I_{HO}	—	12	—	mA
Forward On Voltage (I_F = 20 Adc)	V_F	—	1.4	1.7	Volts
Turn-On Time (I_G = 200 mA, I_F = 10 A)	t_{on}	—	0.5	—	μs
Turn-Off Time (I_F = 10 A, I_R = 10 A, dv/dt = 30 V/μs min.) (V_{FXM} = rated voltage) T_J = 125°C (V_{RXM} = rated voltage)	t_{off}	—	—	12	μs
Forward Voltage Application Rate (T_J = 125°C, gate open)	dv/dt	30	—	—	V/μs
Thermal Resistance (Junction to Case)	θ_{JC}	—	1.0	1.7	°C/W

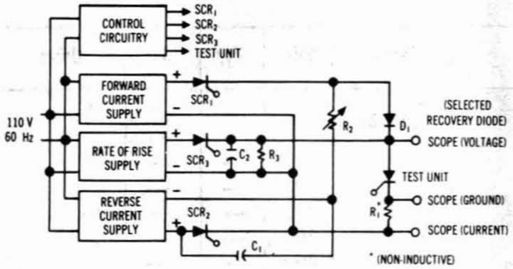
*V_{FOM} for all types can be applied on a continuous dc basis without incurring damage.

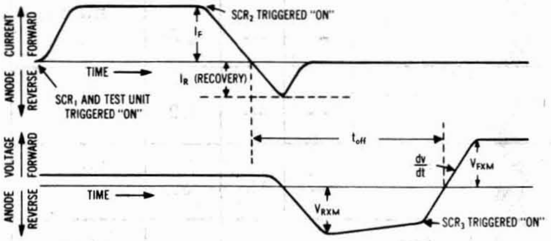
Ratings apply for zero or negative gate voltage. These devices should never be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

CURRENT DERATING



TURN-OFF TIME TEST CIRCUIT †

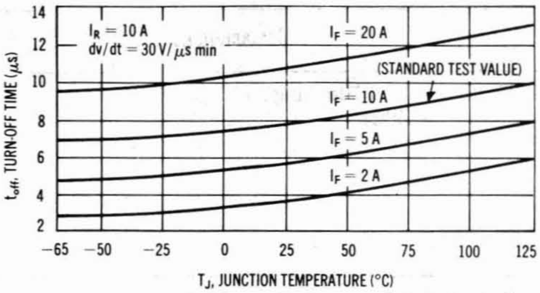

CONTROL CIRCUITRY
SCR_1
SCR_2
SCR_3
TEST UNIT
FORWARD CURRENT SUPPLY
+
−
SCR_1
110 V
60 Hz
RATE OF RISE SUPPLY
+
−
SCR_3
C_2
R_3
REVERSE CURRENT SUPPLY
−
+
SCR_2
C_1
R_2
D_1
(SELECTED RECOVERY DIODE)
SCOPE (VOLTAGE)
TEST UNIT
SCOPE (GROUND)
R_1^*
SCOPE (CURRENT)
* (NON-INDUCTIVE)


ANODE CURRENT
FORWARD
REVERSE
SCR_2 TRIGGERED "ON"
I_F
TIME
I_R (RECOVERY)
SCR_1 AND TEST UNIT TRIGGERED "ON"
ANODE VOLTAGE
FORWARD
REVERSE
t_{off}
$\frac{dv}{dt}$
V_{FXM}
TIME
V_{RXM}
SCR_3 TRIGGERED "ON"

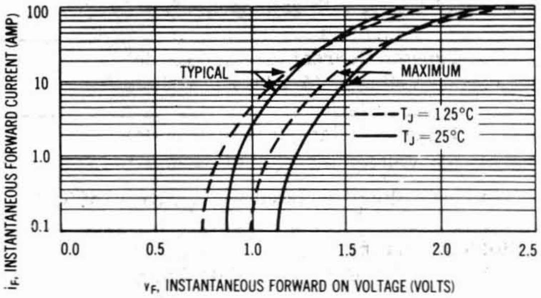
Forward conduction current is passed through the device (SCR_1 and test device triggered on). The anode is then driven negative (SCR_2 triggered on), causing reverse current to flow. The anode-to-cathode potential goes negative with a decrease in reverse current. Forward voltage is then applied to the anode of the device (SCR_3 triggered on). The device has fully recovered when it regains its ability to block the reapplied forward voltage.

† Consult manufacturer for further circuit information.

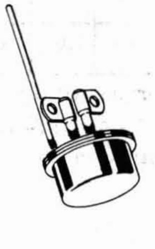
TYPICAL TURN-OFF TIME versus PEAK FORWARD CURRENT AND JUNCTION TEMPERATURE



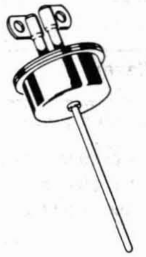
FORWARD CONDUCTING CHARACTERISTICS



MCR2604-1 thru MCR2604-8
MCR2605-1 thru MCR2605-8



CASE 87
MCR2604-1
thru
MCR2604-8



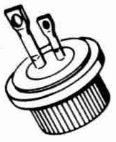
CASE 88
MCR2605-1
thru
MCR2605-8

These series of silicon controlled rectifiers are electrically identical to the 2N4151 thru 2N4198 series, but are available in the cases illustrated.

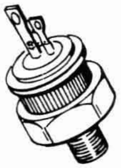
MCR2818-1, -3, -5, -7
MCR2918-1, -3, -5, -7

For Specifications, See Thyristor Selector Guide

MCR2835 SERIES (SILICON)
MCR2935



CASE 91
MCR2835-1
thru
MCR2835-8



CASE 92
MCR2935-1
thru
MCR2935-8

PNPN thyristors (silicon controlled rectifiers) designed for industrial and consumer applications such as power supplies, battery chargers, temperature, motor, light and welder controls, and protective devices.

MAXIMUM RATINGS (T_J = 100° C unless otherwise noted)

Rating	Symbol	Value	Units
Repetitive Peak Reverse Blocking Voltage Ratings apply for zero or negative gate voltage	$V_{ROM(rep)}$* Do not apply positive gate bias concurrently with negative anode potential.		Volts
MCR2835 / MCR2935 -1		25	
-2		50	
-3		100	
-4		200	
-5		300	
-6		400	
-7		500	
-8		600	
Non-Repetitive Peak Reverse Blocking Voltage ($t < 5.0$ ms)	$V_{ROM(non\text{-}rep)}$		Volts
MCR2835 / MCR2935 -1		35	
-2		75	
-3		150	
-4		300	
-5		400	
-6		500	
-7		600	
-8		700	
Forward Current RMS	I_f	35	Amp
Peak Surge Current (one cycle, 60 Hz) (T_J = -40 to +100° C)	$I_{FM(surge)}$	325	Amp
Circuit Fusing Considerations (T_J = -40 to +100° C) (t = 1.0 to 8.3 ms)	I^2t	435	A^2s
Peak Gate Power	P_{GFM}	5.0	Watt
Average Gate Power	$P_{GF(AV)}$	0.5	Watt
Peak Forward Gate Current	I_{GFM}	2.0	Amp
Peak Gate Voltage			Volts
Forward	V_{GFM}	10	
Reverse	V_{GRM}	10	
Operating Junction Temperature Range	T_J	-40 to +100	°C
Storage Temperature Range	T_{stg}	-40 to +150	°C
Stud Torque (MCR2935 Series)	–	30	in. lb.

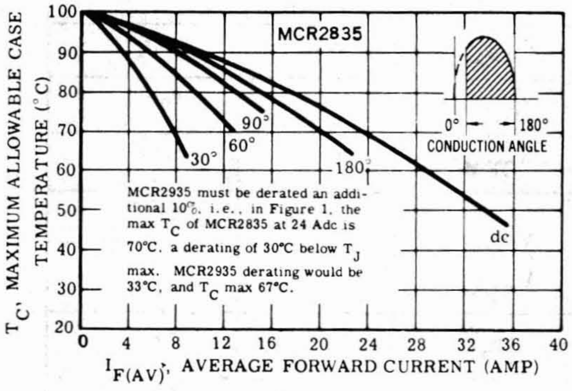
MCR2835, MCR2935 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristics	Symbol	Min	Typ	Max	Unit
Peak Forward Blocking Voltage* ($T_J = 100°C$) MCR2835 / MCR2935 -1 -2 -3 -4 -5 -6 -7 -8	V_{FOM}*	 25 50 100 200 300 400 500 600	 - - - - - - - -	 - - - - - - - -	Volts
Peak Forward Blocking Current (Rated V_{FOM} with gate open, $T_J = 100°C$)	I_{FOM}	-	1.0	5.0	mA
Peak Reverse Blocking Current (Rated V_{ROM}, with gate open, $T_J = 100°C$)	I_{ROM}	-	1.0	5.0	mA
Forward "On" Voltage ($I_F = 35$ A Peak)	V_F	-	1.2	1.5	Volts
Gate Trigger Current (Continuous dc) (Anode Voltage = 7.0 V, $R_L = 100\ \Omega$)	I_{GT}	-	10	40	mA
Gate Trigger Voltage (Continuous dc) (Anode Voltage = 7.0 V, $R_L = 100\ \Omega$) (Anode Voltage = Rated V_{FOM}, $R_L = 100\ \Omega$, $T_J = 100°C$)	V_{GT}	- 0.2	0.7 -	1.5 -	Volts
Holding Current (Anode Voltage = 7.0 V, gate open)	I_{HO}	-	10	50	mA
Turn-On Time ($t_d + t_r$) ($I_F = 35$ Adc, $I_{GT} = 40$ mAdc)	t_{on}	-	1.0	-	μs
Turn-Off Time ($I_F = 10$ A, $I_R = 10$ A) ($I_F = 10$ A, $I_R = 10$ A, $T_J = 100°C$)	t_{off}	- -	15 25	- -	μs
Forward Voltage Application Rate ($T_J = 100°C$)	dv/dt	-	50	-	V/μs
Thermal Resistance MCR2835 MCR2935	θ_{JC}	 - -	 - -	 1.2 1.3	°C/W

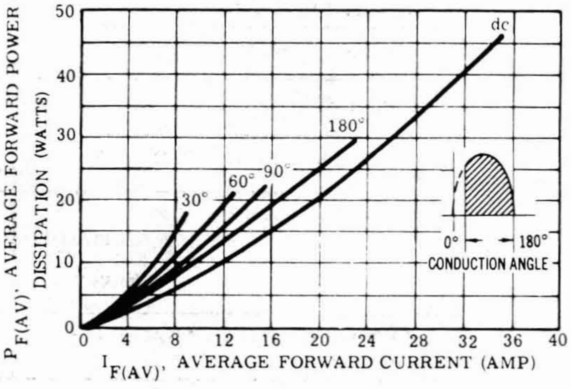
* V_{FOM} for all types can be applied on a continuous dc basis without incurring damage. Ratings apply for zero or negative gate voltage. SCR devices should not be tested with a constant current source for forward or reverse blocking capability such that the voltage applied exceeds the rated blocking voltage.

FIGURE 1 — CURRENT DERATING



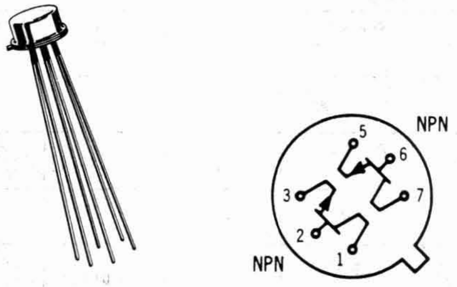
MCR2935 must be derated an additional 10%, i.e., in Figure 1, the max T_C of MCR2835 at 24 Adc is 70°C, a derating of 30°C below T_J max. MCR2935 derating would be 33°C, and T_C max 67°C.

FIGURE 2 — POWER DISSIPATION



MD708, F (SILICON)
MD708A, F
MD708B, F

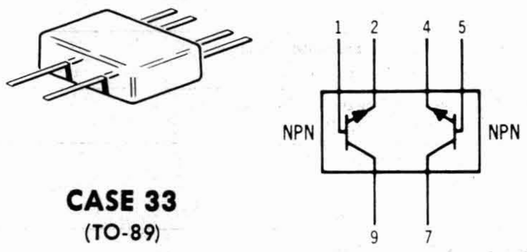
Dual NPN silicon annular transistors designed for high-speed, logic switching and space saving considerations. Matched pairs are available for differential amplifier applications.


NPN
NPN
1
2
3
5
6
7

CASE 32

PINS 4 AND 8 OMITTED

MD708
MD708A
MD708B


1
2
4
5
NPN
NPN
9
7

CASE 33
(TO-89)

MD708F
MD708AF
MD708BF

Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	200		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D			
Metal Can		300	400	mW
Derate above 25°C		1.7	2.3	mW/°C
Flat Package		250	350	mW
Derate above 25°C		1.5	2.0	mW/°C

FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT

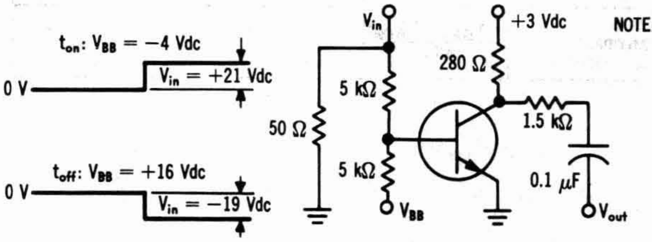
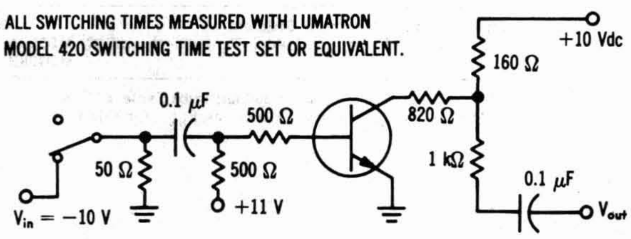

t_{on}: V_{BB} = −4 Vdc
0 V
V_{in} = +21 Vdc
t_{off}: V_{BB} = +16 Vdc
0 V
V_{in} = −19 Vdc
V_{in}
+3 Vdc
280 Ω
5 kΩ
50 Ω
5 kΩ
V_{BB}
1.5 kΩ
0.1 µF
V_{out}

FIGURE 2 — CHARGE-STORAGE TIME CONSTANT TEST CIRCUIT

NOTE: ALL SWITCHING TIMES MEASURED WITH LUMATRON MODEL 420 SWITCHING TIME TEST SET OR EQUIVALENT.


+10 Vdc
160 Ω
0.1 µF
500 Ω
820 Ω
1 kΩ
50 Ω
500 Ω
+11 V
0.1 µF
V_{in} = −10 V
V_{out}

MD708,F/MD708A,F/MD708B,F (continued)

ELECTRICAL CHARACTERISTICS (each side) ($T_A = 25°C$ unless otherwise noted)

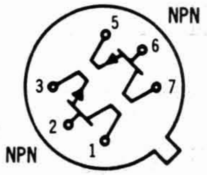
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 30 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	15	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = +150°C)	I_{CBO}	— —	0.015 50	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 0.5 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 100 mAdc, V_{CE} = 5.0 Vdc) (I_C = 150 mAdc, V_{CE} = 5.0 Vdc)	h_{FE}*	40 40 35 30	— 200 — —	—
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{CE(sat)}$	— — —	0.2 0.35 0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{BE(sat)}$	0.65 — —	0.85 0.95 1.1	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	5.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	7.0	pF
Charge-Storage Time Constant (Figure 2) (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc)	t_s	—	25	ns
Turn-On Time (Figure 1) (I_C = 10 mAdc, I_{B1} = 3 mAdc, I_{B2} = 1 mAdc)	t_{on}	—	35	ns
Turn-Off Time (Figure 1) (I_C = 10 mAdc, I_{B1} = 3 mAdc, I_{B2} = 1 mAdc)	t_{off}	—	75	ns
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 10 mAdc, V_{CE} = 1 Vdc) MD708A, MD708AF MD708B, MD708BF	h_{FE1}/h_{FE2}**	0.9 0.8	1.0 1.0	—
Base Voltage Differential (I_C = 10 mAdc, V_{CE} = 1 Vdc) MD708A, MD708AF MD708B, MD708BF	$\lvert V_{BE1} - V_{BE2} \rvert$	— —	5 10	mVdc
Base Voltage Differential Gradient (I_C = 10 mAdc, V_{CE} = 1 Vdc, T_A = -55 to +125°C) MD708A, MD708AF MD708B, MD708BF	$\frac{\Delta(V_{BE1} - V_{BE2})}{\Delta T_A}$	— —	10 20	μV/°C

*Pulse Test: Pulse Width = 300 μs; Duty Cycle = 2%

**The lowest h_{FE} reading is taken as h_{FE1} for this test.

MD918, F (SILICON)
MD918A, F
MD918B, F

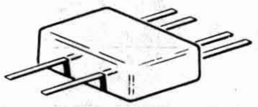
Dual NPN silicon annular transistors designed for ultra-high frequency oscillator and amplifier applications and for differential amplifier applications requiring a matched pair of transistors with a high degree of parameter uniformity under varying environmental conditions.

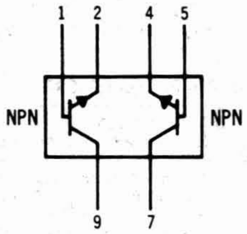


CASE 32C

PINS 4 AND 8 OMITTED

MD918
MD918A
MD918B





CASE 33
(TO-89)

MD918F
MD918AF
MD918BF

Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Collector-Base Voltage	V_{CB}	30		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	50		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D			
Metal Can		300	400	mW
Derate above 25°C		1.7	2.3	mW/°C
Flat Package		250	350	mW
Derate above 25°C		1.5	2.0	mW/°C

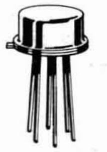
ELECTRICAL CHARACTERISTICS (each side) ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 3 mAdc, I_B = 0)	BV_{CEO}	15	—	Vdc
Collector-Base Breakdown Voltage (I_C = 1 μAdc, I_E = 0)	BV_{CBO}	30	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	— —	0.010 1.0	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 1 mAdc, V_{CE} = 5 Vdc)	h_{FE}	50	—	—
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$	—	0.2	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	—	0.9	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 4 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	600	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz) (V_{CB} = 0, I_E = 0, f = 140 kHz)	C_{ob}	— —	1.7 3.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	—	2.0	pF
Noise Figure (I_C = 1 mAdc, V_{CE} = 6 Vdc, f = 60 MHz, R_S = 400 ohms)	NF	—	6.0	dB
MATCHING CHARACTERISTICS				
DC Current Gain Ratio* (I_C = 1 mAdc, V_{CE} = 5 Vdc) MD918A, MD918AF MD918B, MD918BF	h_{FE1}/h_{FE2}*	0.9 0.8	1.0 1.0	—
Base Voltage Differential (I_C = 1 mAdc, V_{CE} = 5 Vdc) MD918A, MD918AF MD918B, MD918BF	$\lvert V_{BE1} - V_{BE2} \rvert$	— —	5 10	mVdc
Base Voltage Differential Change (I_C = 1 mAdc, V_{CE} = 5 Vdc, T_A = -55 to +125°C) MD918A, MD918AF MD918B, MD918BF	$\frac{\Delta(V_{BE1} - V_{BE2})}{\Delta T_A}$	— —	10 20	μV/°C

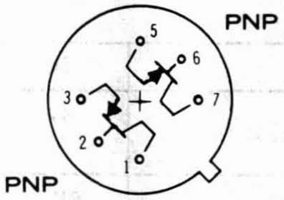
*The lowest h_{FE} reading is taken as h_{FE1} for this ratio.

MD984 (SILICON)

PNP silicon annular dual transistor for high-speed switching and amplifier applications.



CASE 32C



PINS 4 AND 8 OMITTED
PIN CONNECTIONS
(BOTTOM VIEW)

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	40		Vdc
Collector-Emitter Voltage	V_{CEO}	20		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	200		mAdc
Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation (25°C Case Temperature) Derate above 25°C	P_D	1.6 9.1	3.0 17.2	W mW/°C
Total Device Dissipation (25°C Ambient Temperature) Derate above 25°C	P_D	0.5 2.9	0.6 3.4	W mW/°C

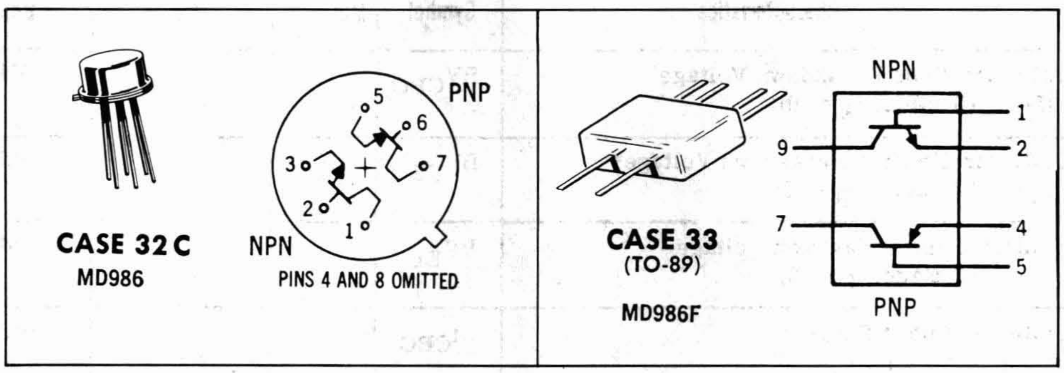
ELECTRICAL CHARACTERISTICS (each side)
($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Minimum	Maximum	Unit
Collector-Base Breakdown Voltage (I_C = -10 μAdc, I_E = 0)	BV_{CBO}	40	---	Vdc
Collector-Emitter Breakdown Voltage* (I_C = -10 mAdc, I_B = 0)	BV_{CEO}*	20	---	Vdc
Emitter-Base Breakdown Voltage (I_E = -10 μAdc, I_C = 0)	BV_{EBO}	5	---	Vdc
Collector Cutoff Current (V_{CB} = -20 Vdc, I_E = 0) (V_{CB} = -20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	--- ---	.025 30	μAdc
Collector-Emitter Saturation Voltage (I_C = -10 mAdc, I_B = -1 mAdc) (I_C = -50 mAdc, I_B = -5 mAdc)	$V_{CE(sat)}$	--- ---	0.3 0.5	Vdc
Base-Emitter Saturation Voltage (I_C = -10 mAdc, I_B = -1 mAdc)	$V_{BE(sat)}$	---	0.9	Vdc
DC Forward Current Transfer Ratio (I_C = -10 mAdc, V_{CE} = -10 Vdc)	h_{FE}	25	---	---
Output Capacitance (V_{CB} = -10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	---	4	pF
Small-Signal Forward Current Transfer Ratio (I_C = -20 mAdc, V_{CE} = -20 Vdc, f = 100 MHz)	h_{fe}	2.5	---	---
Current-Gain—Bandwidth Product (I_C = -20 mAdc, V_{CE} = -20 Vdc)	f_T	250	---	MHz

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2%

MD986, F (SILICON)

NPN-PNP silicon annular Star complementary pair dual transistors for high-speed switching circuits and DC to UHF amplifier applications.



CASE 32C
MD986
PNP
5
6
7
3
2
1
NPN
PINS 4 AND 8 OMITTED
CASE 33
(TO-89)
MD986F
NPN
1
9
2
7
4
5
PNP

Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	40		Vdc
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	200		mAdc
Operating Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ $T_A = 25^{\circ}C$	P_D			
Flat Package		250	350	mW
Derate above 25°C		1.5	2.0	mW/°C
Metal Can		500	600	mW
Derate above 25°C		2.9	3.4	mW/°C

ELECTRICAL CHARACTERISTICS (each side)

(T_A = 25°C unless otherwise noted)

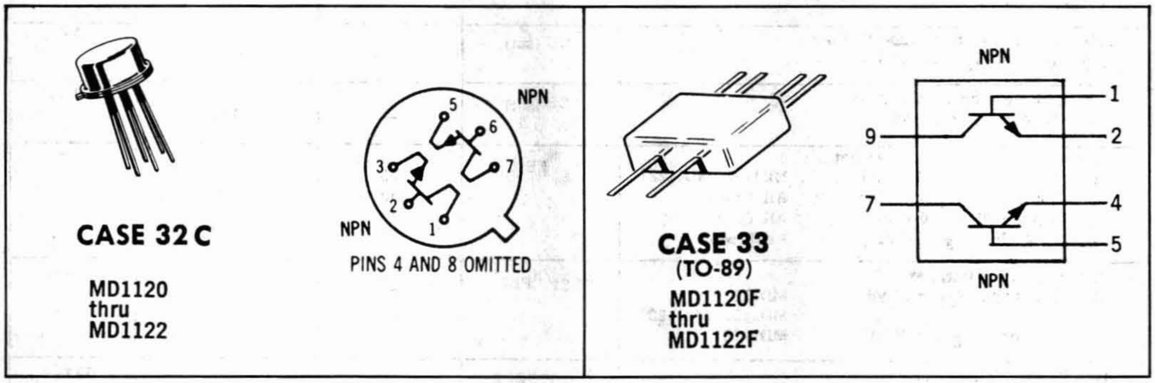
Test Conditions and Limits are given in magnitudes only. Care must be taken to insure the application of proper polarities for the NPN or PNP transistor, respectively.

Characteristics	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	15	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	— —	.025 30	μAdc
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc)	$V_{CE(sat)}$	— —	0.3 0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	—	0.9	Vdc
DC Forward Current Transfer Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc)	h_{FE}	25	—	—
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	4	pF
Current-Gain — Bandwidth Product (V_{CE} = 20 Vdc, I_C = 20 mAdc) TO-5 Package (V_{CE} = 10 Vdc, I_C = 20 mAdc) Flat Package	f_T	200 200	— —	MHz

*Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2%

MD1120, F (SILICON)
MD1121, F
MD1122, F

NPN silicon annular Star dual transistors for differential amplifiers and other applications requiring a matched pair with a high degree of parameter uniformity.


CASE 32C
MD1120
thru
MD1122
NPN
5
6
3
7
2
1
NPN
PINS 4 AND 8 OMITTED
CASE 33
(TO-89)
MD1120F
thru
MD1122F
NPN
1
9
2
7
4
5
NPN

Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	60		Vdc
Collector-Emitter Voltage	V_{CEO}	30		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
D.C. Collector Current	I_C	500		mAdc
Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to + 200		°C
		One Side	Both Sides	
Flat Package Total Device Dissipation @ T_A = 25°C (Derate above 25°C)	P_D	250 1.5	350 2.0	mW mW/°C
Total Device Dissipation @ T_A = 25°C Metal Can (Derate above 25°C)	P_D	500 2.9	600 3.4	mW mW/°C

MD1120-MD1122,F (continued)

ELECTRICAL CHARACTERISTICS (each side)

(T_A = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 μAdc)	BV_{CBO}	60	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc)	BV_{CEO}*	30	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc)	BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc) (V_{CB} = 50 Vdc, T_A = 150°C)	I_{CBO}	— —	0.010 10	μAdc
Emitter Cutoff Current (V_{EB} = 3 Vdc)	I_{EBO}	—	10	nAdc
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	V_{CE} (sat)	—	0.1	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	V_{BE} (sat)	—	0.85	Vdc
DC Forward Current Transfer Ratio (I_C = 10 μAdc, V_{CE} = 10 Vdc) MD1121, MD1122† (I_C = 100 μAdc, V_{CE} = 10 Vdc) All Types (I_C = 1 mAdc, V_{CE} = 10 Vdc) All Types (I_C = 10 mAdc, V_{CE} = 10 Vdc) All Types	h_{FE}	20 30 40 50	100 120 160 200	—
DC Current Gain Ratio ** (I_C = 100 μAdc, V_{CE} = 10 Vdc) MD1120† MD1121, MD1122† (I_C = 1 mAdc, V_{CE} = 10 Vdc) MD1122†	h_{FE1}/h_{FE2}**	0.8 0.9 0.9	1.0 1.0 1.0	—
Base Voltage Differential (I_C = 100 μAdc, V_{CE} = 10 Vdc) MD1120, MD1121† MD1122† (I_C = 1 mAdc, V_{CE} = 10 Vdc) MD1122†	$\|V_{BE1}-V_{BE2}\|$	— — —	10 5 5	mVdc
Base Voltage Differential Change (I_C = 100 μAdc, V_{CE} = 10 Vdc, T_A = -55°C to + 125°C) MD1121, MD1122†	$\frac{\Delta (V_{BE1}-V_{BE2})}{\Delta T_A}$	—	10	μV/°C
Collector Output Capacitance (V_{CB} = 10 Vdc, f = 100 kHz)	C_{ob}	—	8	pF
Small-Signal Forward Current Transfer Ratio **(I_C = 20 mAdc, V_{CE} = 20 Vdc, f= 100 MHz) TO-5 Package** **(I_C = 20 mAdc, V_{CE} = 10 Vdc, f= 100 MHz) Flat Package**	h_{fe}	2.5 2.0	– –	–
Current-Gain-Bandwidth Product **(V_{CE} = 20 Vdc, I_C = 20 mAdc) TO-5 Package** **(V_{CE} = 10 Vdc, I_C = 20 mAdc) Flat Package**	f_T	250 200	– –	MHz

*** Pulse Test: Pulse Width ≤ 300 μs. Duty Cycle ≤ 2%**

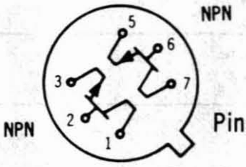
**** The lowest h_{FE} reading is taken as h_{FE1} for this ratio**

† Applies to corresponding Flat Package device type also

MD1126 (SILICON)
MD1127

NPN silicon annular dual transistors for high-speed switching applications.

CASE 32 C



Pins 4 and 8 omitted

Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	200		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 1.7	400 2.3	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	0.75 4.3	1.5 8.6	Watt mW/°C

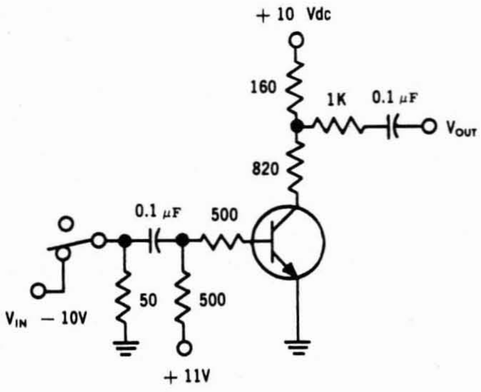
ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 30 mAdc, I_B = 0)	BV_{CEO}*	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 1.0 µAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150° C)	I_{CBO}	- -	0.025 15	µAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}*	30	-	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) MD1126 MD1127	$V_{CE(sat)}$	- -	0.40 0.25	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	0.7	0.85	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain-Bandwidth Product (I_C = 20 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	300	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	6.0	pF
Charge-Storage Time Constant ($I_C = I_{B1} = I_{B2}$ = 10 mAdc) MD1126 ($I_C = I_{B1} = I_{B2}$ = 20 mAdc) MD1127	τ_S	- -	40 25	ns

*Pulse Test: Pulse Width ≤ 300 µs, Duty Cycle ≤ 2.0%.

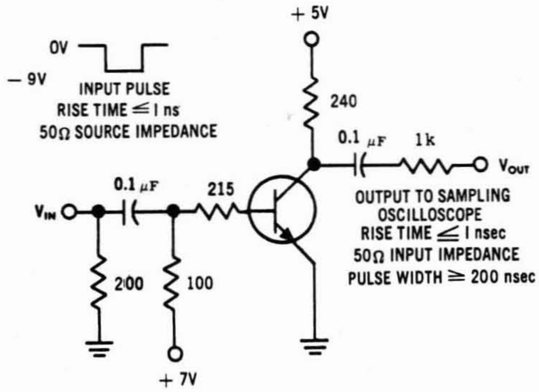
CHARGE STORAGE TIME CONSTANT TEST CIRCUIT

MD1126


+ 10 Vdc
160
1K
0.1 µF
V_{OUT}
820
0.1 µF
500
50
500
V_{IN} – 10V
+ 11V

CHARGE STORAGE TIME CONSTANT TEST CIRCUIT

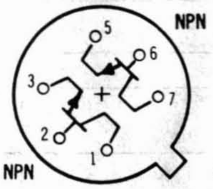
MD1127


0V
– 9V
INPUT PULSE
RISE TIME ≤ 1 ns
50Ω SOURCE IMPEDANCE
+ 5V
240
0.1 µF
1k
V_{OUT}
0.1 µF
215
V_{IN}
OUTPUT TO SAMPLING
OSCILLOSCOPE
RISE TIME ≤ 1 nsec
50Ω INPUT IMPEDANCE
PULSE WIDTH ≥ 200 nsec
200
100
+ 7V

MD1128 (SILICON)

NPN silicon annular dual transistors for high-speed switching applications.

CASE 32C


NPN
5
6
3
7
2
1
NPN

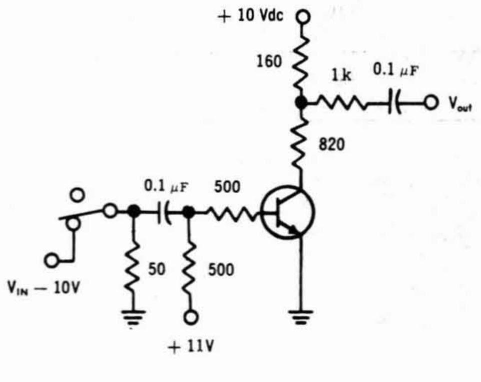
Pin Connections Bottom View
All Leads Electrically Isolated from Case

PINS 4 AND 8 OMITTED

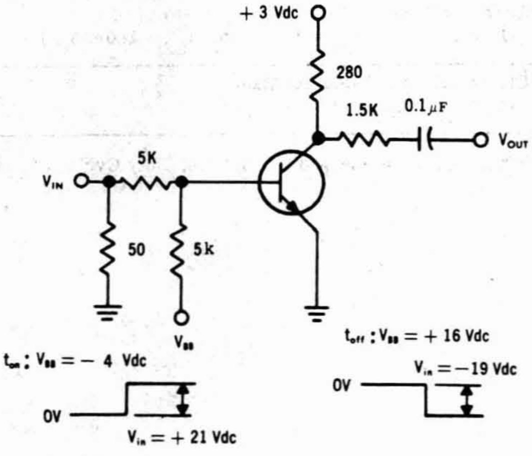
MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	200		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 1.7	400 2.3	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	0.75 4.3	1.5 8.6	Watt mW/°C

CHARGE STORAGE TIME CONSTANT TEST CIRCUIT


+ 10 Vdc
160
1k
0.1 μF
V_{out}
820
0.1 μF
500
50
500
V_{IN} − 10V
+ 11V

TURN-ON AND TURN-OFF TIME TEST CIRCUIT


+ 3 Vdc
280
1.5K
0.1μF
V_{OUT}
5K
V_{IN}
50
5k
V_{BB}
t_{on}: V_{BB} = − 4 Vdc
0V
V_{in} = + 21 Vdc
t_{off} : V_{BB} = + 16 Vdc
V_{in} = −19 Vdc
0V

MD1128 (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 20 Vdc, V_{BE} = 0)	I_{CES}	-	10	μAdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = +150°C)	I_{CBO}	- -	0.025 30	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}	25	-	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$	- -	0.3 0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain-Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	350	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	4.0	pF
SWITCHING CHARACTERISTICS				
Turn-On Time (I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc)	t_{on}	-	20	ns
Turn-Off Time (I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc)	t_{off}	-	35	ns
Charge-Storage Time Constant (I_C = I_{B1} = I_{B2} = 10 mAdc)	τ_S	-	30	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

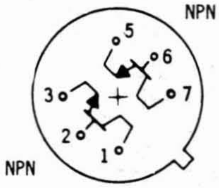
MD1129,F (SILICON)

NPN silicon annular dual transistors for differential amplifiers and other applications requiring a matched pair with a high degree of parameter uniformity.

CASE 32C

MD1129

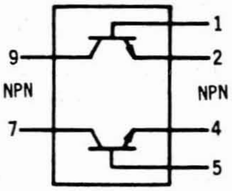
MD1129



PINS 4 AND 8 OMITTED

CASE 33
(TO-89)
MD1129F

MD1129F



Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	60		Vdc
Collector-Emitter Voltage	V_{CEO}	30		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current (Limited by P_D)	I_C	200		mAdc
Operating Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Flat Package Total Device Dissipation $T_A = 25°C$ Derate above 25°C	P_D	250 1.5	350 2	mW mW/°C
TO-5 Package Total Device Dissipation $T_A = 25°C$ Derate above 25°C	P_D	500 2.9	600 3.4	mW mW/°C

MD1129,F (continued)

ELECTRICAL CHARACTERISTICS (each side)

(T_A = 25°C unless otherwise noted)

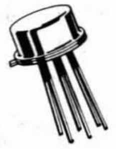
Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 μAdc)	BV_{CBO}	60	-	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc)	BV_{CEO}*	30	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc)	BV_{EBO}	5	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc) (V_{CB} = 50 Vdc, T_A = 150°C)	I_{CBO}	- -	.010 10	μAdc
Emitter Cutoff Current (V_{EB} = 3 Vdc)	I_{EBO}	-	10	nAdc
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$	-	0.1	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	-	0.85	Vdc
DC Forward Current Transfer Ratio (I_C = 10 μAdc, V_{CE} = 10 Vdc) (I_C = 100 μAdc, V_{CE} = 10 Vdc) (I_C = 1 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc)	h_{FE}	60 100 100 100	- 300 - -	-
DC Current Gain Ratio** (I_C = 100 μAdc, V_{CE} = 10 Vdc) (I_C = 1 mAdc, V_{CE} = 10 Vdc)	h_{FE1}/h_{FE2}**	0.9 0.9	1.0 1.0	-
Base Voltage Differential (I_C = 100 μAdc, V_{CE} = 10 Vdc) (I_C = 1 mAdc, V_{CE} = 10 Vdc)	$\lvert V_{BE1}-V_{BE2}\rvert$	- -	5 5	mVdc
Base Voltage Differential Change (I_C - 100 μAdc, V_{CE} = 10 Vdc, T_A = -55°C to +125°C)	$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$	-	10	μV/°C
Collector Output Capacitance (V_{CB} = 10 Vdc, f = 100 kHz)	C_{ob}	-	8	pF
Current-Gain-Bandwidth Product (V_{CE} = 10 Vdc, I_C = 20 mAdc)	f_T	200	-	MHz

*Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2%

**The lowest h_{FE} reading is taken as h_{FE1} for this ratio

MD1130, F (SILICON)

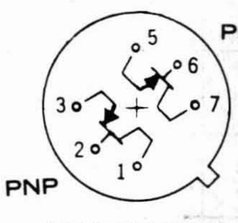
PNP silicon annular dual transistors for differential amplifiers and other applications requiring a matched pair with a high degree of parameter uniformity.



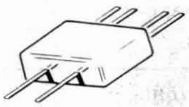
CASE 32C

MD1130

MD1130

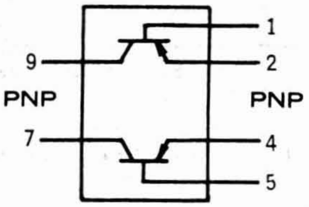


PINS 4 AND 8 OMITTED



CASE 33
(TO-89)
MD1130F

MD1130F



Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	60		Vdc
Collector-Emitter Voltage	V_{CEO}	40		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current (Limited by P_D)	I_C	200		mAdc
Operating Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Flat Package Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	250 1.5	350 2	mW mW/°C
Metal Can Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	500 2.9	600 3.4	mW mW/°C

MD1130, F (continued)

ELECTRICAL CHARACTERISTICS (each side)

(T_A = 25°C unless otherwise noted)

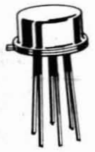
Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = -10 μAdc)	BV_{CBO}	60	-	Vdc
Collector-Emitter Breakdown Voltage* (I_C = -10 mAdc)	BV_{CEO}*	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = -10 μAdc)	BV_{EBO}	5	-	Vdc
Collector Cutoff Current (V_{CB} = -50 Vdc) (V_{CB} = -50 Vdc, T_A = 150°C)	I_{CBO}	 - -	 .010 10	μAdc
Emitter Cutoff Current (V_{EB} = -3 Vdc)	I_{EBO}	-	10	nAdc
Collector-Emitter Saturation Voltage (I_C = -10 mAdc, I_B = -1 mAdc)	$V_{CE(sat)}$	-	0.25	Vdc
Base-Emitter Saturation Voltage (I_C = -10 mAdc, I_B = -1 mAdc)	$V_{BE(sat)}$	-	0.9	Vdc
DC Forward Current Transfer Ratio (I_C = -10 μAdc, V_{CE} = -10 Vdc) (I_C = -100 μAdc, V_{CE} = -10 Vdc) (I_C = -1 mAdc, V_{CE} = -10 Vdc) (I_C = -10 mAdc, V_{CE} = -10 Vdc)	h_{FE}	 60 100 100 100	 - 300 - -	-
DC Current Gain Ratio** (I_C = -100 μAdc, V_{CE} = -10 Vdc) (I_C = -1 mAdc, V_{CE} = -10 Vdc)	h_{FE1}/h_{FE2}**	 0.9 0.9	 1.0 1.0	-
Base Voltage Differential (I_C = -100 μAdc, V_{CE} = -10 Vdc) (I_C = -1 mAdc, V_{CE} = -10 Vdc)	$\lvert V_{BE1} - V_{BE2} \rvert$	 - -	 5 5	mVdc
Base Voltage Differential Change (I_C = -100 μAdc, V_{CE} = -10 Vdc, T_A = -55°C to +125°C)	$\frac{\Delta(V_{BE1} - V_{BE2})}{\Delta T_A}$	-	10	μV/°C
Collector Output Capacitance (V_{CB} = -10 Vdc, F = 100 kHz)	C_{ob}	-	4	pF
Current-Gain – Bandwidth Product (V_{CE} = -10 Vdc, I_C = -20 mAdc)	f_T	200	-	MHz

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2%

** The lowest h_{FE} reading is taken as h_{FE1} for this ratio

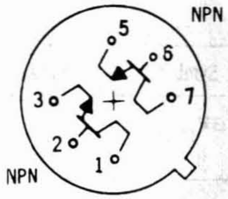
MD1131, F (SILICON)

NPN silicon annular dual transistors for high-frequency oscillator and amplifier applications.

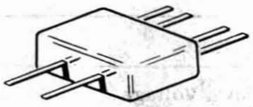


CASE 32C

MD1131

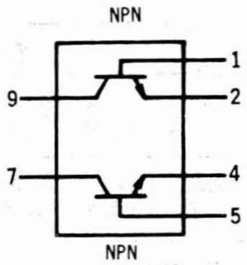


Pins 4 and 8 omitted



CASE 33

MD1131F



Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	30		Vdc
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	50		mAdc
Operating Junction Temperature	T_J	+200		°C
Storage Temperature	T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ T_A = 25°C	P_D			
Metal Can		300	400	mW
Derate above 25°C		1.7	2.3	mW/°C
Flat Package		250	350	mW
Derate above 25°C		1.5	2.0	mW/°C

ELECTRICAL CHARACTERISTICS (each side)

($T_A = 25°C$ unless otherwise noted)

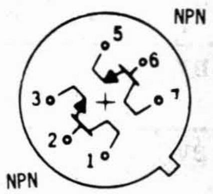
Characteristic	Symbol	Minimum	Maximum	Unit
Collector-Base Breakdown Voltage ($I_C = 1\ \mu Adc$, $I_E = 0$)	BV_{CBO}	30	-	Vdc
Collector-Emitter Breakdown Voltage ($I_C = 3\ mAdc$, $I_B = 0$)	BV_{CEO}	15	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10\ \mu Adc$, $I_C = 0$)	BV_{EBO}	5	-	Vdc
Collector Cutoff Current ($V_{CB} = 15\ Vdc$, $I_E = 0$) ($V_{CB} = 15\ Vdc$, $I_E = 0$, $T_A = +150°C$)	I_{CBO}	- -	.010 1.0	μAdc
Collector-Emitter Saturation Voltage ($I_C = 10\ mAdc$, $I_B = 1\ mAdc$)	$V_{CE(sat)}$	-	0.4	Vdc
Base-Emitter Saturation Voltage ($I_C = 10\ mAdc$, $I_B = 1\ mAdc$)	$V_{BE(sat)}$	-	1.0	Vdc
DC Forward Current Transfer Ratio ($I_C = 1\ mAdc$, $V_{CE} = 5\ Vdc$)	h_{FE}	50	-	-
Output Capacitance ($V_{CB} = 10\ Vdc$, $f = 140\ kHz$) ($V_{CB} = 0\ Vdc$, $f = 140\ kHz$)	C_{ob}	- -	1.7 3.0	pF
Input Capacitance ($V_{BE} = 0.5\ Vdc$, $f = 140\ kHz$)	C_{ib}	-	2.0	pF
Small-Signal Forward Current Transfer Ratio ($I_C = 4\ mAdc$, $V_{CE} = 10\ Vdc$, $f = 100\ MHz$)	h_{fe}	6.0	-	-

MD1132, F (SILICON)

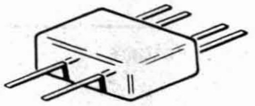
NPN silicon annular dual transistors for differential amplifiers and other applications requiring a matched pair with a high degree of parameter uniformity.

CASE 32C

MD1132

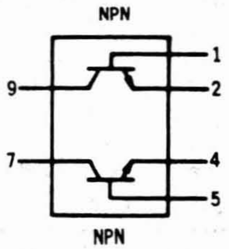


PINS 4 AND 8 OMITTED



CASE 33

MD1132F



Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	30		Vdc
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	50		mAdc
Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C Metal Can MD1132 Derating Factor Above 25°C	P_D	 300 1.7	 400 2.3	 mW mW/°C
Flat Package: MD1132F Derating Factor Above 25°C		250 1.5	350 2.0	mW mW/°C

ELECTRICAL CHARACTERISTICS (each side)

(T_A = 25°C unless otherwise noted)

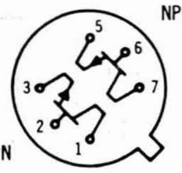
Characteristics	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 1 μAdc)	BV_{CBO}	30	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 3 mAdc)	BV_{CEO}	15	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc)	BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc) (V_{CB} = 15 Vdc, T_A = 150°C)	I_{CBO}	— —	.010 1.0	μAdc
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$	—	0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	—	1.0	Vdc
DC Forward Current Transfer Ratio (I_C = 1 mAdc, V_{CE} = 5 Vdc)	h_{FE}	50	—	—
DC Current Gain Ratio* (I_C = 1 mAdc, V_{CE} = 5 Vdc)	h_{FE1}/h_{FE2}*	0.9	1.0	—
Base Voltage Differential (I_C = 1 mAdc, V_{CE} = 5 Vdc)	$\|V_{BE1}-V_{BE2}\|$	—	5	mVdc
Base Voltage Differential Change (I_C = 1 mAdc, V_{CE} = 5 Vdc, T_A = -55 to +25°C) (I_C = 1 mAdc, V_{CE} = 5 Vdc, T_A = +25 to +125°C)	$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$	— —	10 10	μV/°C
Collector Output Capacitance (V_{CB} = 10 Vdc, f = 140 kHz) (V_{CB} = 0 Vdc, f = 140 kHz)	C_{ob}	— —	1.7 3.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, f = 140 kHz)	C_{ib}	—	2.0	pF
Small Signal Forward Current Transfer Ratio (I_C = 4 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	h_{fe}	6.0	—	—

*The lowest h_{FE} reading is taken as h_{FE1} for this ratio

MD1134 (SILICON)

NPN silicon annular dual transistor for high-speed switching applications.

CASE 32C



Pin Connections Bottom View
All Leads Electrically Isolated from Case
PINS 4 AND 8 OMITTED

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current - Peak*	I_C^*	500		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	500 2.9	600 3.4	mW mW/°C

* 10 μs Pulse.

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}^*	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	0.4 30	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C) (I_C = 100 mAdc, V_{CE} = 2.0 Vdc)	h_{FE}	50 20 20	- - -	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	-	0.25	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	0.70	0.85	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	500	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	4.0	pF
Input Capacitance (V_{BE} = 1.0 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	4.0	pF

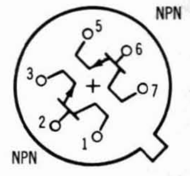
*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

MD2218, MD2218A (SILICON)
MD2219, MD2219A
MD2218F, MD2218AF
MD2219F, MD2219AF

Dual NPN silicon annular transistors designed for high-speed switching circuits, DC to VHF amplifier applications and complementary circuitry with the PNP MD2904 Series.

MD2218, A
MD2219, A

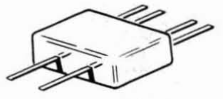
CASE 32 C



PINS 4 AND 8 OMITTED

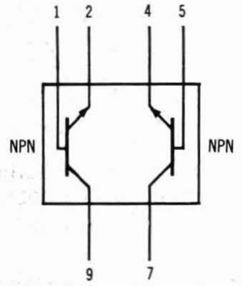
Pin Connections, Bottom View

All Leads Electrically Isolated from Case



MD2218F, AF
MD2219F, AF

CASE 33
(TO-89)



Pin Connections, Bottom View

Lead 1 identified by square impression or dot on underside of case.

All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	MD2218* MD2219*	MD2218A* MD2219A*	Unit
Collector-Emitter Voltage	V_{CEO}	30	40	Vdc
Collector-Base Voltage	V_{CB}	60	75	Vdc
Emitter-Base Voltage	V_{EB}	5	6	Vdc
Collector Current	I_C	600		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ $T_A = 25^\circ C$	P_D			
Metal Can		500	600	mW
Derate above 25°C		2.9	3.4	mW/°C
TO-89 Flat Package		250	350	mW
Derate above 25°C		1.5	2.0	mW/°C
Total Device Dissipation @ $T_C = 25^\circ C$	P_D			
Metal Can		1.2	2.0	Watts
Derate above 25°C		6.83	11.43	mW/°C

*Apply also to corresponding "F" (flat package) type unless otherwise noted.

MD2218, A, F, AF, MD2219, A, F, AF (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)
Characteristics apply also to corresponding flat-package type numbers.

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	MD2218, MD2219 MD2218A, MD2219A		BV_{CEO}*	30 40	— —	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	MD2218, MD2219 MD2218A, MD2219A		BV_{CBO}	60 75	— —	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	MD2218, MD2219 MD2218A, MD2219A		BV_{EBO}	5 6	— —	Vdc
Collector Cutoff Current			I_{CEX}			μAdc
(V_{CE} = 50 Vdc, $V_{EB(off)}$ = 3 Vdc)	MD2218, MD2219 MD2218A, MD2219A			— —	0.020 0.015	
(V_{CE} = 50 Vdc, $V_{EB(off)}$ = 3 Vdc, T_A = 150°C)	All Types			—	25	
Base Cutoff Current (V_{CE} = 50 Vdc, $V_{EB(off)}$ = 3 Vdc)			I_{BL}	—	0.030	μAdc
ON CHARACTERISTICS						
DC Current Gain*		1	h_{FE}*			—
(I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	MD2218, MD2218A MD2219, MD2219A			20 35	— —	
(I_C = 1 mAdc, V_{CE} = 10 Vdc)	MD2218, MD2218A MD2219, MD2219A			25 50	— —	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	MD2218, MD2218A MD2219, MD2219A			35 75	— —	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	MD2218, MD2218A MD2219, MD2219A			40 100	120 300	
(I_C = 150 mAdc, V_{CE} = 1 Vdc)	MD2218, MD2218A MD2219, MD2219A			20 50	— —	
(I_C = 300 mAdc, V_{CE} = 10 Vdc)	MD2218 MD2218A MC2219 MD2219A			20 25 30 40	— — — —	
Collector-Emitter Saturation Voltage*		2, 3, 4	$V_{CE(sat)}$*			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)	MD2218, MD2219 MD2218A, MD2219A			— —	0.4 0.3	
(I_C = 300 mAdc, I_B = 30 mAdc)	MD2218, MD2219 MD2218A, MD2219A			— —	1.2 0.9	
Base-Emitter Saturation Voltage*		3, 4	$V_{BE(sat)}$*			Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)	MD2218, MD2219 MD2218A, MD2219A			0.6 0.6	1.3 1.2	
(I_C = 300 mAdc, I_B = 30 mAdc)	MD2218, MD2219 MD2218A, MD2219A			— —	2.0 1.8	
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	MD2218 MD2218A, MD2219 MD2219A	16	f_T	200 250 300	— — —	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		17	C_{ob}	—	8	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	MD2218, MD2219 MD2218A, MD2219A	17	C_{ib}	— —	30 25	pF
Delay Time V_{CC} = 30 Vdc, $V_{EB(off)}$ = 0.5 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc	MD2218, MD2219 MD2218A, MD2219A	11, 14	t_d	— —	20 15	ns
Rise Time	MD2218, MD2219 MD2218A, MD2219A	11, 14	t_r	— —	40 30	ns
Storage Time V_{CC} = 30 Vdc, I_C = 150 mAdc, I_{B1} = $-I_{B2}$ = 15 mAdc	MD2218, MD2219 MD2218A, MD2219A	13, 15	t_s	— —	280 250	ns
Fall Time	MD2218, MD2219 MD2218A, MD2219A	13, 15	t_f	— —	70 60	ns

*Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2%

MD2218, A, F, AF, MD2219, A, F, AF (continued)

FIGURE 1 — NORMALIZED CURRENT GAIN CHARACTERISTICS

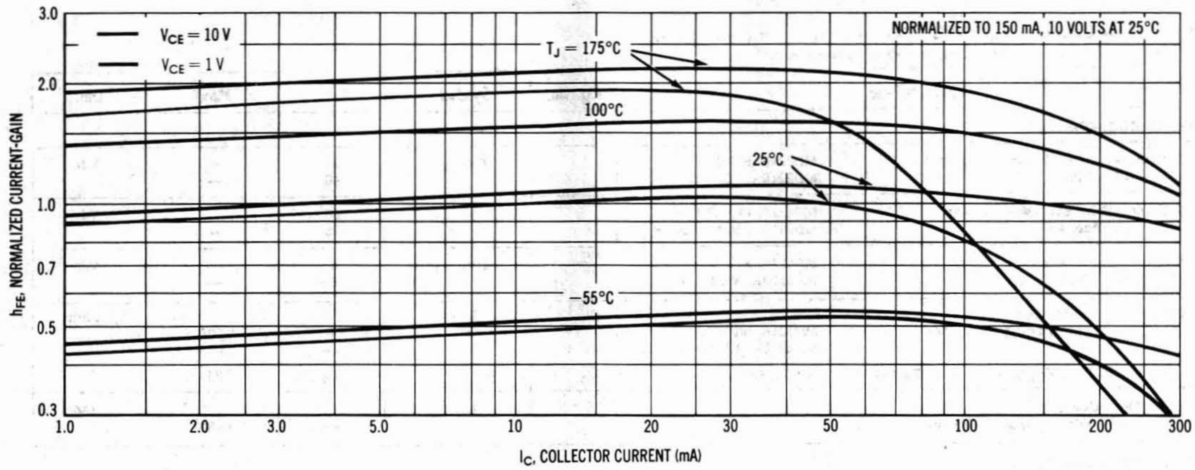
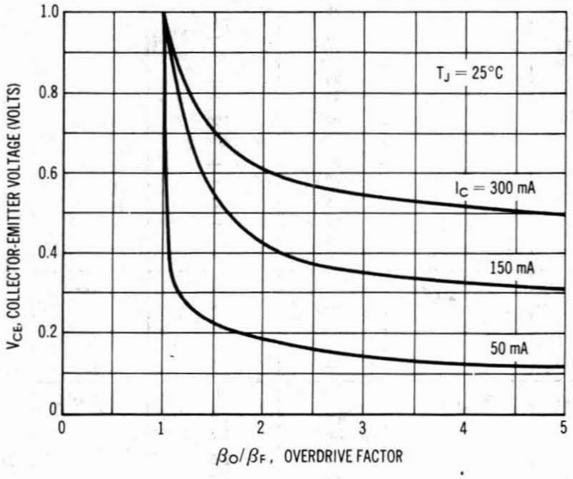


FIGURE 2 — COLLECTOR CHARACTERISTICS IN SATURATION REGION



This graph shows the effect of base current on collector current. β_o (current gain at the edge of saturation) is the current gain of the transistor at 1 volt, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit.

EXAMPLE: For type MD2219, estimate a base current (I_{BF}) to insure saturation at a temperature of 25°C and a collector current of 150 mA.

Observe that at $I_C = 150$ mA an overdrive factor of at least 2.5 is required to drive the transistor well into the saturation region. From Figure 1, it is seen that h_{FE} @ 1 volt is approximately 0.62 of h_{FE} @ 10 volts. Using the guaranteed minimum gain of 100 @ 150 mA and 10 V, $\beta_o = 62$ and substituting values in the overdrive equation, we find:

$$\frac{\beta_o}{\beta_F} = \frac{h_{FE} @ 1\,V}{I_C/I_{BF}} \qquad 2.5 = \frac{62}{150/I_{BF}} \qquad I_{BF} \approx 6\text{ mA}$$

FIGURE 3 — "ON" VOLTAGES

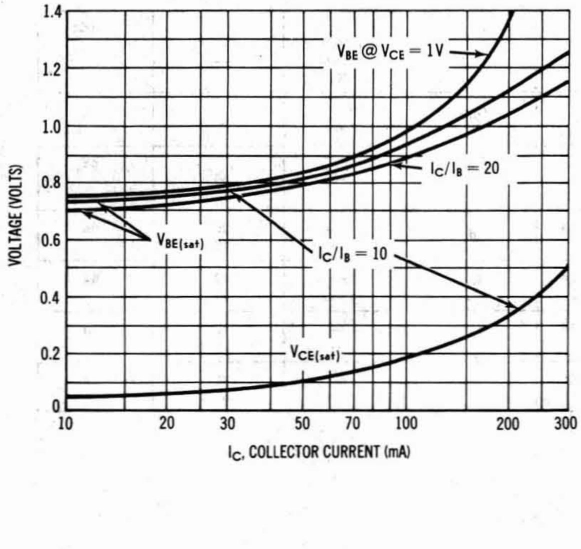
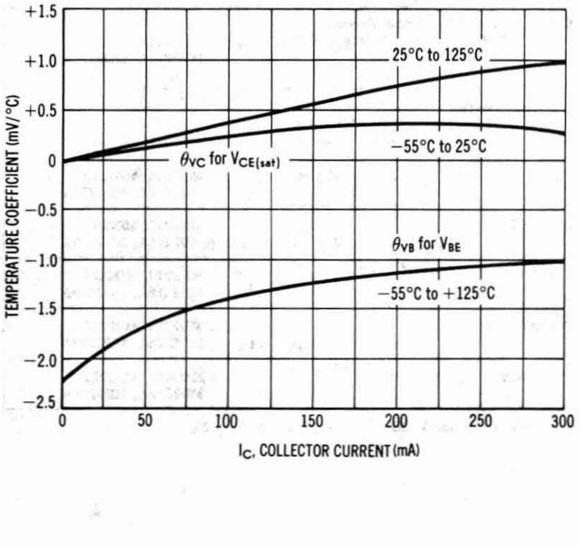


FIGURE 4 — TEMPERATURE COEFFICIENTS



SMALL SIGNAL CHARACTERISTICS

NOISE FIGURE

$V_{CE} = 10\ V,\ T_A = 25°C$

FIGURE 5 — FREQUENCY EFFECTS

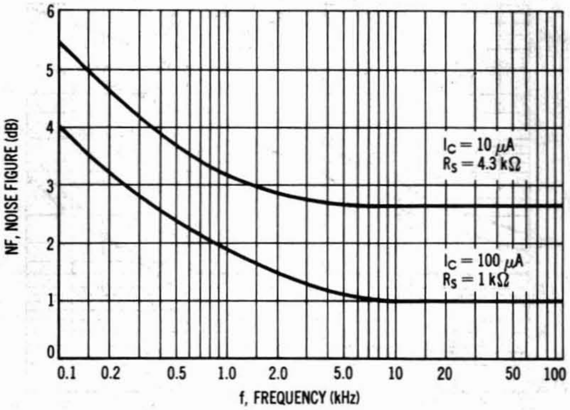
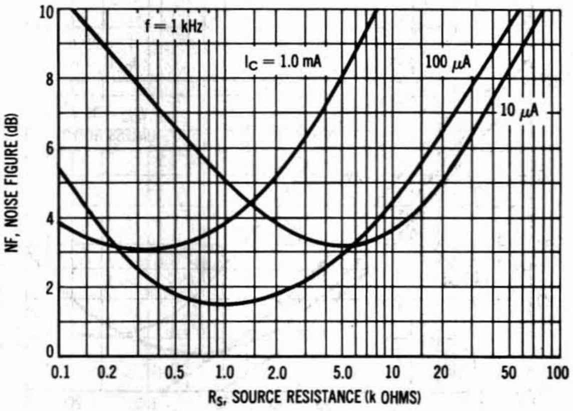


FIGURE 6 — SOURCE RESISTANCE EFFECTS



h PARAMETERS

$V_{CE} = 10\ V,\ f = 1\ kHz,\ T_A = 25°C$

FIGURE 7 — INPUT IMPEDANCE

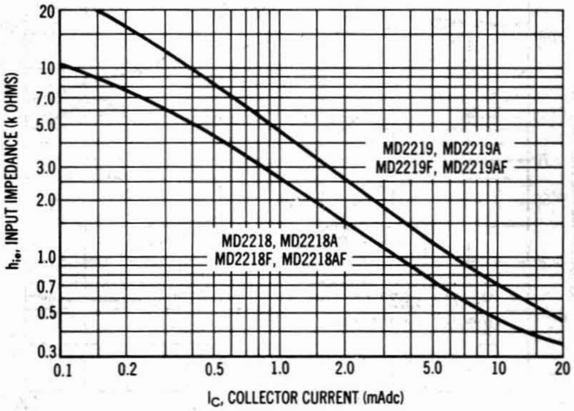


FIGURE 8 — VOLTAGE FEEDBACK RATIO

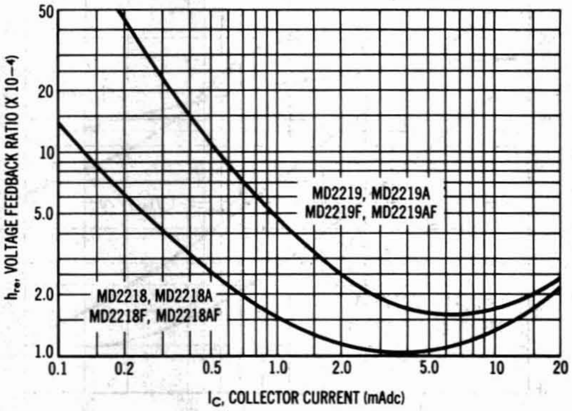


FIGURE 9 — CURRENT GAIN

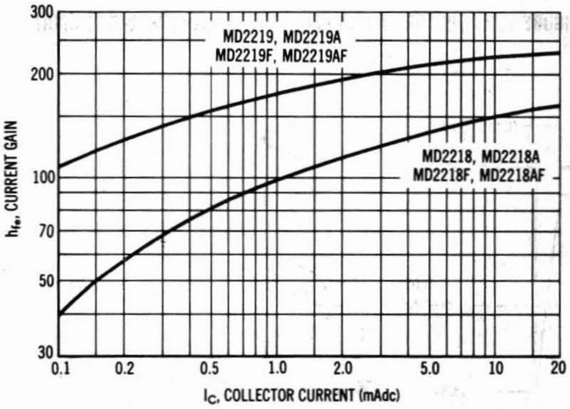
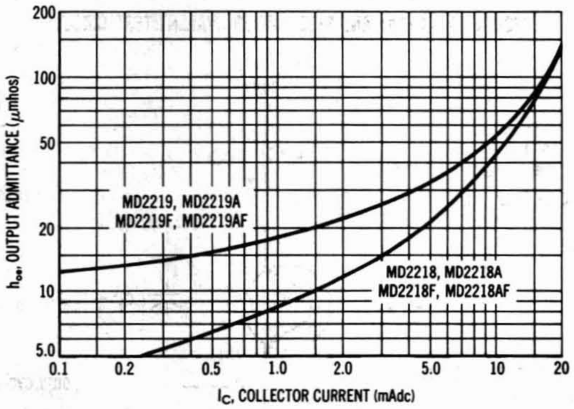


FIGURE 10 — OUTPUT ADMITTANCE



SWITCHING TIME CHARACTERISTICS

FIGURE 11 — TURN-ON TIME

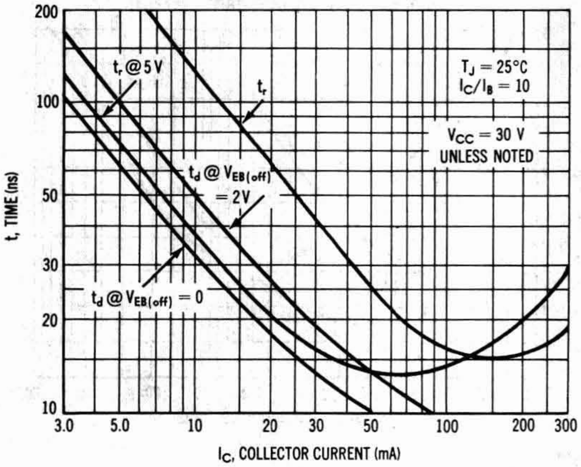


FIGURE 12 — CHARGE DATA

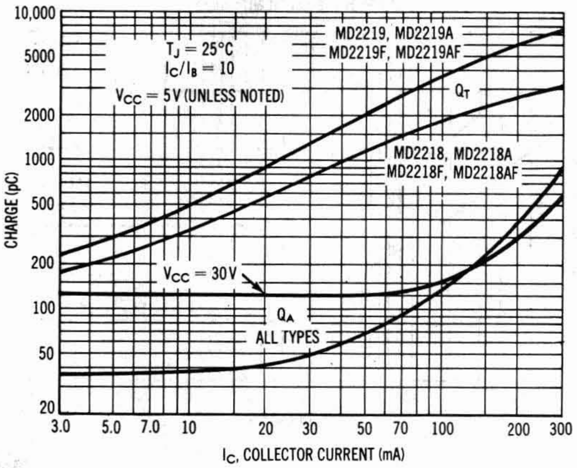


FIGURE 13 — TURN OFF BEHAVIOR

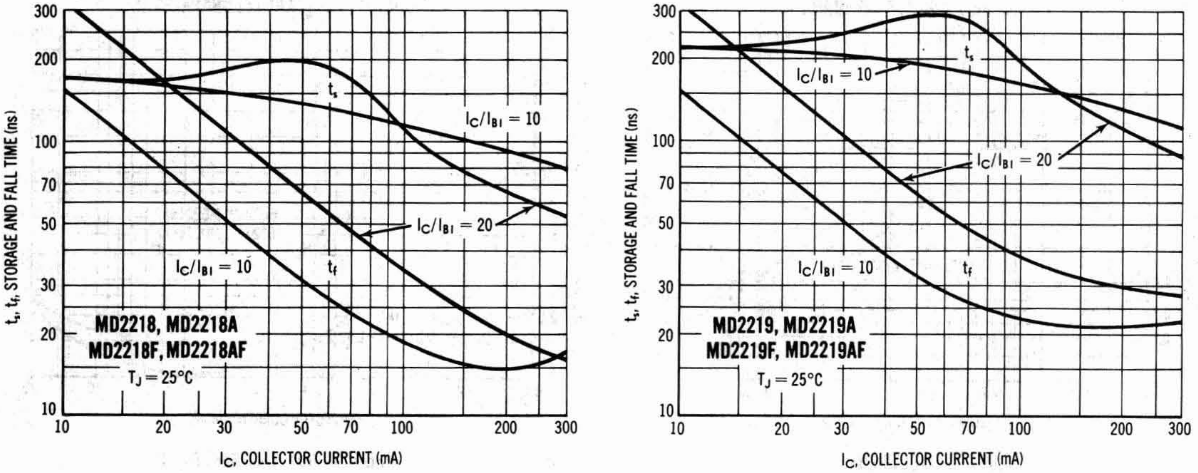


FIGURE 14 — DELAY AND RISE TIME EQUIVALENT TEST CIRCUIT

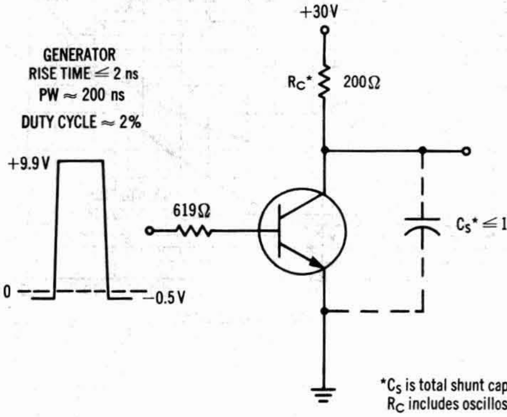
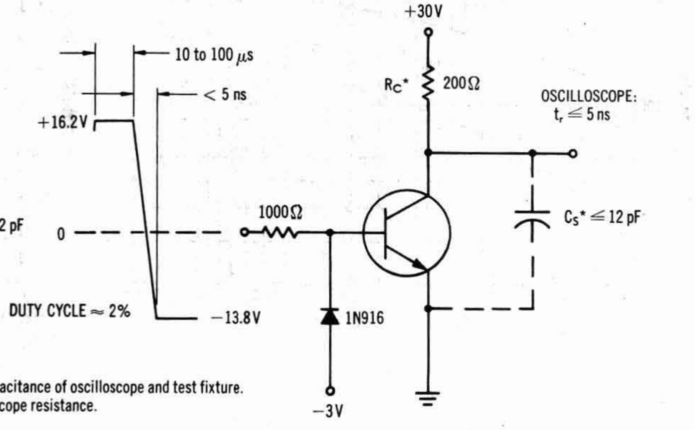

+30 V
GENERATOR
RISE TIME ≤ 2 ns
PW ≈ 200 ns
DUTY CYCLE ≈ 2%
R_C*
200 Ω
+9.9 V
619 Ω
C_S* ≤ 12 pF
0
−0.5 V

FIGURE 15 — STORAGE TIME AND FALL TIME EQUIVALENT TEST CIRCUIT


+30 V
10 to 100 μs
< 5 ns
+16.2 V
R_C*
200 Ω
OSCILLOSCOPE:
t_r ≤ 5 ns
1000 Ω
0
C_S* ≤ 12 pF
DUTY CYCLE ≈ 2%
−13.8 V
1N916
−3 V

*C_S is total shunt capacitance of oscilloscope and test fixture.
R_C includes oscilloscope resistance.

FIGURE 16 — CURRENT-GAIN — BANDWIDTH PRODUCT AND COLLECTOR-BASE TIME CONSTANT DATA

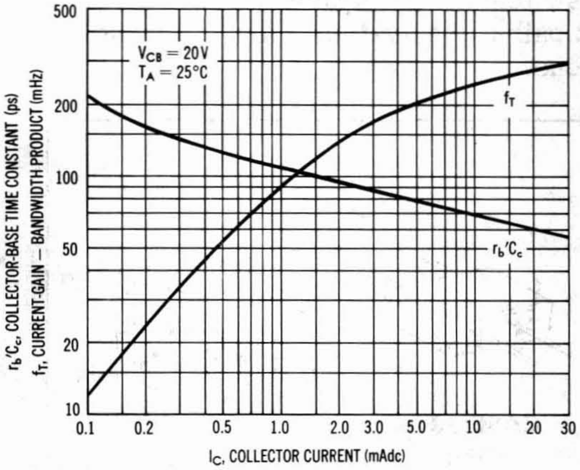


FIGURE 17 — CAPACITANCES

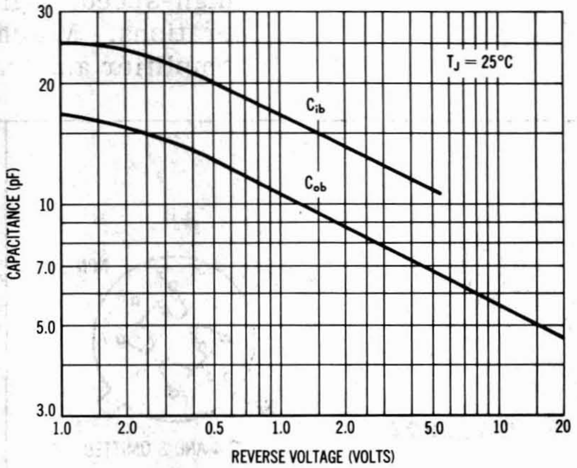


FIGURE 18 — ACTIVE REGION SAFE OPERATING AREAS

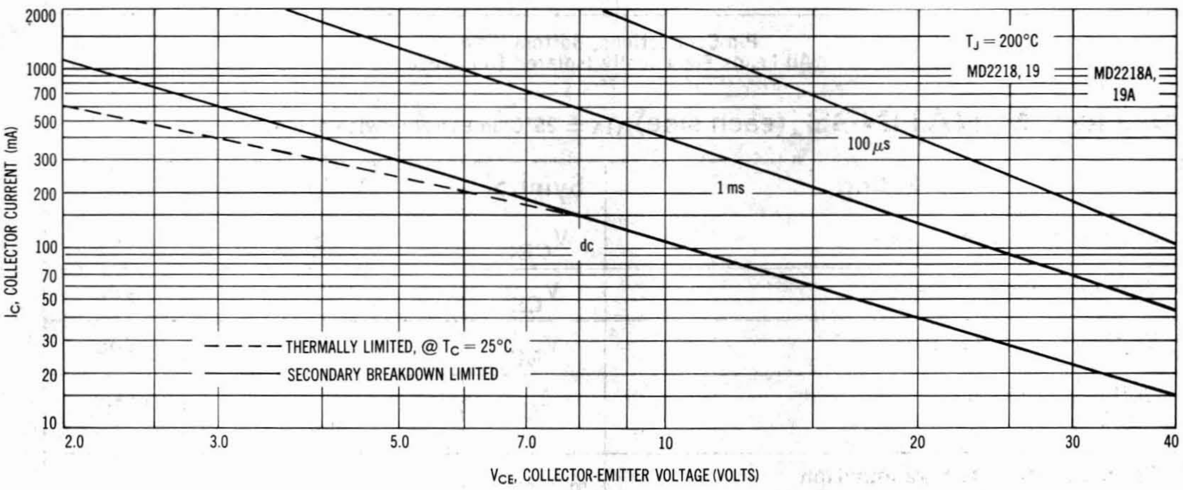
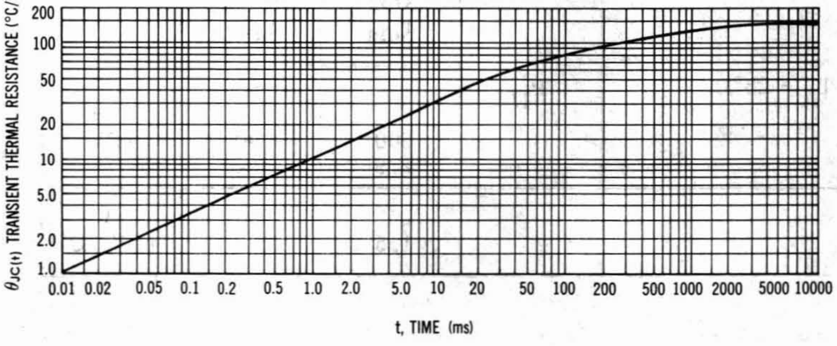


FIGURE 19 — TRANSIENT THERMAL RESISTANCE



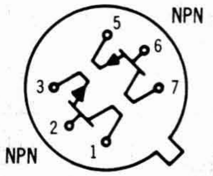
The above graph shows the maximum I_C-V_{CE} limits of the device both from the standpoint of thermal dissipation (at 25°C case temperature), and secondary breakdown. For case temperatures other than 25°C, the thermal dissipation curve must be modified in accordance with the derating factor in the Maximum Ratings table.

To avoid possible device failure, the collector load line must fall below the limits indicated by the applicable curve. Thus, for certain operating conditions the device is thermally limited, and for others it is limited by secondary breakdown.

For pulse applications, the maximum Ic-Vce product indicated by the dc thermal limits can be exceeded. Pulse thermal limits may be calculated by using the transient thermal resistance curve of Figure 19.

MD2369, F (SILICON)
MD2369A, F
MD2369B, F

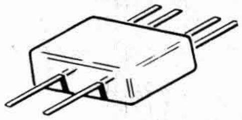
Dual NPN silicon annular transistors designed for high-speed, logic switching and space saving considerations. Matched pairs are available for differential amplifier applications.

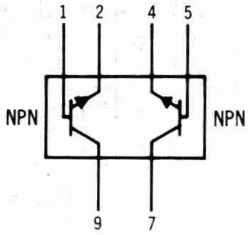


PINS 4 AND 8 OMITTED

CASE 32C

MD2369
MD2369A
MD2369B





CASE 33
(TO-89)

MD2369F
MD2369AF
MD2369BF

Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current (10 μs Pulse)	I_C	500		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D			
Metal Can Derate above 25°C		500 2.9	600 3.4	mW mW/°C
Flat Package Derate above 25°C		250 1.5	350 2.0	mW mW/°C

MD2369,F/MD2369A,F/MD2369B,F (continued)

ELECTRICAL CHARACTERISTICS (each side) ($T_A = 25°C$ unless otherwise noted)

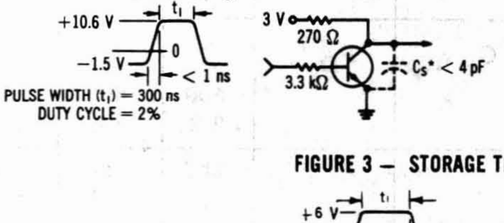
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage * (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	15	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	BV_{CBO}	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)	BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = +150°C)	I_{CBO}	— —	0.03 30	µAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)	h_{FE}*	40 20	140 —	—
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$	—	0.25	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	0.7	0.85	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	500	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	—	4	pF
Input Capacitance (V_{BE} = 1 Vdc, I_C = 0, f = 140 MHz)	C_{ib}	—	4	pF
Charge Storage Time Constant (Figure 3)	t_s	—	13	ns
Turn-On Time (Figure 1)	t_{on}	—	15	ns
Turn-Off Time (Figure 2)	t_{off}	—	20	ns
MATCHING CHARACTERISTICS				
DC Current Gain Ratio** (I_C = 3 mAdc, V_{CE} = 1 Vdc) MD2369A, MD2369AF MD2369B, MD2369BF	h_{FE1}/h_{FE2}	0.9 0.8	1.0 1.0	—
Base Voltage Differential (I_C = 3 mAdc, V_{CE} = 1 Vdc) MD2369A, MD2369AF MD2369B, MD2369BF	$\lvert V_{BE1} - V_{BE2}\rvert$	— —	5 10	mVdc
Base Voltage Differential Gradient (I_C = 3 mAdc, V_{CE} = 1 Vdc, T_A = -55 to +125°C) MD2369A, MD2369AF MD2369B, MD2369BF	$\frac{\Delta(V_{BE1} - V_{BE2})}{\Delta T_A}$	— —	10 20	µV/°C

*Pulse Test: Pulse Width = 300 µs; Duty Cycle = 2%

**The lowest h_{FE} reading is taken as h_{FE1} for this test.

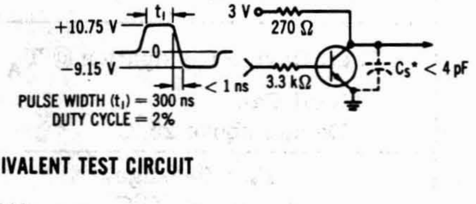
SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 — t_{on} CIRCUIT — 10 mA



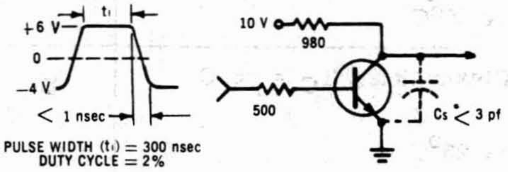
+10.6 V
t₁
0
−1.5 V
< 1 ns
3 V
270 Ω
3.3 kΩ
Cs* < 4 pF
PULSE WIDTH (t₁) = 300 ns
DUTY CYCLE = 2%

FIGURE 2 — t_{off} CIRCUIT — 10 mA



+10.75 V
t₁
-0-
−9.15 V
< 1 ns
3 V
270 Ω
3.3 kΩ
Cs* < 4 pF
PULSE WIDTH (t₁) = 300 ns
DUTY CYCLE = 2%

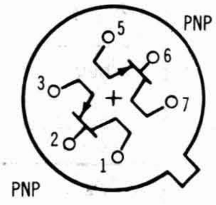
FIGURE 3 — STORAGE TIME EQUIVALENT TEST CIRCUIT



+6 V
t₁
0
−4 V
< 1 nsec
10 V
980
500
Cs* < 3 pf
PULSE WIDTH (t₁) = 300 nsec
DUTY CYCLE = 2%

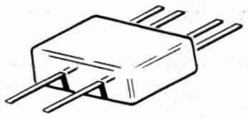
MD2904, A, F, AF (SILICON)
MD2905, A, F, AF

Dual PNP silicon annular transistors designed for high-speed switching circuits, DC to VHF amplifier applications and complementary circuitry with NPN MD2218 Seires.



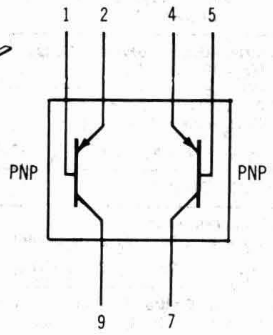
CASE 32 C
MD2904, A
MD2905, A

PINS 4 AND 8 OMITTED



(TO-89)

CASE 33
MD2904F, AF
MD2905F, AF



Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage MD2904, MD2904F, MD2905, MD2905F MD2904A, MD2904AF, MD2905A, MD2905AF	V_{CEO}	 40 60		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	600		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ $T_A = 25^{\circ}C$ Metal Can Derate above 25°C	P_D	 500 2.9	 600 3.4	 mW mW/°C
Flat Package Derate above 25°C		250 1.5	350 2.0	mW mW/°C
Total Device Dissipation @ $T_C = 25^{\circ}C$ Metal Can Derate above 25°C	P_D	 1.2 6.83	 2.0 11.43	 Watts mW/°C

MD2904, A, F, AF, MD2905, A, F, AF (continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristics apply also to corresponding flat-package type numbers.

Characteristic		Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	MD2904, MD2905		BV_{CEO}*	40	—	Vdc
	MD2904A, MD2905A			60	—	
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)			BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_B = 10 μAdc, I_C = 0)			BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CE} = 50 Vdc, $V_{BE(off)}$ = 3 Vdc)			I_{CEX}	—	0.020	μAdc
(V_{CE} = 50 Vdc, $V_{BE(off)}$ = 3 Vdc, T_A = 150°C)				—	30	
Base Cuttoff Current (V_{CE} = 50 Vdc, $V_{BE(off)}$ = 3 Vdc)			I_{BL}	—	0.030	μAdc
ON CHARACTERISTICS						
DC Current Gain* (I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	MD2904	1	h_{FE}*	20	—	—
	MD2905			35	—	
	MD2904A			40	—	
	MD2905A			75	—	
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	MD2904			25	—	
	MD2905			50	—	
	MD2904A			40	—	
	MD2905A			100	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	MD2904			35	—	
	MD2905			75	—	
	MD2904A			40	—	
	MD2905A			100	—	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)	MD2904, MD2904A			40	120	
	MD2905, MD2905A			100	300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)	MD2904			20	—	
	MD2905			30	—	
	MD2904A			40	—	
	MD2905A			50	—	
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)		2, 3, 4	$V_{CE(sat)}$*	—	0.4	Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)				—	1.6	
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)		3, 4	$V_{BE(sat)}$*	—	1.3	Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)				—	2.6	
DYNAMIC CHARACTERISTICS						
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		16	f_T	200	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		17	C_{ob}	—	8	pF
Input Capacitance (V_{BE} = 2 Vdc, I_C = 0, f = 100 kHz)		17	C_{ib}	—	30	pF
SWITCHING CHARACTERISTICS						
Turn-On-Time	V_{CC} = 30 Vdc, $V_{BE(off)}$ = 0.5 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc	11, 15	t_{on}	—	45	ns
Delay Time		11, 15	t_d	—	12	ns
Rise Time		11, 15	t_r	—	35	ns
Turn-Off-Time	V_{CC} = 30 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc	15	t_{off}	—	130	ns
Storage Time		13, 15	t_s	—	100	ns
Fall Time		14, 15	t_f	—	40	ns

*Pulse Test: Pulse Width ≤ 300 μs, duty cycle ≤ 2%

FIGURE 1 — DC CURRENT GAIN

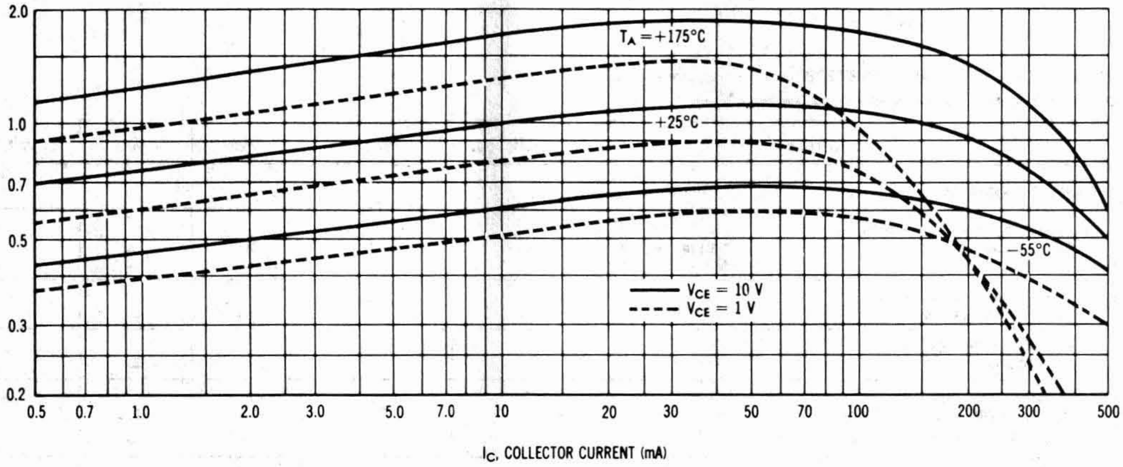
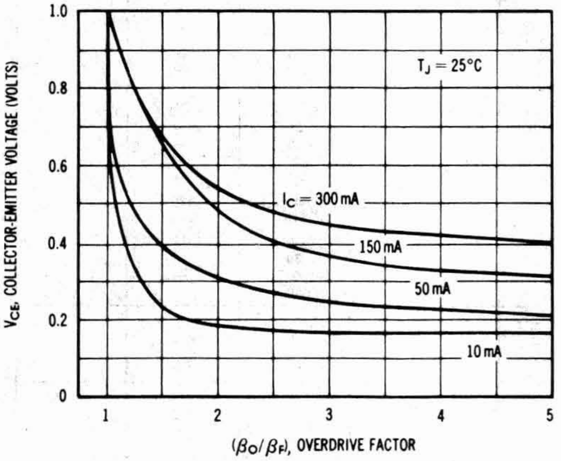


FIGURE 2 — NORMALIZED COLLECTOR SATURATION REGION



This graph shows the effect of base current on collector current. β_O (current gain at edge of saturation) is the current gain of the transistor at 1 volt, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit.

EXAMPLE: For type MD2905, estimate a base current (I_{BF}) to insure saturation at a temperature of 25°C and a collector current of 150 mA.

Observe that at I_C = 150 mA an overdrive factor of at least 3 is required to drive the transistor well into the saturation region. From Figure 1, it is seen that h_{FE} @ 1 volt is approximately 0.60 of h_{FE} @ 10 volts. Using the guaranteed minimum of 100 @ 150 mA and 10 V, $\beta_O = 60$ and substituting values in the overdrive equation, we find:

$$\frac{\beta_O}{\beta_F} = \frac{h_{FE} @ 1\ V}{I_C/I_{BF}} \qquad 3 = \frac{60}{150/I_{BF}} \qquad I_{BF} \approx 7.5\ \text{mA}$$

FIGURE 3 — "ON" VOLTAGES

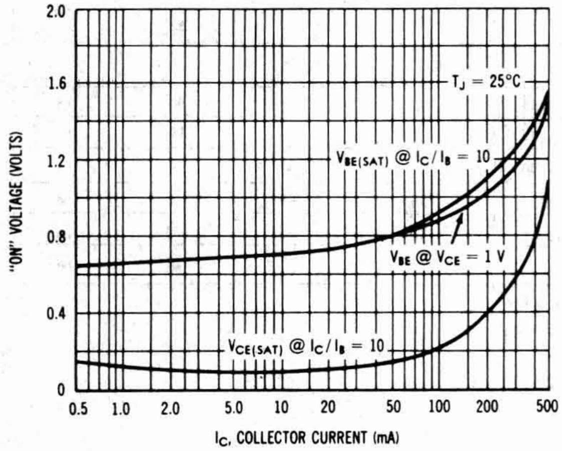
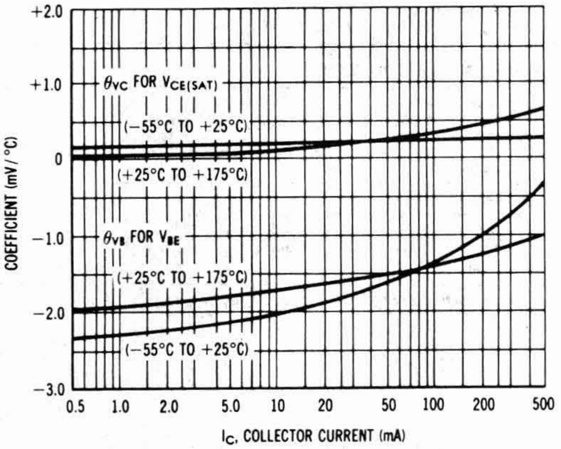


FIGURE 4 — TEMPERATURE COEFFICIENTS



SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE

$V_{CE} = 10\ V$, $T_A = 25°C$

FIGURE 5 — FREQUENCY EFFECTS

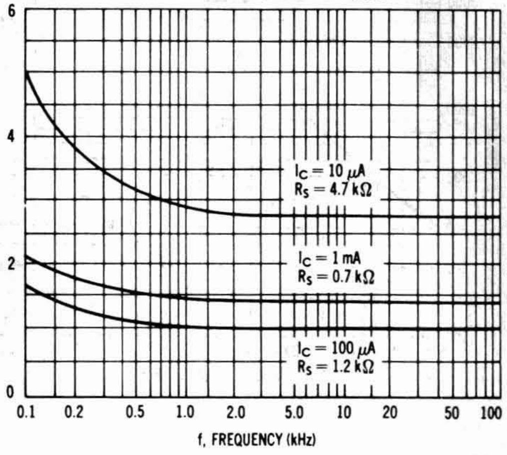
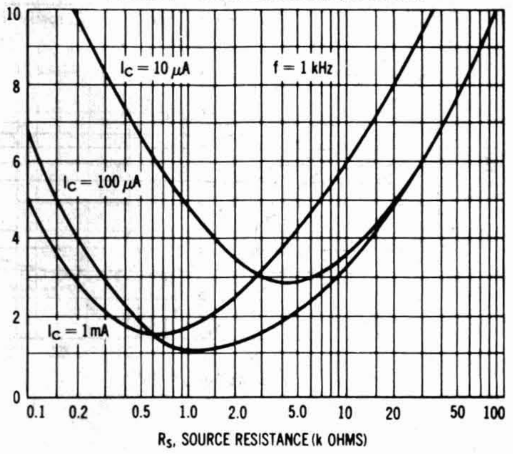


FIGURE 6 — SOURCE RESISTANCE EFFECTS



h PARAMETERS

$V_{CE} = 10\ V$, f = 1 kHz, $T_A = 25°C$

FIGURE 7 — INPUT IMPEDANCE

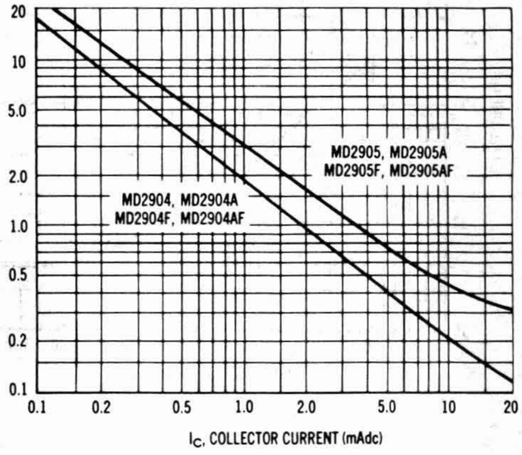


FIGURE 8 — VOLTAGE FEEDBACK RATIO

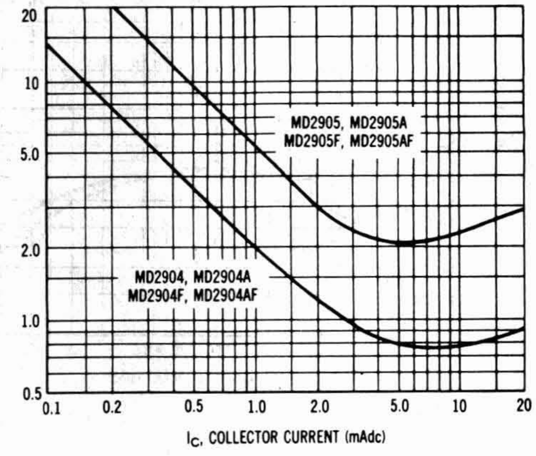


FIGURE 9 — CURRENT GAIN

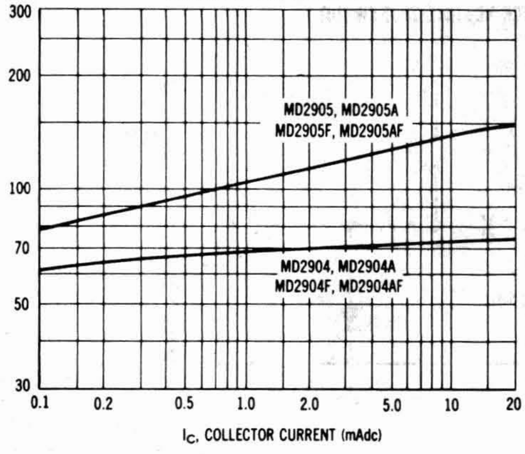


FIGURE 10 — OUTPUT ADMITTANCE

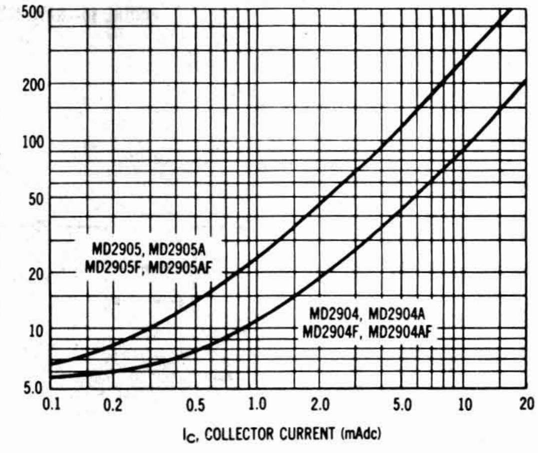


FIGURE 11 — TURN ON TIME

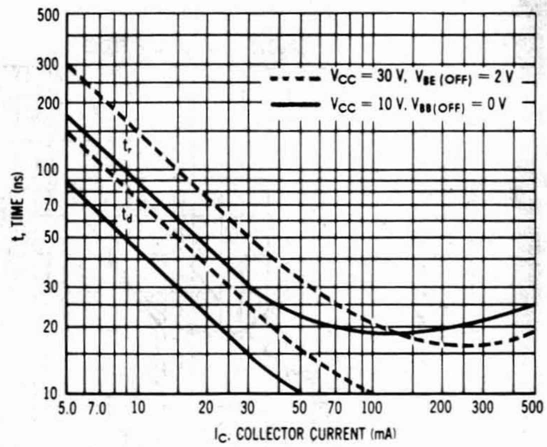


FIGURE 12 — CHARGE DATA

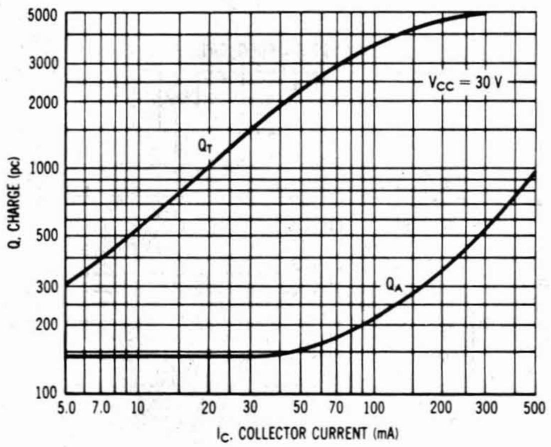


FIGURE 13 — STORAGE TIME

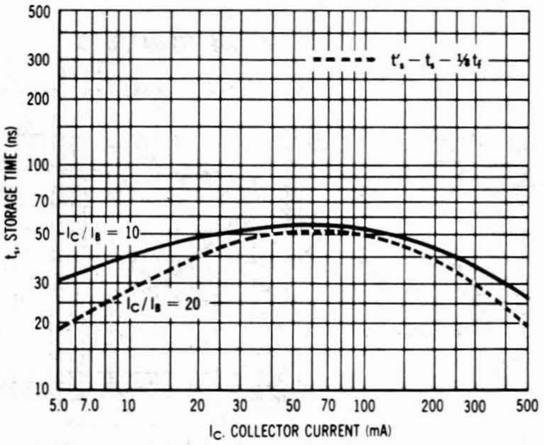


FIGURE 14 — FALL TIME

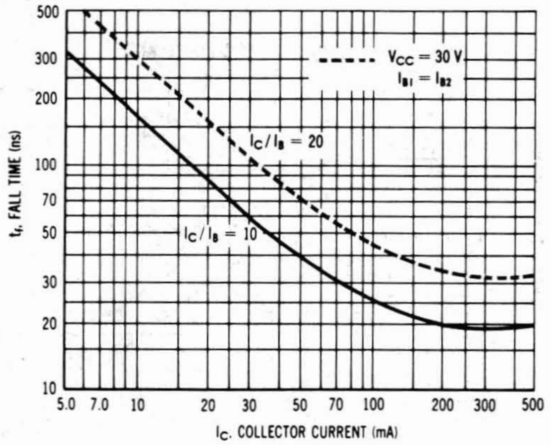


FIGURE 15 – SATURATED SWITCHING TIME TEST CIRCUIT

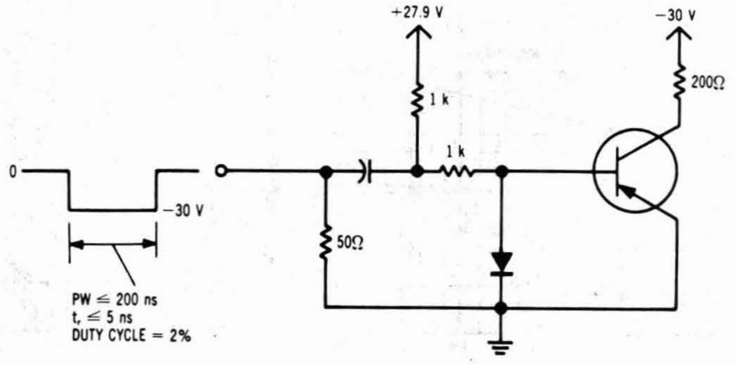

+27.9 V
−30 V
1 k
200Ω
1 k
0
−30 V
50Ω
PW ≤ 200 ns
t_r ≤ 5 ns
DUTY CYCLE = 2%

FIGURE 16 — CURRENT-GAIN — BANDWIDTH PRODUCT

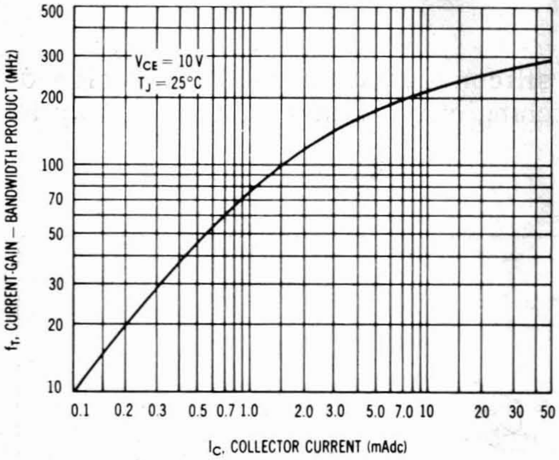


FIGURE 17 — CAPACITANCE

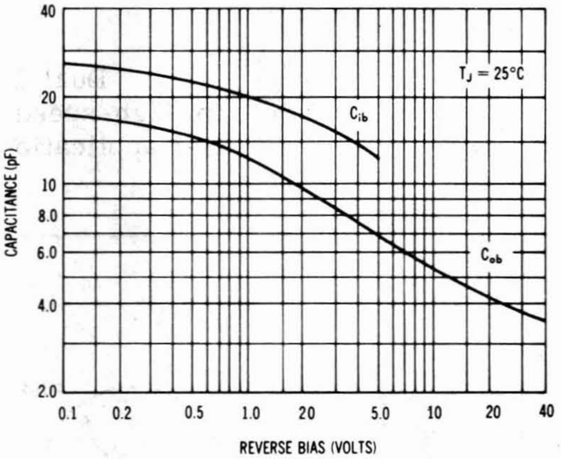


FIGURE 18 — ACTIVE REGION SAFE OPERATING AREAS

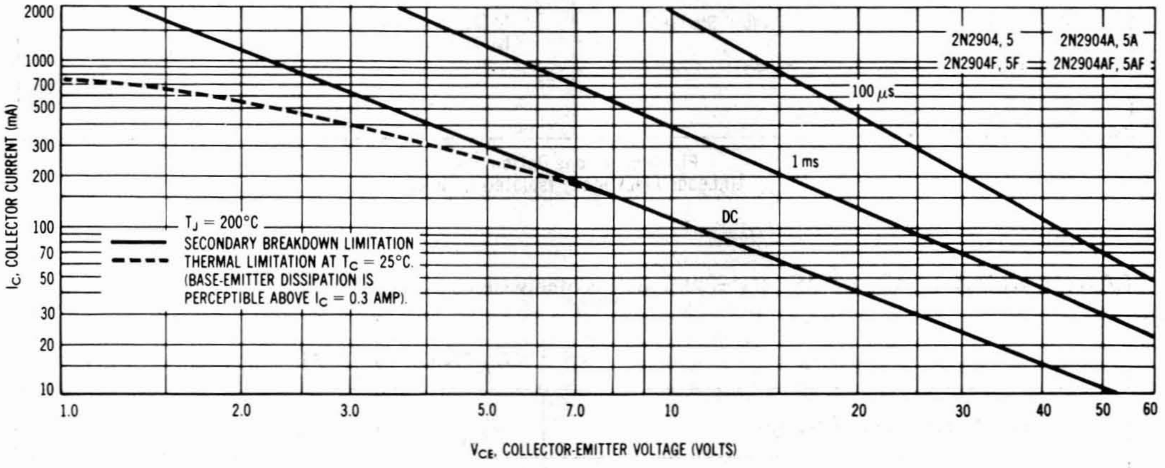
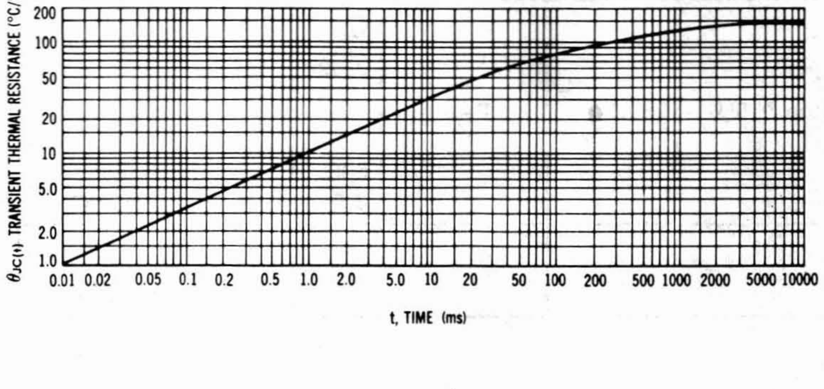


FIGURE 19 — TRANSIENT THERMAL RESISTANCE



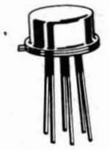
The above graph shows the maximum I_C-V_{CE} limits of the device both from the standpoint of thermal dissipation (at 25°C case temperature), and secondary breakdown. For case temperatures other than 25°C, the thermal dissipation curve must be modified in accordance with the derating factor in the Maximum Ratings table.

To avoid possible device failure, the collector load line must fall below the limits indicated by the applicable curve. Thus, for certain operating conditions the device is thermally limited, and for others it is limited by secondary breakdown.

For pulse applications, the maximum I_C-V_{CE} product indicated by the dc thermal limits can be exceeded. Pulse thermal limits may be calculated by using the transient thermal resistance curve of Figure 19.

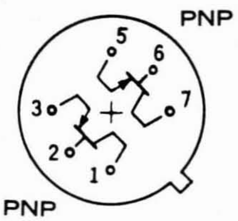
MD3133, F (SILICON)
MD3134, F

Dual PNP silicon annular transistors designed for high-speed switching circuits and DC to VHF amplifier applications.

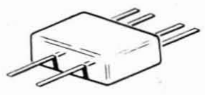


CASE 32C

MD3133
MD3134

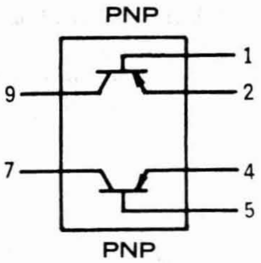


PINS 4 AND 8 OMITTED



CASE 33
(TO-89)

MD3133F
MD3134F



Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	35		Vdc
Collector-Base Voltage	V_{CB}	50		Vdc
Emitter-Base Voltage	V_{EB}	4		Vdc
Collector Current	I_C	600		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to + 200		$^{\circ}C$
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D			
Metal Can Derate above 25°C		500 2.9	600 3.4	mW mW/°C
TO-89 Flat Package Derate above 25°C		250 1.5	350 2.0	mW mW/°C

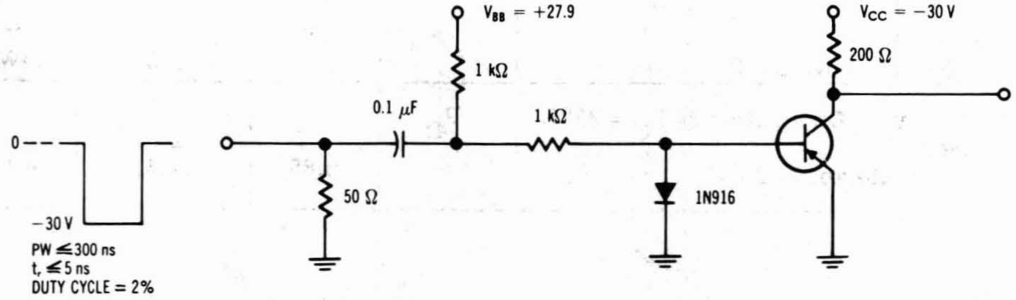
MD3133, F and MD3134, F (Continued)

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	35	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	50	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4	—	Vdc
Collector-Cutoff Current (V_{CE} = 30 Vdc, $V_{EB(off)}$ = 0.5 Vdc)	I_{CEX}	—	0.1	μAdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0) (V_{CB} = 30 Vdc, I_E = 20, T_A = 150°C)	I_{CBO}	— —	0.05 30	μAdc
Base Cutoff Current (V_{CE} = 30 Vdc, $V_{EB(off)}$ = 0.5 Vdc)	I_{BL}	—	0.1	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 1 mAdc, V_{CE} = 10 Vdc) MD3133, MD3133F MD3134, MD3134F (I_C = 150 mAdc, V_{CE} = 10 Vdc) MD3133, MD3133F MD3134, MD3134F	h_{FE}*	25 50 40 100	— — 120 300	—
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$*	—	0.6	Vdc
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$*	—	1.5	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	200	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	10	pF
Input Capacitance (V_{BE} = 2 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	40	pF
Turn-On Time, Figure 1 (V_{CC} = 30 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc,	t_{on}	—	75	ns
Turn-Off Time, Figure 1 (V_{CC} = 30 Vdc, I_C = 150 mAdc I_{B1} = I_{B2} = 15 mAdc)	t_{off}	—	150	ns

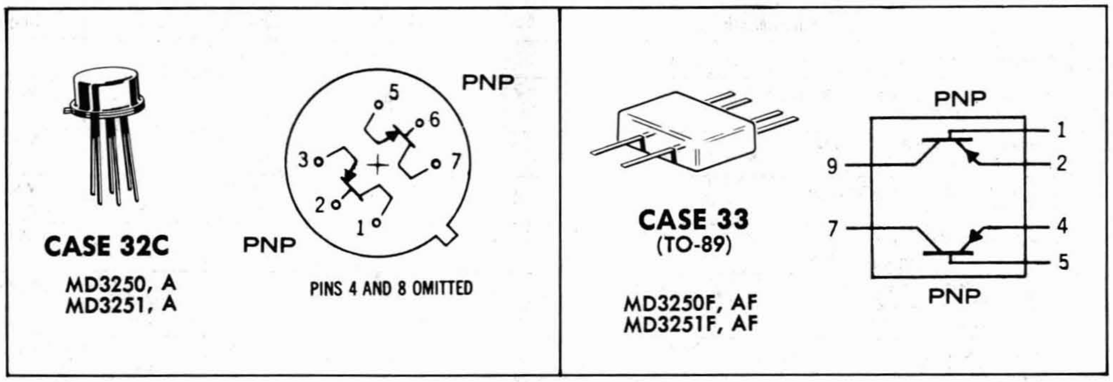
*Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2%

FIGURE 1 — TURN-ON AND TURN-OFF TIME TEST CIRCUIT



MD3250, A, F, AF (SILICON)
MD3251, A, F, AF

Dual PNP silicon annular transistors, especially designed for low-level, differential amplifier applications.


CASE 32C
MD3250, A
MD3251, A
PNP
PNP
5
6
7
3
2
1
PINS 4 AND 8 OMITTED
CASE 33
(TO-89)
MD3250F, AF
MD3251F, AF
PNP
PNP
1
2
9
7
4
5

Pin Connections Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (each side) ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	50		Vdc
Collector-Emitter Voltage	V_{CEO}	40		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
DC Collector Current	I_C	50		mAdc
Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ $T_A = 25°C$	P_D			
Metal Can		500	600	mW
Derate above 25°C		2.9	3.4	mW/°C
Flat Pack		250	350	mW
Derate above 25°C		1.5	2.0	mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D			
Metal Can		1.2	2.0	mW
Derate above 25°C		6.85	11.42	mW/°C

MD3250, A, F, AF and MD3251, A, F, AF (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit

OFF CHARACTERISTICS

Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	50	—	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	40		—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5	—	—	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)		I_{CBO}	 — —	 — —	 0.01 10	μAdc
Emitter Cutoff Current (V_{EB} = 3 Vdc, I_C = 0)		I_{EBO}	—	—	20	nAdc

ON CHARACTERISTICS

DC Forward Current Transfer Ratio*		h_{FE}*				—
(I_C = 10 μAdc, V_{CE} = 5 Vdc)	MD3250, MD3250A MD3251, MD3251A		25 50	— —	— —	
(I_C = 100 μAdc, V_{CE} = 5 Vdc)	MD3250, MD3250A MD3251, MD3251A		50 100	— —	150 300	
(I_C = 100 μAdc, V_{CE} = 5 Vdc, T_A = -55°C)	MD3250, MD3250A MD3251, MD3251A		25 50	— —	— —	
(I_C = 1 mAdc, V_{CE} = 5 Vdc)	MD3250, MD3250A MD3251, MD3251A		50 100	— —	150 300	
(I_C = 10 mAdc, V_{CE} = 5 Vdc)	MD3250, MD3250A MD3251, MD3251A		50 100	— —	— —	
(I_C = 50 mAdc, V_{CE} = 5 Vdc)	MD3250, MD3250A MD3251, MD3251A		15 30	— —	— —	
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc)		$V_{CE(sat)}$*	 — —	 — —	 0.25 0.50	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5 mAdc)		$V_{BE(sat)}$*	 0.6 —	 — —	 0.9 1.2	Vdc

SMALL SIGNAL CHARACTERISTICS

Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	MD3250, MD3250A MD3251, MD3251A	f_T	200 250	— —	— —	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	—	6	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	—	8	pF
Small Signal Current Gain (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	MD3250, MD3250A MD3251, MD3251A	h_{fe}	50 100	— —	200 400	—
Voltage Feedback Ratio (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	MD3250, MD3250A MD3251, MD3251A	h_{re}	— —	— —	10 20	$X10^{-4}$
Input Impedance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	MD3250, MD3250A MD3251, MD3251A	h_{ie}	1 2	— —	6 12	kohms
Output Admittance (I_C = 1.0 mA, V_{CE} = 10 V, f = 1 kHz)	MD3250, MD3250A MD3251, MD3251A	h_{oe}	4 10	— —	40 60	μmhos
Wide Band Noise Figure (I_C = 100 μA, V_{CE} = 10 V, R_g = 3 kohm, Noise Bandwidth 10 cps to 15.7 kHz)	MD3250, MD3250A MD3251, MD3251A	NF	— —	— —	4 3	dB

MATCHING CHARACTERISTICS (Types MD3250A and MD3251A only)

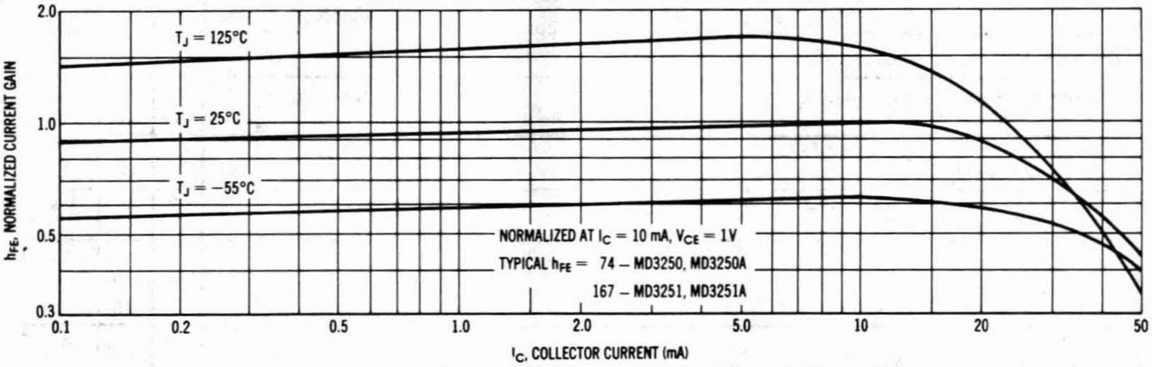
DC Current Gain Ratio** (I_C = 100 μAdc and 1 mAdc, V_{CE} = 5 Vdc)	MD3250A, MD3251A	h_{FE1}/h_{FE2}**	0.9	—	1.0	—
Base Voltage Differential (I_C = 10 μA, to 10 mA, V_{CE} = 5 Vdc) (I_C = 100 μAdc, V_{CE} = 5 Vdc)	 MD3250A, MD3251A MD3250A, MD3251A	$\lvert V_{BE1}-V_{BE2}\rvert$	 — —	 — —	 5 3	mVdc
Base Voltage Differential Change (I_C = 100 μAdc, V_{CE} = 5 Vdc, T_A = -55 to +25°C) (I_C = 100 μAdc, V_{CE} = 5 Vdc, T_A = 25 to 125°C)	 MD3250A, MD3251A MD3250A, MD3251A	$\frac{\Delta(V_{BE1}-V_{BE2})}{\Delta T_A}$	 — —	 — —	 10 10	mV/°C

*Pulse Test ≤ 300 μs, duty cycle ≤ 2%

** The lowest h_{FE} reading is taken as h_{FE1} for this ratio

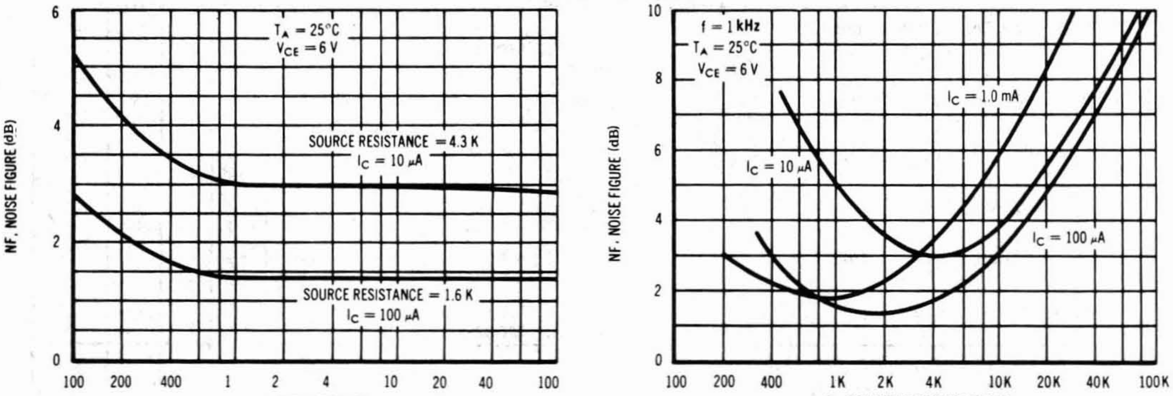
MD3250, A, F, AF and MD3251, A, F, AF (continued)

NORMALIZED CURRENT GAIN CHARACTERISTICS



AUDIO SMALL SIGNAL CHARACTERISTICS

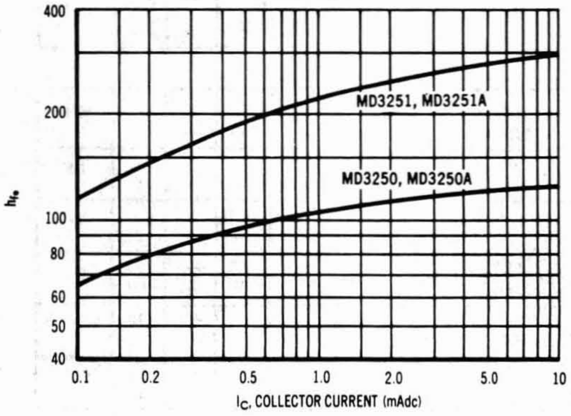
SPOT NOISE FIGURE



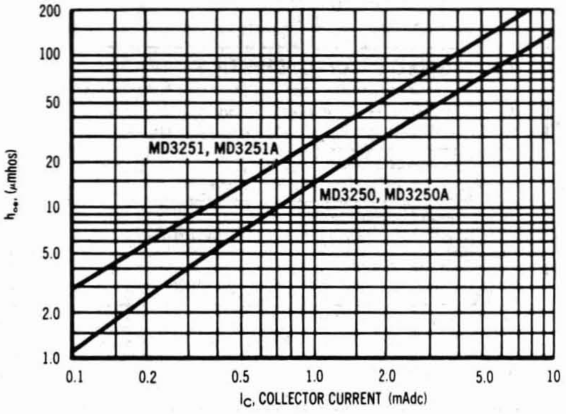
h PARAMETERS

$V_{CE} = 10$ Vdc, f = 1 kHz, $T_A = 25°C$

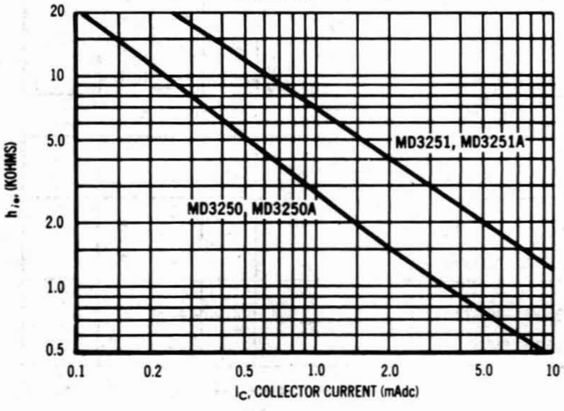
CURRENT GAIN



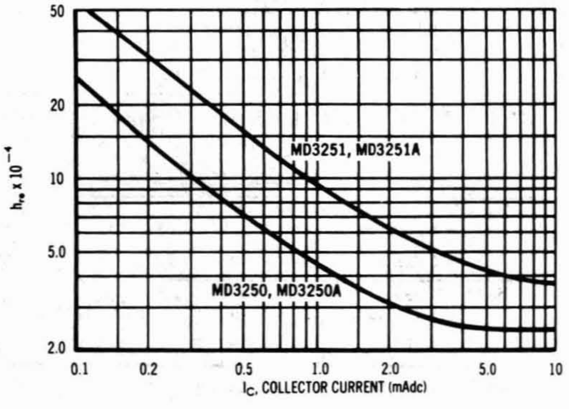
OUTPUT ADMITTANCE



INPUT IMPEDANCE

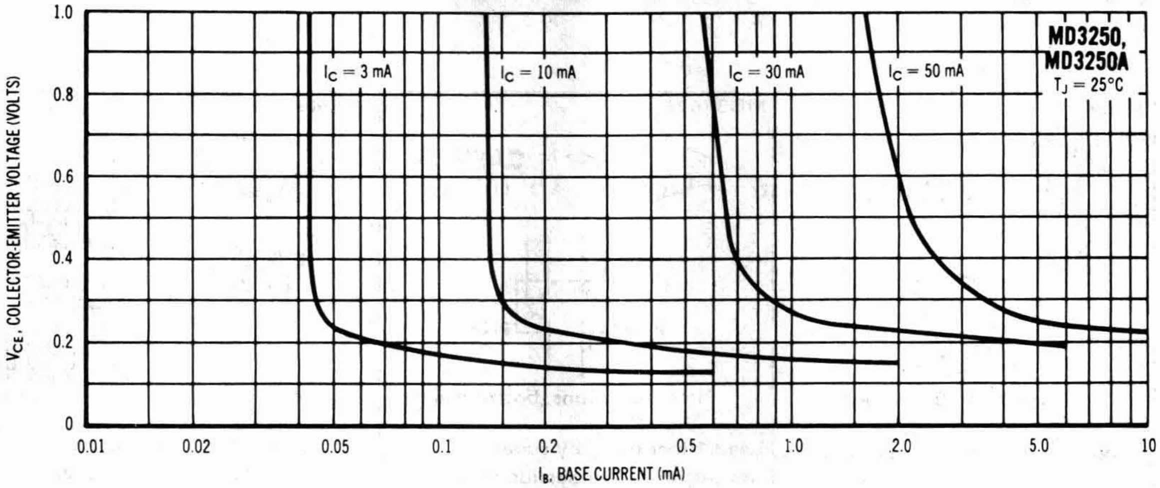


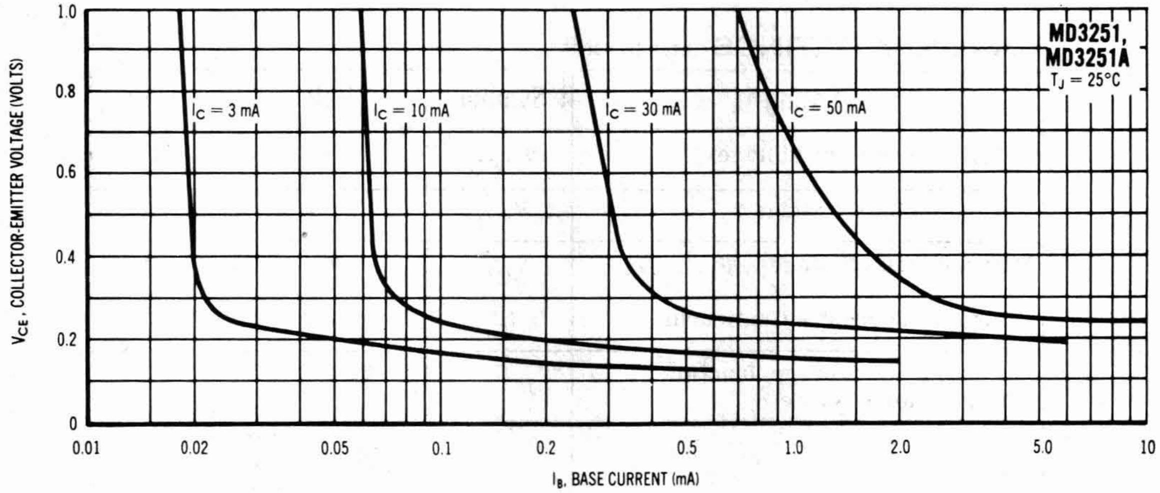
VOLTAGE FEEDBACK RATIO



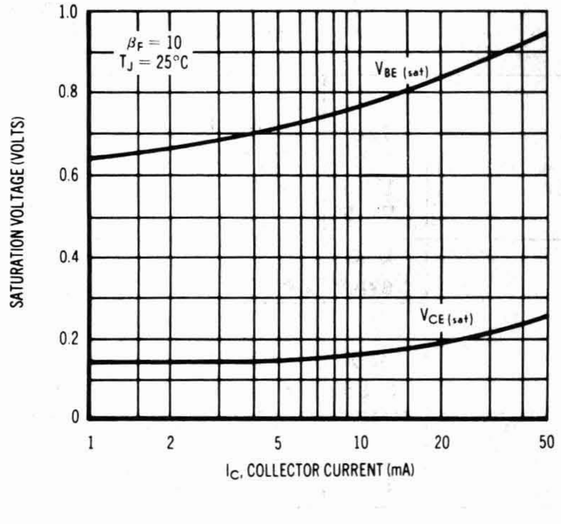
STATIC CHARACTERISTICS

COLLECTOR SATURATION REGION

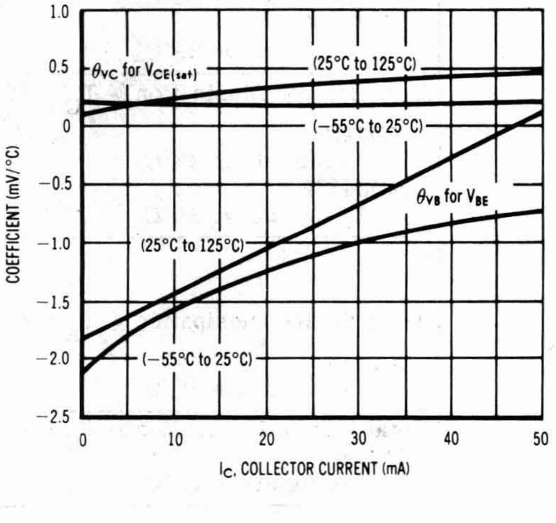




SATURATION VOLTAGES

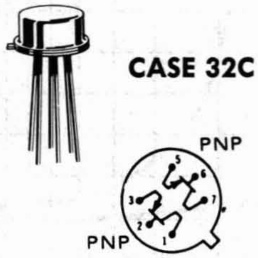
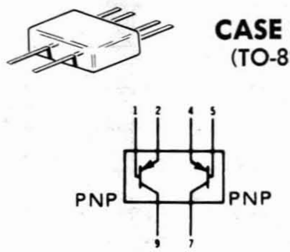
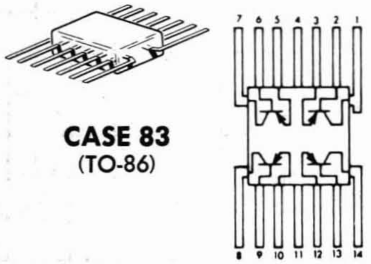


TEMPERATURE COEFFICIENTS



MD3467 (SILICON)
MD3467F
MQ3467

Dual and quad PNP silicon annular transistors designed for medium-current, high-speed switching and driver applications where space reduction is required.

MD3467	MD3467F	MQ3467
 **CASE 32C** Pins 4 and 8 omitted Pin connections, bottom view	 **CASE 33** (TO-89) Pin connections, bottom view Lead 1 identified by square impression on underside of case.	 7 6 5 4 3 2 1 8 9 10 11 12 13 14 **CASE 83** (TO-86) Lead 1 identified by color dot or by elbow on lead.

All leads isolated from case

MAXIMUM RATINGS (each transistor)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	40		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current - Continuous	I_C	1.0		Adc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ $T_A = 25°C$	P_D			
MD3467		500	600	mW
Derate above 25°C		2.86	3.43	mW/°C
MD3467F		250	350	mW
Derate above 25°C		1.43	2.0	mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D			
MD3467		1.0	2.0	Watts
Derate above 25°C		5.7	11.4	mW/°C
MD3467F		1.25	2.5	Watts
Derate above 25°C		7.15	14.3	mW/°C
		One Device	**Four Devices**	
Total Device Dissipation @ $T_A = 25°C$	P_D			mW
MQ3467		400	500	
Derate above 25°C		2.28	2.86	mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D			Watts
MQ3467		1.25	5.0	
Derate above 25°C		7.15	28.6	mW/°C

ELECTRICAL CHARACTERISTICS (each transistor) (T_A = 25°C unless otherwise noted)

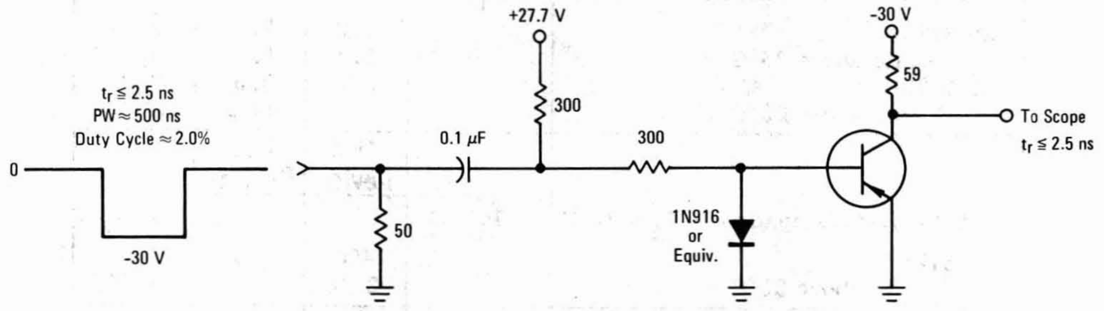
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	40		-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40		-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0		-	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)	I_{CBO}	-	30	100	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	30	100	nAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 500 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}*	20	40	-	-
Collector-Emitter Saturation Voltage* (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{CE(sat)}$*	-	0.35	0.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{BE(sat)}$*	-	0.9	1.2	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	150	250	-	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{cb}	-	11	20	pF
Collector-Emitter Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{eb}	-	60	80	pF

SWITCHING CHARACTERISTICS

Delay Time	(I_C = 500 mAdc, I_{B1} = 50 mAdc)	t_d	-	7.0	10	ns
Rise Time		t_r	-	15	30	ns
Storage Time	(I_C = 500 mAdc, I_{B1} = I_{B2} = 50 mAdc)	t_s		30	80	ns
Fall Time		t_f	-	16	30	ns

*Pulse Test: Pulse Width ≈ 300 μs, Duty Cycle ≈ 2.0%

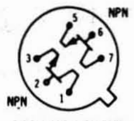
FIGURE 1 – SWITCHING TIMES TEST CIRCUIT



MD3725 (SILICON)
MD3725F
MQ3725

MD3725

CASE 32C

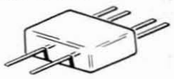


PINS 4 AND 8 OMITTED
Pin Connections, Bottom View

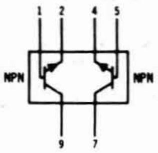
All leads isolated from case

Dual and quad NPN silicon annular transistors designed for medium-current, high-speed switching and driver applications where space reduction is required.

MD3725F



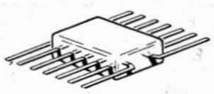
CASE 33
(TO-89)



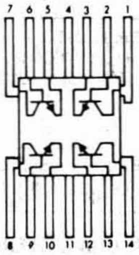
Pin Connections, Bottom View

Lead 1 identified by square impression or dot on underside of case
All leads isolated from case

MQ3725



CASE 83
(TO-86)



Lead 1 identified by color dot or by elbow on lead.
All leads electrically isolated from package.

MAXIMUM RATINGS (each transistor)

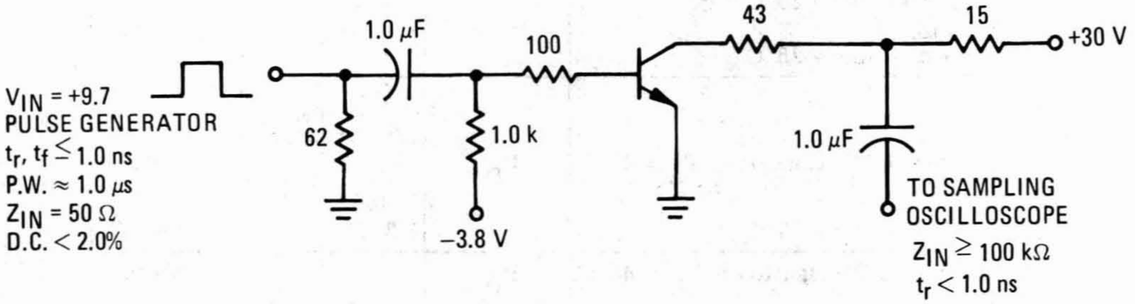
Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	40		Vdc
Collector-Base Voltage	V_{CB}	65		Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current - Continuous	I_C	1.0		Adc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ T_A = 25°C	P_D			
MD3725		500	600	mW
Derate above 25°C		2.9	3.4	mW/°C
MD3725F		250	350	mW
Derate above 25°C		1.5	2.0	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D			
MD3725		1.0	2.0	Watts
Derate above 25°C		5.7	11.4	mW/°C
MD3725F		1.25	2.5	Watts
Derate above 25°C		7.1	14.3	mW/°C
		One Device	**Four Devices**	
Total Device Dissipation @ T_A = 25°C	P_D			mW
MQ3725		400	500	
Derate above 25°C		2.28	2.86	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D			Watts
MQ3725		1.25	5.0	
Derate above 25°C		7.15	28.6	mW/°C

MD3725, MD3725F, MQ3725 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	65	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	6.0	-	Vdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0) (V_{CB} = 40 Vdc, I_E = 0, T_A = 100°C)	I_{CBO}	- -	1.7 120	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 100 mAdc, V_{CE} = 1.0 Vdc) (I_C = 500 mAdc, V_{CE} = 2.0 Vdc)	h_{FE}	50 30	150 -	-
Collector-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{CE(sat)}$	- -	0.26 0.52	Vdc
Base-Emitter Saturation Voltage (I_C = 100 mAdc, I_B = 10 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)	$V_{BE(sat)}$	- 0.85	0.86 1.2	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	250	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	10	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	55	pF
SWITCHING CHARACTERISTICS				
Turn-On Time (Figure 1) (I_C = 500 mAdc, I_{B1} = 50 mAdc)	t_{on}	-	45	ns
Turn-Off Time (Figure 1) (I_C = 500 mAdc, I_{B1} = I_{B2} = 50 mAdc)	t_{off}	-	75	ns

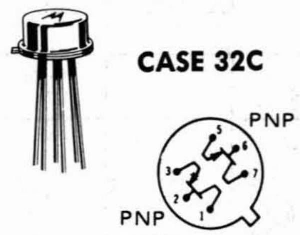
FIGURE 1


V_IN = +9.7
PULSE GENERATOR
t_r, t_f ≤ 1.0 ns
P.W. ≈ 1.0 μs
Z_IN = 50 Ω
D.C. < 2.0%
1.0 μF
62
1.0 k
100
−3.8 V
43
15
+30 V
1.0 μF
TO SAMPLING
OSCILLOSCOPE
Z_IN ≥ 100 kΩ
t_r < 1.0 ns

MD3762 (SILICON)
MD3762F
MQ3762

Dual and quad PNP silicon annular transistors designed for high-current, high-speed switching and driver applications where space reduction is required.

MD3762

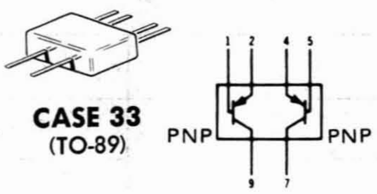


CASE 32C

Pins 4 and 8 omitted

Pin connections, bottom view

MD3762F

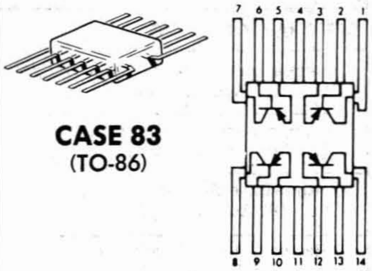


CASE 33
(TO-89)

Pin connections, bottom view

Lead 1 identified by square impression on underside of case.

MQ3762



CASE 83
(TO-86)

Lead 1 identified by color dot or by elbow on lead.

All leads isolated from case

MAXIMUM RATINGS (each transistor)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	40		Vdc
Collector-Base Voltage	V_{CB}	40		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current - Continuous	I_C	1.5		Adc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C	P_D			
MD3762		500	600	mW
Derate above 25°C		2.86	3.43	mW/°C
MD3762F		250	350	mW
Derate above 25°C		1.43	2.0	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D			
MD3762		1.0	2.0	Watts
Derate above 25°C		5.7	11.4	mW/°C
MD3762F		1.25	2.5	Watts
Derate above 25°C		7.15	14.3	mW/°C
		One Device	Four Devices	
Total Device Dissipation @ T_A = 25°C	P_D			mW
MQ3762		400	500	
Derate above 25°C		2.28	2.86	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D			Watts
MQ3762		1.25	5.0	
Derate above 25°C		7.15	28.6	mW/°C

ELECTRICAL CHARACTERISTICS (each transistor) (T_A = 25°C unless otherwise noted)

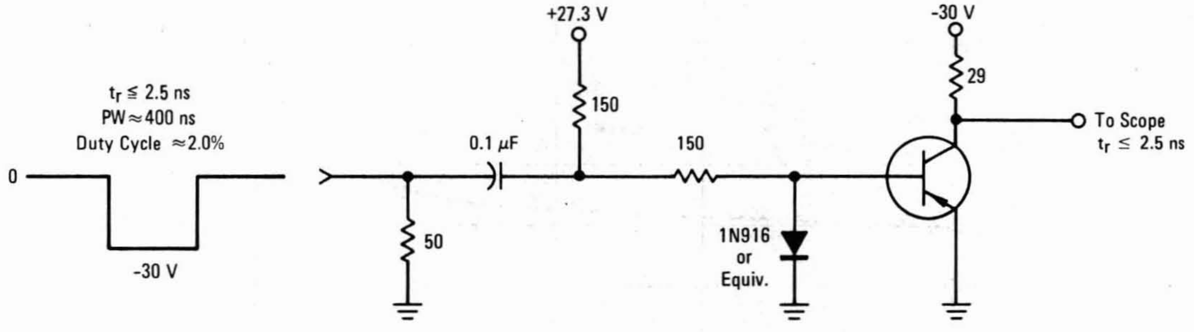
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	40		-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40		-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0		-	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)	I_{CBO}	-	30	100	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	30	100	nAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}*	20	40	-	-
Collector-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	$V_{CE(sat)}$*	-	0.7	1.0	Vdc
Base-Emitter Saturation Voltage* (I_C = 1.0 Adc, I_B = 0.1 Adc)	$V_{BE(sat)}$*	-	1.1	1.4	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	150	250	-	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{cb}	-	11	20	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{eb}	-	60	80	pF

SWITCHING CHARACTERISTICS

Characteristic		Symbol	Min	Typ	Max	Unit
Delay Time	(I_C = 1.0 Adc, I_{B1} = 0.1 Adc)	t_d	-	7.0	10	ns
Rise Time		t_r	-	15	30	ns
Storage Time	(I_C = 1.0 Adc, I_{B1} = I_{B2} = 0.1 Adc)	t_s	-	30	80	ns
Fall Time		t_f	-	16	30	ns

*Pulse test: Pulse Width ≈ 300 μs, Duty Cycle ≈ 2.0%

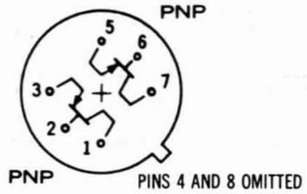
FIGURE 1 — SWITCHING TIMES TEST CIRCUIT



MD4957 (SILICON)

CASE 32C

Dual PNP silicon annular 450-MHz amplifier designed for high-gain, low-noise amplifier, oscillator, and mixer applications.



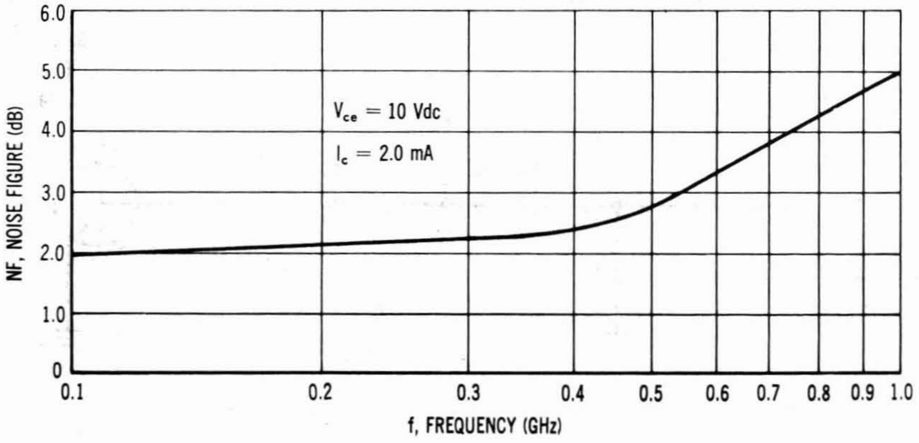
Pin Connections, Bottom View

All leads electrically isolated from case

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	30		Vdc
Collector-Base Voltage	V_{CB}	30		Vdc
Emitter-Base Voltage	V_{EB}	3.0		Vdc
Collector Current	I_C	30		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	**Both Sides**	
Total Device Dissipation @ T_A = 25°C	P_D	200	400	mW
Derate above 25°C		1.15	2.3	mW/°C

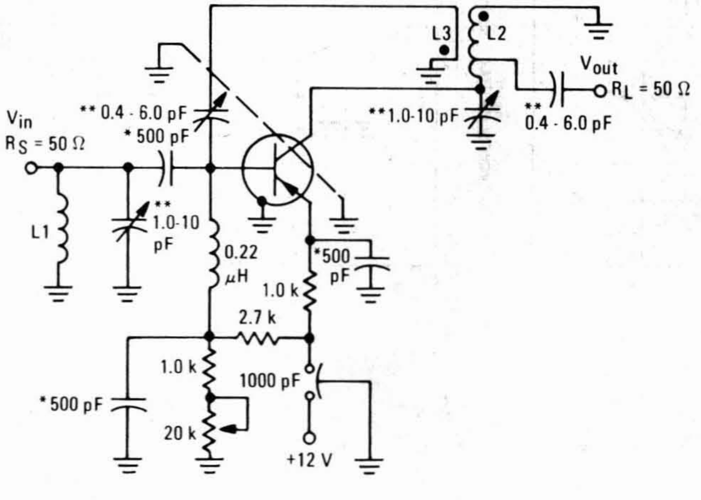
TYPICAL NOISE FIGURE vs. FREQUENCY



ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)	BV_{CEO}	30	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	30	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	-	-	0.1	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 2.0 mAdc, V_{CE} = 10 Vdc)	h_{FE}	20	-	150	-
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	1000	1500	-	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{cb}	-	0.4	0.8	pF
Small-Signal Current Gain (I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	20	-	200	-
Collector-Base Time Constant (I_E = 2.0 mAdc, V_{CB} = 10 Vdc, f = 63.6 MHz)	$r_b'C_c$	-	4.0	8.0	ps
Noise Figure (I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 450 MHz) Figure 1 (I_C = 2.0 mAdc, V_{CE} = 10 Vdc, R_S = 50 ohms, f = 1.0 GHz)	NF	- -	2.6 5.0	- -	dB
FUNCTIONAL TESTS					
Common-Emitter Amplifier Power Gain (V_{CE} = 10 Vdc, I_C = 2.0 mAdc, f = 450 MHz) (V_{CE} = 10 Vdc, I_C = 2.0 mAdc, R_S = 50 ohms, f = 1.0 GHz)	G_{pe}	- -	18 13	- -	dB

FIGURE 1 — NOISE FIGURE AND POWER GAIN TEST CIRCUIT



* Button type capacitors

** Variable air piston type capacitors

1. L1 - silver plated brass bar, 1.0 in. lg by 0.25 in od.
2. L2 - silver plated brass bar, 1.5 in. lg by 0.25 in od. Tap is 0.25 in. from collector
3. L3 - ½ turn of AWG No. 16 wire 0.25 in. from and parallel to L2.
4. The noise source is a hot-cold body (All type 70 or equivalent) with a test receiver (AIL type 136 or equivalent).

COMMON EMITTER Y PARAMETER VARIATIONS

Y PARAMETERS VS FREQUENCY

$V_{CE} = 10$ Vdc
$I_C = 2.0$ mA

FIGURE 2 — INPUT ADMITTANCE

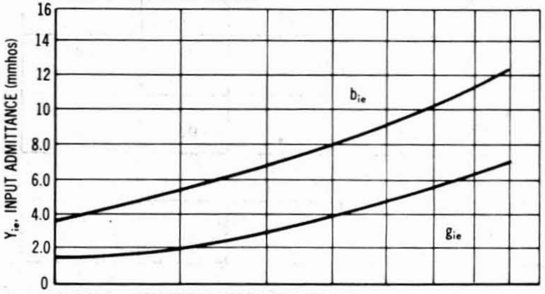


FIGURE 3 — FORWARD TRANSFER ADMITTANCE

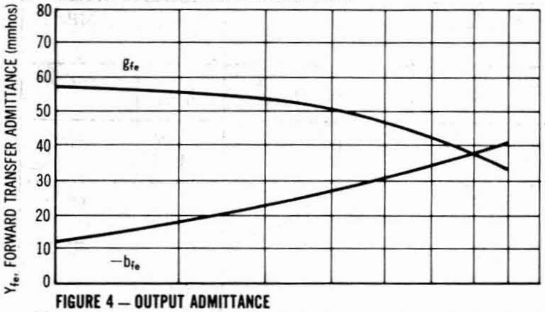


FIGURE 4 — OUTPUT ADMITTANCE

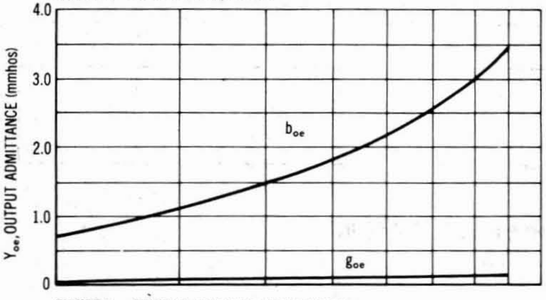
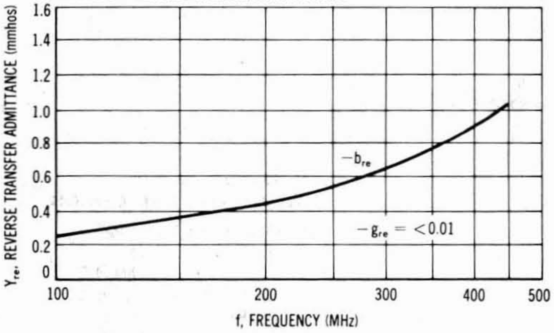


FIGURE 5 — REVERSE TRANSFER ADMITTANCE



Y PARAMETERS VS CURRENT

$V_{CE} = 10$ Vdc ——— $V_{CE} = 15$ Vdc — — —

f = 450 MHz

FIGURE 6 — INPUT ADMITTANCE

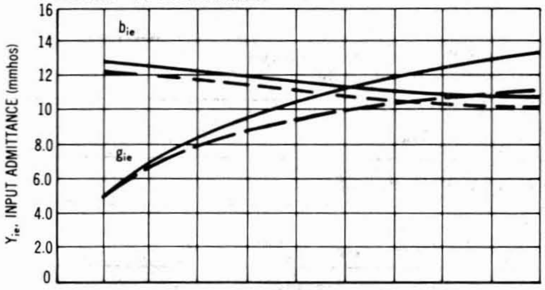


FIGURE 7 — FORWARD TRANSFER ADMITTANCE

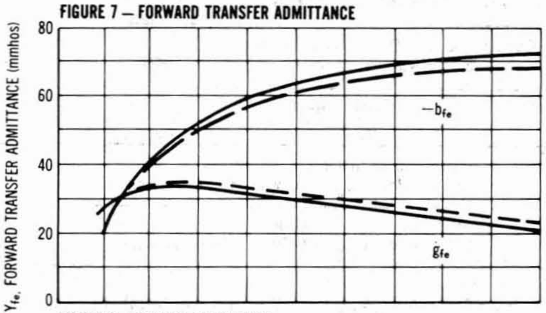


FIGURE 8 — OUTPUT ADMITTANCE

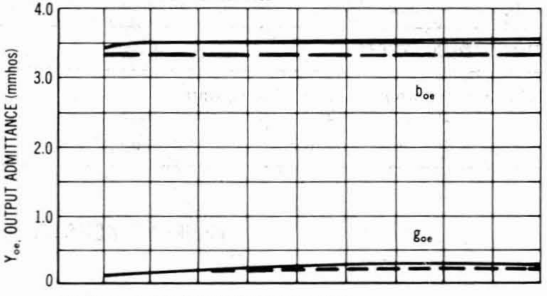
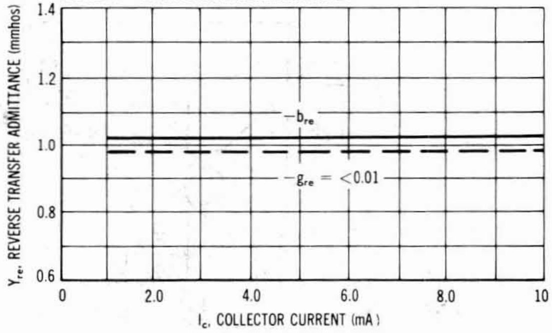


FIGURE 9 — REVERSE TRANSFER ADMITTANCE



COMMON BASE Y PARAMETER VARIATIONS

Y PARAMETERS versus FREQUENCY

$V_{CB} = 10$ Vdc

$I_C = 2.0$ mA

FIGURE 10 — INPUT ADMITTANCE

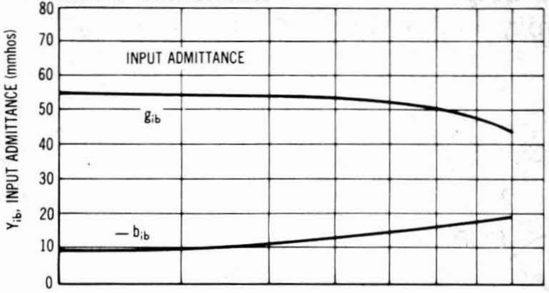


FIGURE 11 — FORWARD TRANSFER ADMITTANCE

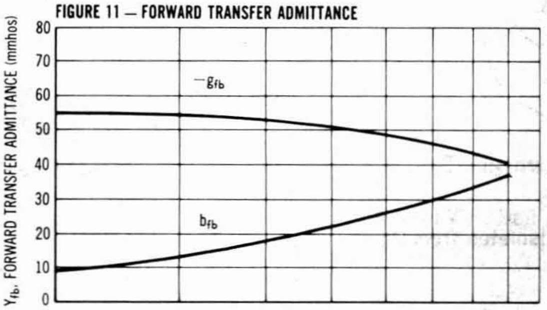


FIGURE 12 — OUTPUT ADMITTANCE

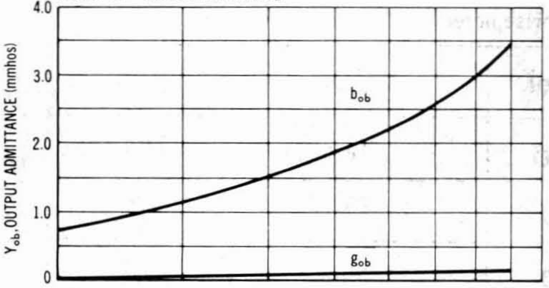
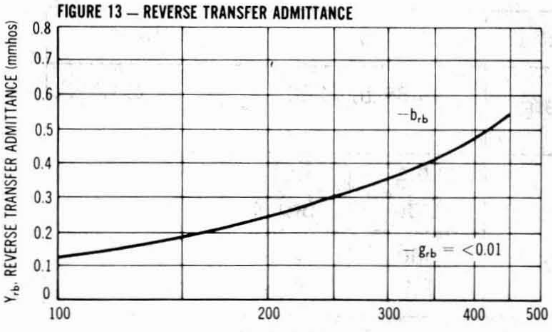


FIGURE 13 — REVERSE TRANSFER ADMITTANCE



Y PARAMETERS versus CURRENT

$V_{CB} = 10$ Vdc —— $V_{CB} = 15$ Vdc — — —

f = 450 MHz

FIGURE 14 — INPUT ADMITTANCE

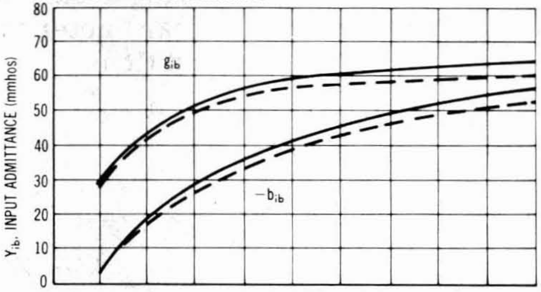


FIGURE 15 — FORWARD TRANSFER ADMITTANCE

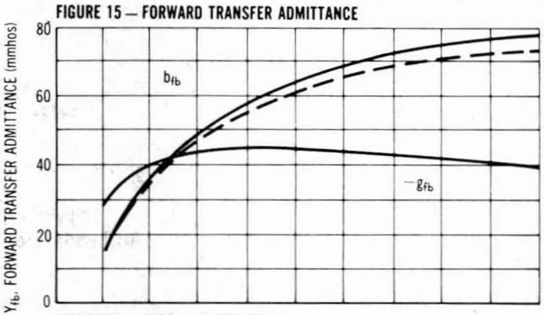


FIGURE 16 — OUTPUT ADMITTANCE

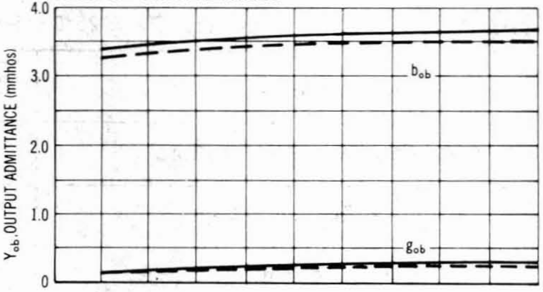
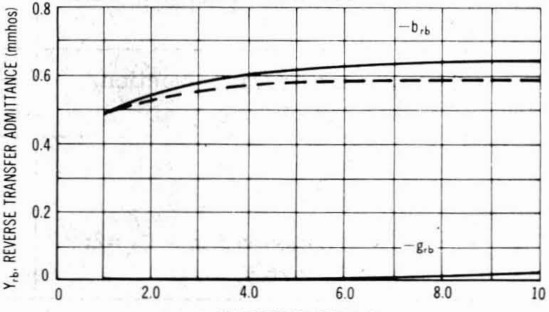


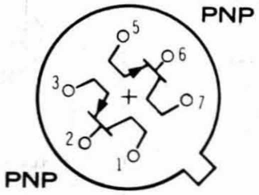
FIGURE 17 — REVERSE TRANSFER ADMITTANCE



MD5000, A, B (SILICON)

CASE 32 C

Dual PNP silicon annular transistors designed for ultra-high frequency oscillator and amplifier applications and for differential-amplifier applications requiring a matched pair of transistors with a high degree of parameter uniformity under varying environmental conditions.



PINS 4 AND 8 OMITTED

Pin Connections, Bottom View
All Leads Electrically Isolated from Case

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	15		Vdc
Collector-Base Voltage	V_{CB}	20		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	50		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Side	Both Sides	
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 1.7	400 2.3	mW mW/°C

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

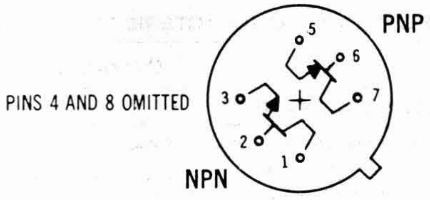
Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 3 mAdc, I_B = 0)		BV_{CEO}	15	—	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	20	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5	—	—	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 150°C)		I_{CBO}	— —	— —	0.010 1.0	μAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 3 mAdc, V_{CE} = 1 Vdc)		h_{FE}	20	50	—	—
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{CE(sat)}$	—	—	0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)		$V_{BE(sat)}$	—	—	1.0	Vdc
DYNAMIC CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 4 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	600	900	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz)		C_{ob}	—	—	1.7	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)		C_{ib}	—	—	2.0	pF
Noise Figure (I_C = 1 mAdc, V_{CE} = 6 Vdc, f = 60 MHz, R_S = 400 ohms)		NF	—	3.0	6.0	dB
FUNCTIONAL TEST						
Amplifier Power Gain (I_C = 6 mAdc, V_{CB} = 12 Vdc, R_G = R_L = 50 ohms, f = 200 MHz)		G_{pe}	15	20	—	dB
MATCHING CHARACTERISTICS						
DC Current Gain Ratio* (I_C = 4 mAdc, V_{CE} = 10 Vdc)	MD5000 MD5000A MD5000B	h_{FE1}/h_{FE2}*	— 0.9 0.8	0.7 — —	— 1.0 1.0	—
Base Voltage Differential (I_C = 4 mAdc, V_{CE} = 10 Vdc)	MD5000 MD5000A MD5000B	$\lvert V_{BE1} - V_{BE2}\rvert$	— — —	5 — —	— 5 10	mVdc
Base Voltage Differential Change (I_C = 4 mAdc, V_{CE} = 10 Vdc, T_A = -55 to +125°C)	MD5000 MD5000A MD5000B	$\frac{\Delta(V_{BE1} - V_{BE2})}{\Delta T_A}$	— — —	10 — —	— 10 20	μV/°C

*The lowest h_{FE} reading is taken as h_{FE1} for this ratio.

MD6001 (SILICON)
MD6002

CASE 32 C

Silicon annular complementary-pair dual transistor is designed for high-speed switching circuits, DC to VHF amplifier applications and complementary circuitry.


PINS 4 AND 8 OMITTED
PNP
NPN
1
2
3
5
6
7

PIN CONNECTIONS
(BOTTOM VIEW)

MAXIMUM RATINGS (each side) ($T_A = 25°C$ unless otherwise specified)

Test Conditions and Limits are given in magnitudes only. Care must be taken to insure the application of proper polarities for the NPN or PNP transistor, respectively.

Rating	Symbol	Value		Unit
Collector-Base Voltage	V_{CB}	60		Vdc
Collector-Emitter Voltage	V_{CEO}	30		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
DC Collector Current (Limited by P_D)	I_C	300		mAdc
Junction Temperature	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C
		ONE SIDE	BOTH SIDES	
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	500 2.9	600 3.4	mW mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.2 6.83	2.0 11.43	W mW/°C

NPN SATURATED SWITCHING TIME TEST CIRCUITS

For PNP Switching Tests, reverse diodes, voltage polarities, and input pulses.

FIGURE 1 — NPN TURN-ON TIME

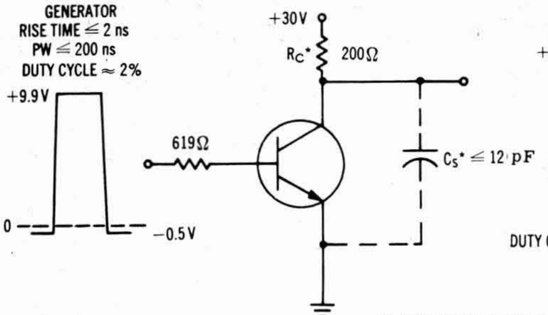
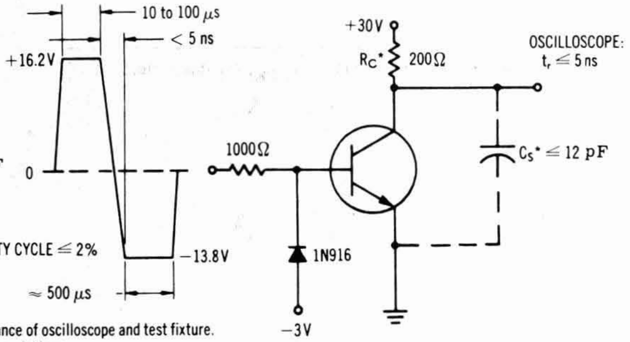

GENERATOR
RISE TIME ≤ 2 ns
PW ≤ 200 ns
DUTY CYCLE ≈ 2%
+9.9 V
0
−0.5 V
619Ω
+30V
Rc* 200Ω
Cs* ≤ 12 pF

FIGURE 2 — NPN TURN-OFF TIME


10 to 100 μs
< 5 ns
+16.2V
0
DUTY CYCLE ≤ 2%
−13.8V
≈ 500 μs
1000Ω
1N916
−3V
+30V
Rc* 200Ω
OSCILLOSCOPE:
tr ≤ 5 ns
Cs* ≤ 12 pF

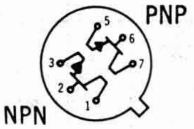
*C_S is total shunt capacitance of oscilloscope and test fixture.
R_C includes oscilloscope resistance.

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	30	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CE} = 50 Vdc, V_{EB} = 3 Vdc) (V_{CE} = 50 Vdc, V_{EB} = 3 Vdc, T_A = 150°C)	I_{CEX}	— —	0.02 30	μAdc
Base Cutoff Current (V_{CE} = 50 Vdc, V_{EB} = 3 Vdc)	I_{BL}	—	0.03	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 0.1 mAdc, V_{CE} = 10 Vdc) MD6001 MD6002	h_{FE}*	20 35	— —	—
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc) MD6001 MD6002		25 50	— —	
(I_C = 10 mAdc, V_{CE} = 10 Vdc) MD6001 MD6002		35 75	— —	
(I_C = 150 mAdc, V_{CE} = 10 Vdc) MD6001 MD6002		40 100	120 300	
(I_C = 150 mAdc, V_{CE} = 1 Vdc) MD6001 MD6002		20 50	— —	
(I_C = 300 mAdc, V_{CE} = 10 Vdc) MD6001 MD6002		20 30	— —	
Base-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 300 mAdc, I_B = 30 mAdc)	$V_{BE(sat)}$*	— —	1.3 2.0	Vdc
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 300 mAdc, I_B = 30 mAdc)	$V_{CE(sat)}$*	— —	0.4 1.4	Vdc
DYNAMIC CHARACTERISTICS				
Gain - Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	—	200	MHz
Collector Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	8	pF
Collector Input Capacitance (V_{BE} = 2 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	30	pF
Delay Time — See Figure 1 — V_{CC} = 30 V, $V_{BE(off)}$ = 0.5 V	t_d	---	20	ns
Rise Time — I_C = 150 mA, I_{B1} = 15 mA	t_r	---	40	ns
Storage Time — See Figure 2 — V_{CC} = 30 V, I_C = 150 mA	t_s	---	280	ns
Fall Time — I_{B1} = I_{B2} = 15 mA	t_f	—	70	ns

*Pulse Test: PW ≦ 300 μsec, Duty Cycle ≦ 2%

MD6100 (SILICON)



PINS 4 AND 8 OMITTED

Pin Connections,
Bottom View

CASE 32 C

Dual NPN-PNP complementary-pair silicon annular transistor designed for complementary circuits where low-level, low-noise amplification is required.

MAXIMUM RATINGS (each side)

Rating	Symbol	Value		Unit
		One Side	Both Sides	
Collector-Emitter Voltage	V_{CEO}	45		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current-Continuous	I_C	50		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	500 2.9	600 3.4	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.2 6.83	2.0 11.43	Watts mW/°C

ELECTRICAL CHARACTERISTICS (each side) (T_A = 25°C unless otherwise noted)

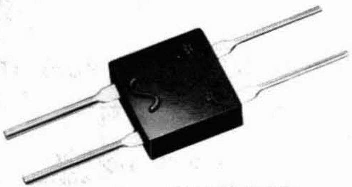
Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	45	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	— —	0.010 10	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 μAdc, V_{CE} = 5 Vdc) (I_C = 100 μAdc, V_{CE} = 5 Vdc) (I_C = 500 μAdc, V_{CE} = 5 Vdc) (I_C = 1 mAdc, V_{CE} = 5 Vdc) (I_C = 10 mAdc, V_{CE} = 5 Vdc)	h_{FE}*	50 100 150 150 125	— — — — —	—
Collector-Emitter Saturation Voltage* (I_C = 100 μAdc, I_B = 10 μAdc) (I_C = 1 mAdc, I_B = 0.1 mAdc)	$V_{CE(sat)}$*	— —	0.2 0.25	Vdc
Base-Emitter Saturation Voltage* (I_C = 100 μAdc, I_B = 10 μAdc) (I_C = 1 mAdc, I_B = 0.1 mAdc)	$V_{BE(sat)}$*	— —	0.7 0.8	Vdc
Base-Emitter On Voltage (I_C = 100 μAdc, V_{CE} = 5 Vdc)	$V_{BE(on)}$	—	0.7	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5 Vdc, f = 30 MHz)	f_T	30	—	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	4	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	8	pF
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3k ohms, Noise Bandwidth = 10 Hz to 15 kHz)	NF	—	4	dB

*Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2%

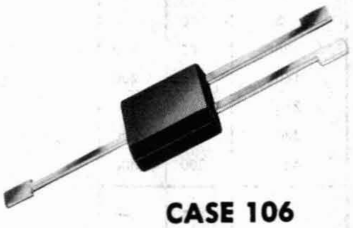
SILICON
MINIATURE DIODE ASSEMBLIES

MDA920 SERIES
MDA930 SERIES
MDA940 SERIES
MDA950 SERIES

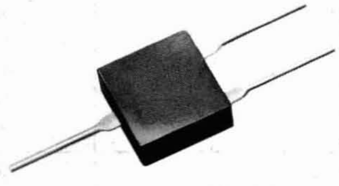
CASE 108
MDA920



CASE 109
MDA920A



CASE 106
MDA930
MDA940
MDA950



CASE 107
MDA930A
MDA940A
MDA950A

Miniature Integral Diode Assemblies (MIDA) are low-current rectifier circuit configurations designed with a high output-current/size ratio for applications where space is at a premium. MIDA packages are available with flat ribbon leads and with round leads. For round leads, add suffix "A" to type number. Example, MDA920A-1.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Value	Unit
Maximum Forward Voltage Drop per Cell (I_F = 500 mA Continuous)	V_F	1.2	Vdc
Maximum Reverse Current* (Figure 2) (V_R = Rated V_{RM}) 25°C 100°C	I_R*	60 600	μAdc

*2 cells in parallel - MDA920 series
1 cell - MDA930, MDA940, and MDA950 series

MECHANICAL CHARACTERISTICS

CASE: Transfer molded plastic encapsulation.

FINISH: All external surfaces are corrosion-resistant, terminals are readily solderable.

POLARITY: Embossed symbol on 4-lead devices.
Terminal designation by color dots on 3-lead devices:
AC input — yellow
+DC output — red
−DC output — white

MOUNTING POSITION: Any.

WEIGHT (approx.): 0.4 gram.

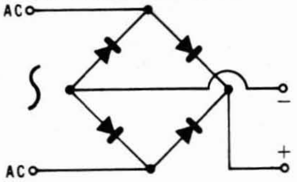
MINIATURE DIODE ASSEMBLIES (continued)

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

TYPE NO.	SCHEMATIC DIAGRAM	PEAK REVERSE VOLTAGE PER CELL (DC or RECURRENT) V_{RM} Volts	SINE WAVE RMS INPUT VOLTAGE (LINE to LINE) V_{in} Volts	DC OUTPUT VOLTAGE		DC OUTPUT CURRENT @ 75°C AMBIENT I_{out} Amps	PEAK FULL WAVE ONE CYCLE SURGE CURRENT NON-REPETITIVE (SINUSOIDAL 60 cps) $I_{FM(surge)}$ Amps	PEAK FULL WAVE REPETITIVE FORWARD CURRENT (NONSINUSOIDAL 60 cps) $I_{FM(rep)}$ Amps
				Res. Load V_{out} Volts	Cap. Load V_{out} Volts			
MDA920-1	A	25	18	15	25	1.0	32.0	5.0
-2		50	35	30	50			
-3		100	70	62	100			
-4		200	140	124	200			
-5		300	210	185	300			
-6		400	280	250	400			
-7		600	420	380	600			
MDA930-1	B	25	9	—	25	0.5	32.0	5.0
-2		50	18	—	50			
-3		100	35	—	100			
-4		200	70	—	200			
-5		300	105	—	300			
-6		400	140	—	400			
-7		600	210	—	600			
MDA940-1	C	25	9	8	13	1.0	32.0	5.0
-2		50	18	15	25			
-3		100	35	30	50			
-4		200	70	62	100			
-5		300	105	92	150			
-6		400	140	125	200			
-7		600	210	190	300			
MDA950-1	D	25	9	8	13	1.0	32.0	5.0
-2		50	18	15	25			
-3		100	35	30	50			
-4		200	70	62	100			
-5		300	105	92	150			
-6		400	140	125	200			
-7		600	210	190	300			

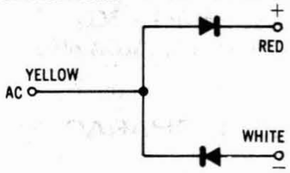
SINGLE PHASE FULL WAVE BRIDGE

A



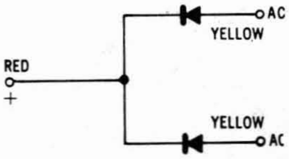
SINGLE PHASE VOLTAGE DOUBLER

B



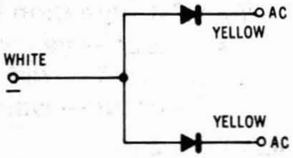
SINGLE PHASE CENTER TAP COMMON CATHODE

C



SINGLE PHASE CENTER TAP COMMON ANODE

D



MINIATURE DIODE ASSEMBLIES (continued)

FIGURE 1 — TYPICAL FORWARD CHARACTERISTICS

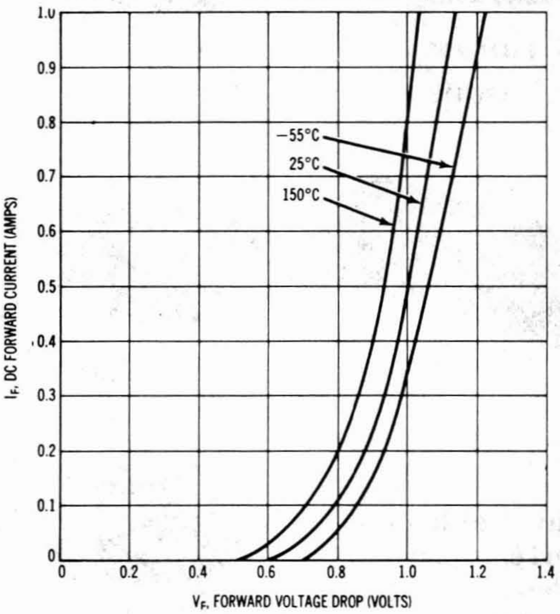


FIGURE 2 — TYPICAL REVERSE CHARACTERISTICS

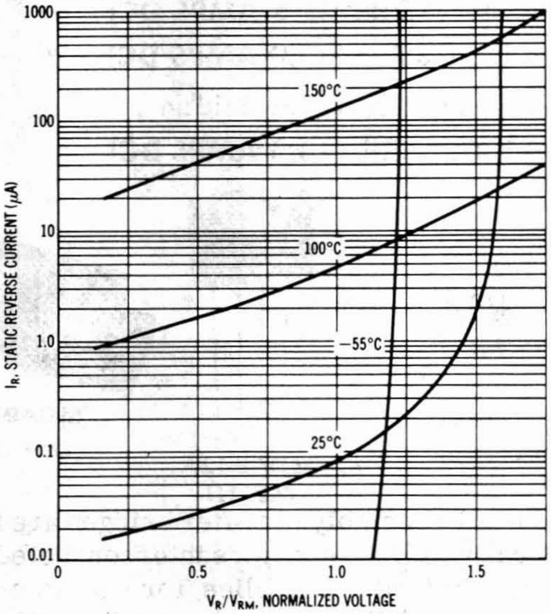


FIGURE 3 — MAX ALLOWABLE SURGE CURRENT

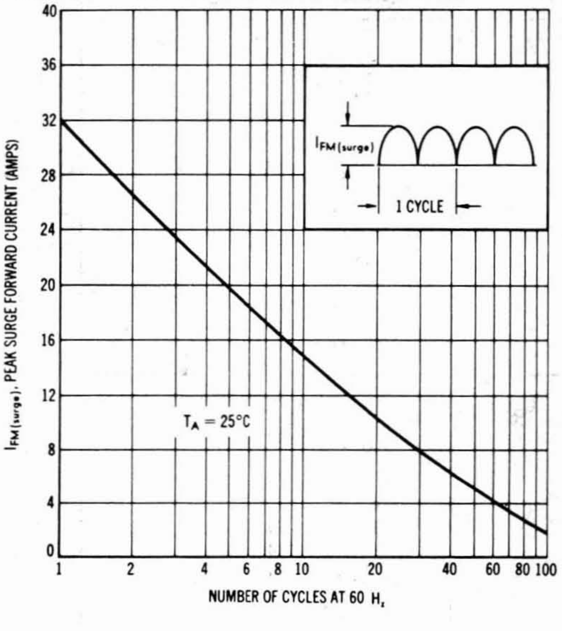
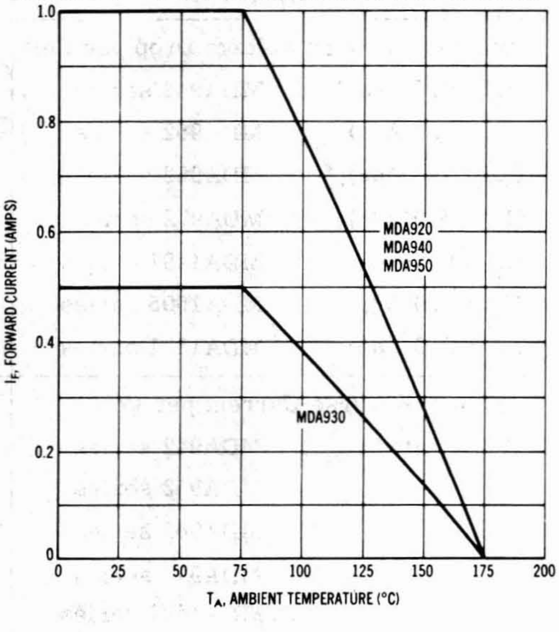


FIGURE 4 — MAX ALLOWABLE DC OUTPUT CURRENT



SILICON
MOLDED ASSEMBLY RECTIFIER BRIDGES

Single-Phase Full-Wave Bridge

MDA942 SERIES (1.5 AMPS DC)
MDA952 SERIES (6.0 AMPS DC)
MDA962 SERIES (10.0 AMPS DC)
MDA972 SERIES (16.0 AMPS DC)
MDA1491 SERIES (1.5 AMPS DC)
MDA1591 SERIES (4.0 AMPS DC)

Three-Phase Full-Wave Bridge

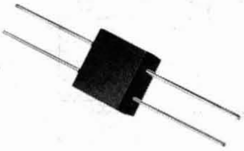
MDA1505 SERIES (8.0 AMPS DC)

MDA952

CASE 113

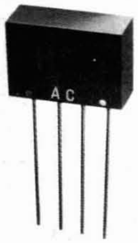
MDA962

CASE 115



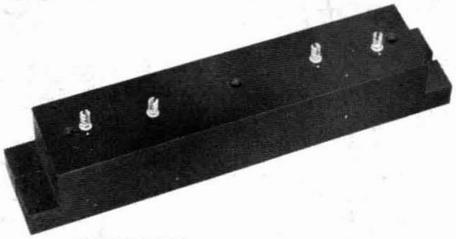
MDA942

CASE 110



MDA942A

CASE 111



MDA972

CASE 116

MDA1505

CASE 114

MDA1491
MDA1591

CASE 112

Molded assembly rectifier bridges are individual hermetically sealed rectifiers interconnected and encapsulated in molded assemblies for use as single-phase and three-phase full-wave bridge configurations, with output current from 1.5 to 16 amps, peak reverse voltage from 50 to 600 volts.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Value	Unit
Maximum Forward Voltage Drop per Cell		V_F		Vdc
(I_F = 0.75 Adc)	MDA942 series		1.1	
(I_F = 3.0 Adc)	MDA952 series		1.0	
(I_F = 5.0 Adc)	MDA962 series		1.0	
(I_F = 5.0 Adc)	MDA972 series		1.0	
(I_F = 0.75 Adc)	MDA1491 series		1.1	
(I_F = 4.0 Adc)	MDA1505 series		1.0	
(I_F = 2.0 Adc)	MDA1591 series		1.0	
Maximum Reverse Current per Cell		I_R		mAdc
(V_R = Rated V_{RM})	MDA942 series		0.01	
	MDA952 series		1.0	
	MDA962 series		1.0	
	MDA972 series		1.0	
	MDA1491 series		0.01	
	MDA1505 series		1.0	
	MDA1591 series		1.0	

RECTIFIER BRIDGES (continued)

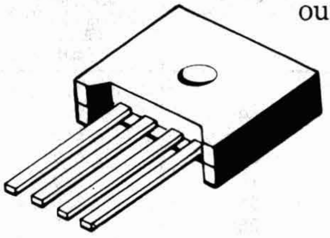
MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

TYPE NO.	PEAK REVERSE VOLTAGE PER CELL (DC or RECURRENT) Volts	SINE WAVE RMS INPUT VOLTAGE (LINE to LINE) Volts	DC OUTPUT VOLTAGE		DC OUTPUT CURRENT @ 55°C AMBIENT Amps	PEAK FULL WAVE ONE CYCLE SURGE CURRENT (60 Hz) Amps	PEAK FULL WAVE RECURRENT FORWARD CURRENT (60 Hz) Amps
			Res. Load Volts	Cap. Load Volts			
MDA942-1	50	35	30	50	1.50	25	6.0
-2	100	70	62	100	1.50	25	6.0
-3	200	140	124	200	1.50	25	6.0
-4	300	210	185	300	1.50	25	6.0
-5	400	280	250	400	1.50	25	6.0
-6	600	420	380	600	1.50	25	6.0
MDA952-1	50	35	30	50	6.00	150	35
-2	100	70	62	100	6.00	150	35
-3	200	140	124	200	6.00	150	35
-4	300	210	185	300	6.00	150	35
-5	400	280	250	400	6.00	150	35
-6	600	420	380	600	6.00	150	35
MDA962-1	50	35	30	50	10.0	250	60
-2	100	70	62	100	10.0	250	60
-3	200	140	124	200	10.0	250	60
-4	300	210	185	300	10.0	250	60
-5	400	280	250	400	10.0	250	60
MDA972-1	50	35	30	50	16.0	250	60
-2	100	70	62	100	16.0	250	60
-3	200	140	124	200	16.0	250	60
-4	300	210	185	300	16.0	250	60
-5	400	280	250	400	16.0	250	60
MDA1491-1	50	35	30	50	1.50	25	6.0
-2	100	70	62	100	1.50	25	6.0
-3	200	140	124	200	1.50	25	6.0
-4	300	210	185	300	1.50	25	6.0
-5	400	280	250	400	1.50	25	6.0
-6	600	420	380	600	1.50	25	6.0
MDA1591 -1	50	35	30	50	4.00	100	25
-2	100	70	62	100	4.00	100	25
-3	200	140	124	200	4.00	100	25
-4	300	210	185	300	4.00	100	25
-5	400	280	250	400	4.00	100	25
-6	600	420	380	600	4.00	100	25
MDA1505 -1	50	35	47	50	8.00	200	45
-2	100	70	95	100	8.00	200	45
-3	200	140	190	200	8.00	200	45
-4	300	210	285	300	8.00	200	45
-5	400	280	380	400	8.00	200	45
-6	600	420	570	600	8.00	200	45

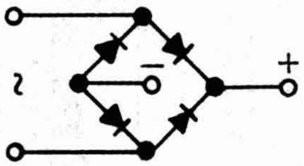
Maximum Operating and Storage Temperature: -65°C to +150°C (All Types)

MDA960 SERIES (SILICON)
(2.5 Adc)
MDA970 SERIES
(4.0 Adc)

Miniature integral diode assemblies diffused silicon dice interconnected and transfer molded into rectifier circuit assemblies for use in applications where high output-current size ratio is of prime importance.



CASE 117



MAXIMUM RATINGS

Type No.	Peak Reverse Voltage Per Cell (DC or Recurrent) $V_{RM(rep)}$ Volts	Sine Wave RMS Input Voltage (Line to Line) V_R Volts	DC Output Voltage		DC Output Current @ 55°C Ambient I_o Amps ①	Peak Full Wave One Cycle Surge Current (60 Hz) $I_{FM(surge)}$ Amps ②	Peak Full-Wave Repetitive Forward Current (Nonsinusoidal 60 Hz) $I_{FM(rep)}$ Amps
			Res. Load Volts	Cap. Load Volts			
MDA960 -1	50	35	30	50	2.5	100	15
-2	100	70	62	100	2.5	100	15
-3	200	140	124	200	2.5	100	15
MDA970 -1	50	35	30	50	4.0	150	25
-2	100	70	62	100	4.0	150	25
-3	200	140	124	200	4.0	150	25

① See Fig. 2 ② See Fig. 4 Maximum Operating and Storage Temperature: -65°C to +150°C (All Types)

MECHANICAL CHARACTERISTICS

CASE: Transfer-molded plastic encapsulation.

FINISH: All external surfaces are corrosion-resistant. Leads are readily solderable.

POLARITY: Embossed symbols

AC input = ~
+DC output = +
-DC output = -

MOUNTING POSITION: Any

WEIGHT (approx.): 7.5 grams

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Value	Unit
Maximum Forward Voltage Drop per Cell $(I_F = 1.25$ Adc$)$ MDA960 $(I_F = 2.0$ Adc$)$ MDA970	V_F	1.0	Vdc
Maximum Reverse Current per Cell $(V_R$ = Rated $V_{RM})$	I_R	1.0	mA

FIGURE 1 — TYPICAL FORWARD VOLTAGE CHARACTERISTICS (PER CELL)

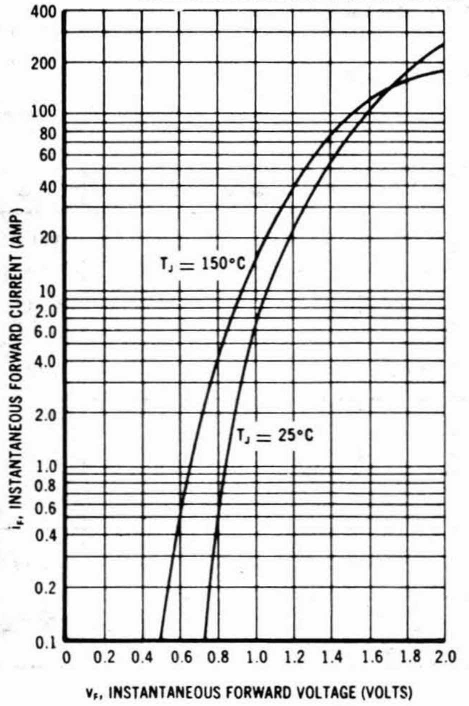


FIGURE 2 — MAXIMUM CURRENT RATING (RESISTIVE OR INDUCTIVE LOAD)

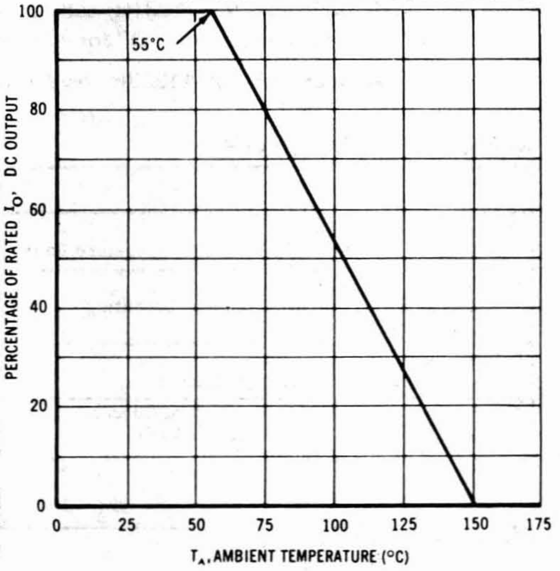


FIGURE 3 — TYPICAL RECTIFICATION EFFICIENCY

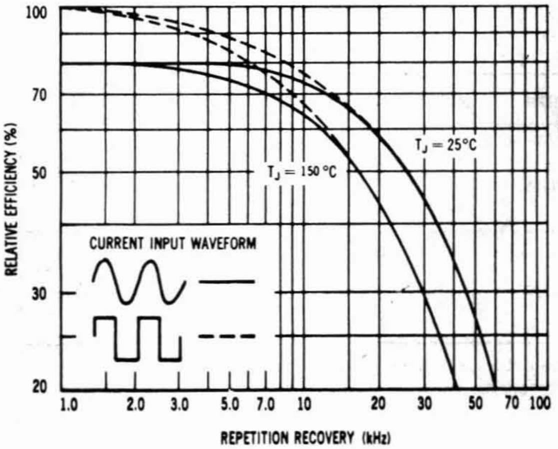
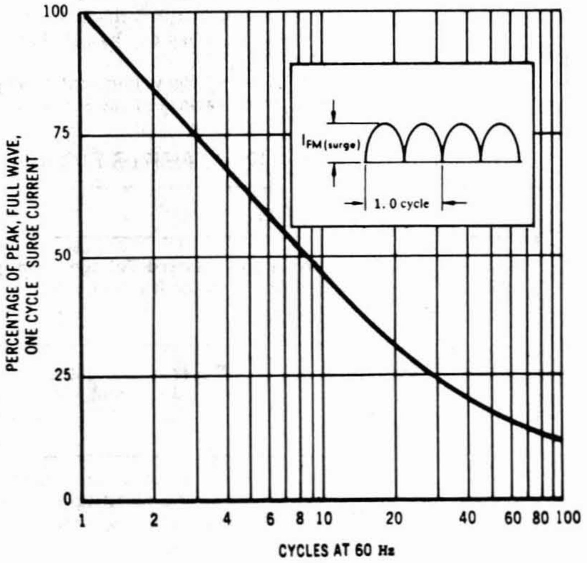
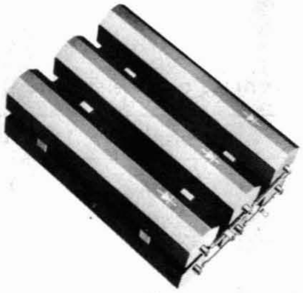


FIGURE 4 — MAXIMUM ALLOWABLE FULL-WAVE SURGE CURRENT AT RATED LOAD CONDITIONS



HIGH VOLTAGE SILICON RECTIFIER MOLDED ASSEMBLIES

MDA1330H
MDA1331H
MDA1332H
MDA1333H



I_O — to 2.5 A
$V_{RM(rep)}$ = 5000 and 10,000 VOLTS

Compensated series-connected rectifier cells for high-voltage, single-phase, half-wave circuit applications. Each cell in the series string is shunted by a high-voltage capacitor and resistor for equal voltage distribution.

NOTES:

1. MDA1330H and MDA1331H, add suffix "C" for common cathode, "U" for common anode, "D" for voltage doubler.
2. MDA1332H and MDA1333H, reverse polarity available by adding suffix "R".

MAXIMUM RATINGS

Rating	Symbol	MDA1330H	MDA1331H	MDA1332H	MDA1333H	Units
Peak Repetitive Reverse Voltage ① (Rated Current, Over Operating Temperature Range)	$V_{RM(rep)}$	5,000	10,000	5,000	10,000	Volts
RMS Reverse Voltage (Rated Current Over the Complete Operating Temperature Range)	V_r	3,500	7,000	3,500	7,000	Volts
DC Blocking Voltage ② (Over Operating Temperature Range)	V_R	3,000	6,000	3,000	6,000	Volts
Average Half Wave Rectified Forward Current (Resistive Load, 180° Conduction Angle, 60cps, Free Convection Cooling) T_A = 40°C	I_O	1.0	1.0	2.5	2.5	Amps
T_A = 100°C		0.3	0.3	0.5	0.5	
Peak 1 Cycle Surge Current (T_A = 40°C, Superimposed on Rated Current at Rated Voltage)	$I_{FM(surge)}$	25	25	250	250	Amps
Operating Frequency Range	DC to 400					cps
Operating and Storage Temperature Range	-55 to +110					°C

① $V_{RM(rep)}$ ratings of 5,000 or 10,000 volts peak are both the maximum repetitive and non-repetitive ratings. Where voltage transient suppression is employed, these assemblies can be reliably operated at the maximum ratings.

② The DC Blocking Voltage rating (V_R), is established by the continuous power dissipation ratings of the shunting resistors and is not a function of the series rectifiers.

ELECTRICAL CHARACTERISTICS

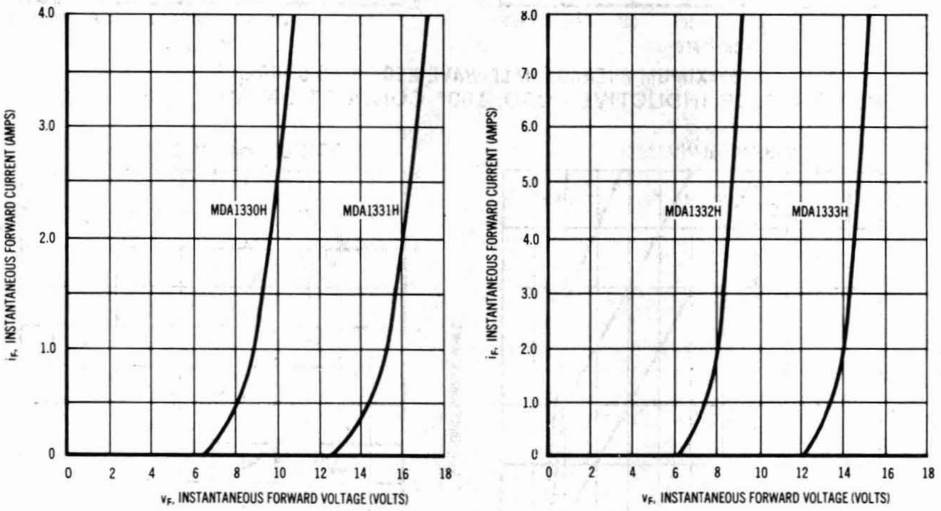
Rating	Symbol	MDA1330H	MDA1331H	MDA1332H	MDA1333H	Units
Maximum Full-Cycle Average Forward Voltage Drop (Half-Wave, Resistive Load, Rated Current and Voltage, T_A=40°C)	$V_{F(AV)}$	5.0	10.0	5.0	10.0	Volts
Maximum Full-Cycle Average Reverse Current (Half-Wave, Resistive Load, Rated Current and Voltage, T_A=40°C)	$I_{R(AV)}$	0.2	0.2	3.0	3.0	mA

Note: Ambient temperatures are measured at the cold air source point i.e. immediately below the rectifier legs under convection cooling and on the cool air side with forced air cooling.

ELECTRICAL DESIGN NOTES

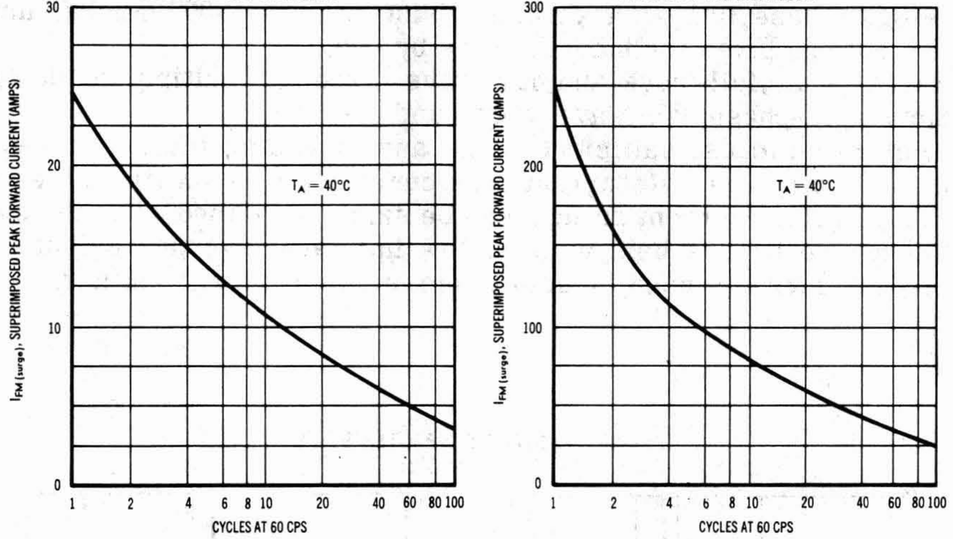
1. For single-phase, full-wave circuits using "Series 1300" stacks, multiply the current ratings given for the half-wave by two.
2. For three-phase, full-wave and half-wave circuits, multiply given current ratings for single-phase, half-wave by two and one half.
3. For capacitive loads, sufficient surge and capacitor inrush current protection must be employed. Recurrent peak currents up to six times the single-phase average output-current ratings can be safely sustained when the average value of these peaks are held at or below the rated average output. Non-repetitive peak currents must be held to the maximum surge ratings.

TYPICAL FORWARD CHARACTERISTICS
($T_J = 25°C$)



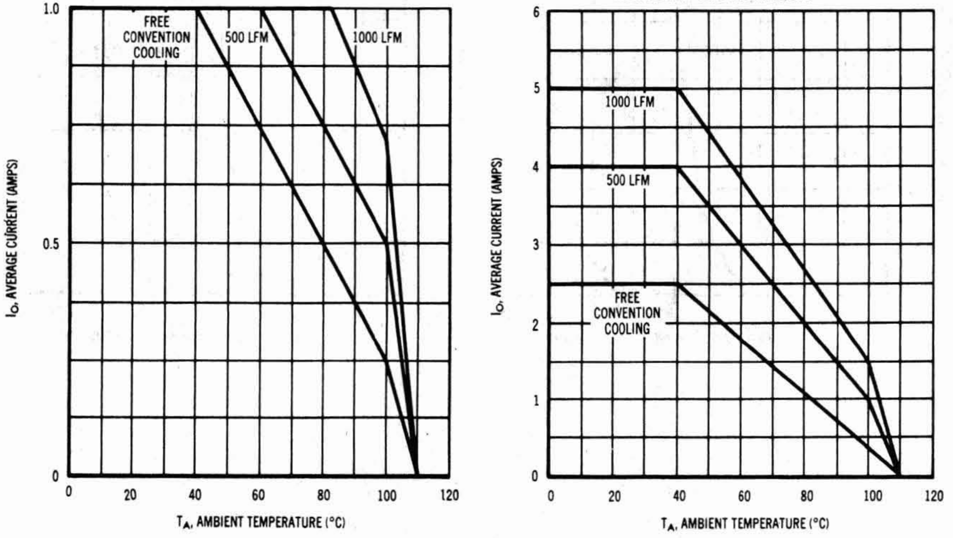
HIGH VOLTAGE SILICON RECTIFIERS (continued)

MAXIMUM SURGE CURRENT
RATED CONDITIONS


MDA1330H and MDA1331H

MDA1332H and MDA1333H

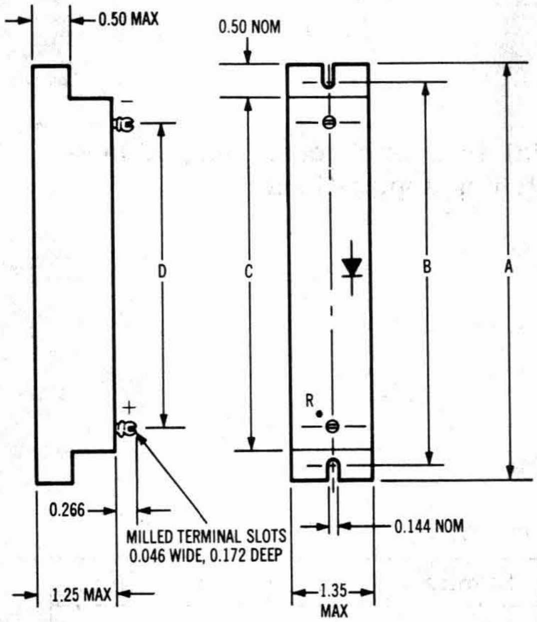
MAXIMUM AVERAGE HALF-WAVE RECTIFIED CURRENT
(RESISTIVE OR INDUCTIVE LOAD, 180° CONDUCTION ANGLE, 60 CPS)


MDA1330H and MDA1331H

MDA1332H and MDA1333H

HIGH VOLTAGE SILICON RECTIFIERS (continued)

MECHANICAL DESIGN INFORMATION AND OUTLINE DIMENSIONS FOR THE BASIC MDA1330H AND MDA1331H RECTIFIER LEGS.


0.50 MAX
0.50 NOM
−
+
D
C
B
A
R
0.266
MILLED TERMINAL SLOTS
0.046 WIDE, 0.172 DEEP
0.144 NOM
1.25 MAX
1.35
MAX

POLARITY DOTS: RED = +DC OUTPUT

Device	A Dim	B Dim	C Dim	D Dim
MDA1330H	4.25max	3.70±0.05	3.25max	3.00nom
MDA1331H	7.00max	6.39±0.05	6.00max	5.25nom

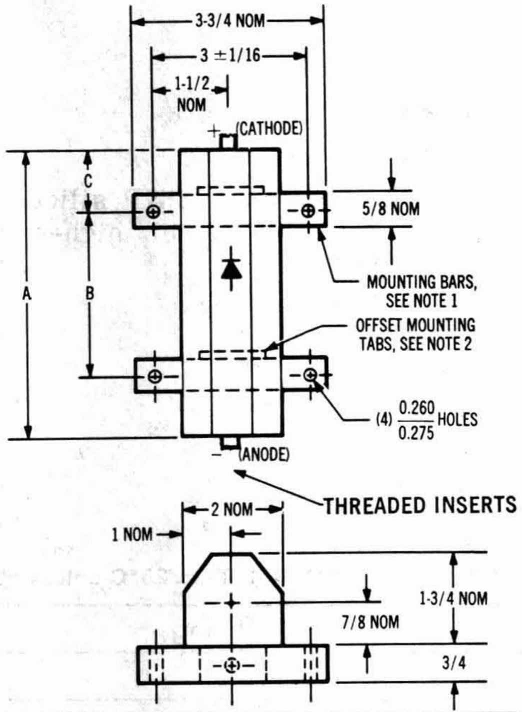
NOTES: These basic rectifier legs are suitable for chassis mounting and connection into multiple leg circuits. Center tapped versions of the MDA1330H and MDA1331H are also available for use in lower voltage, Center tapped and Voltage Doubler applications. The center tapped versions of the MDA1330H and MDA1331H are designated by a different suffix letter as follows: instead of "H" specify

"C" for common cathode, center tap

"U" for common anode, center tap

"D" for voltage doubler.

MECHANICAL DESIGN INFORMATION AND OUTLINE DIMENSIONS FOR THE BASIC MDA1332H AND MDA1333H RECTIFIER LEGS.

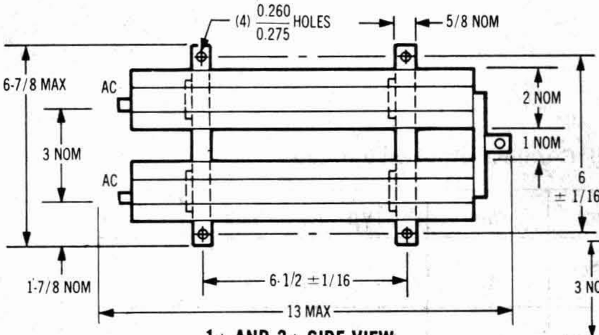

3-3/4 NOM
3 ±1/16
1-1/2
NOM
+ (CATHODE)
C
5/8 NOM
A
B
MOUNTING BARS,
SEE NOTE 1
OFFSET MOUNTING
TABS, SEE NOTE 2
(4) 0.260/0.275 HOLES
− (ANODE)
THREADED INSERTS
2 NOM
1 NOM
1-3/4 NOM
7/8 NOM
3/4

Device	A Dim	B Dim	C Dim
MDA1332H	5-5/8 nom	3-1/4 1/16	1-1/8 nom
MDA1333H	11-1/4 nom	6-1/2±1/16	2-3/8 nom

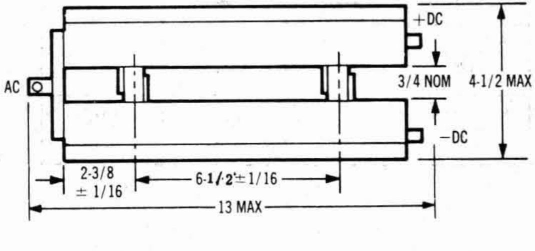
NOTE 1. Insulated mounting bars are supplied with all Series 1300 stacks and the single unit bar is shown above. For multiple leg circuits, mounting bars are available in lengths suitable for 2 or 3 legs mounted side by side. In addition, the mounting arrangement used is also suitable for mounting legs top and bottom on the same bar with stand-offs employed for support of the assembly.

NOTE 2. Offset mounting taps are used to provide more compact multiple leg assemblies. When top & bottom or side by side mounting is employed, reverse polarity legs are often required in some circuits. Legs of reverse polarity to that shown above are designated by an "R" suffix, i.e. MDA1332HR.

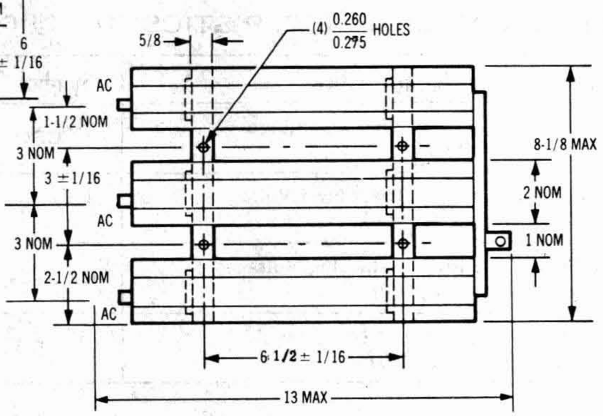
1φ TOP VIEW


(4) 0.260/0.275 HOLES
5/8 NOM
6-7/8 MAX
AC
3 NOM
AC
2 NOM
1 NOM
6
± 1/16
1-7/8 NOM
6-1/2 ±1/16
13 MAX

1φ AND 3φ SIDE VIEW


+DC
AC
3/4 NOM
4-1/2 MAX
−DC
2-3/8
± 1/16
6-1/2 ±1/16
13 MAX

3φ BR TOP VIEW


5/8
(4) 0.260/0.275 HOLES
AC
1-1/2 NOM
3 NOM
3 ±1/16
AC
3 NOM
2-1/2 NOM
AC
8-1/8 MAX
2 NOM
1 NOM
6 1/2 ± 1/16
13 MAX

MF3304 (SILICON)

CASE 20
(TO-72)

PNP silicon epitaxial transistor designed for low-level, high-speed switching applications.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	18	Vdc
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	200 1.14	mW mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	300 1.71	mW mW/°C
Operating Junction Temperature	T_J	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage (I_C = 100 μA, I_B = 0)	BV_{CBO}	18	—	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μA, I_B = 0)	BV_{CES}	12	—	—	Vdc
Collector-Emitter Sustaining Voltage* (I_C = 10 mA, I_B = 0)	$V_{CEO(sus)}$*	12	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μA, I_C = 0)	BV_{EBO}	5	—	—	Vdc

MF3304 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current (V_{CB} = 9 V, I_E = 0)	I_{CBO}	—	—	10	nA
Collector Reverse Current (V_{CE} = 6 V, V_{EB} = 0) (V_{CE} = 6 V, V_{EB} = 0, 150°C)	I_{CES}	— —	— —	10 10	nA μA
Collector-Emitter Saturation Voltage (I_C = 1.0 mA, I_B = 0.1 mA) (I_C = 10 mA, I_B = 1.0 mA) (I_C = 10 mA, I_B = 1.0 mA, 125°C) (I_C = 50 mA, I_B = 5.0 mA)	$V_{CE(sat)}$	— — — —	— — — —	0.15 0.16 0.23 0.50	Vdc
Base-Emitter Saturation Voltage (I_C = 1.0 mA, I_B = 0.1 mA) (I_C = 10 mA, I_B = 1.0 mA) (I_C = 50 mA, I_B = 5.0 mA)	$V_{BE(sat)}$	0.7 0.8 —	— — —	0.8 0.9 1.2	Vdc
DC Current Gain (I_C = 1.0 mA, V_{CE} = -0.3 V) (I_C = 10 mA, V_{CE} = -0.3 V) (I_C = 10 mA, V_{CE} = -0.3 V, -55°C) (I_C = 50 mA, V_{CE} = -1.0 V)	h_{FE}	20 30 15 20	— — — —	— 120 — —	
High-Frequency Current Gain (I_C = 10 mA, V_{CE} = -5.0 V, f = 100 MHz)	h_{fe}	6.0	—	—	—
Output Capacitance** (V_{CB} = -5.0 V, I_E = 0, f = 140 kHz)	C_{ob}**	—	—	2.5	pF
Emitter Transition Capacitance (V_{EB} = -0.5 V, I_C = 0, f = 140 kHz)	C_{TE}	—	—	2.5	pF
Collector-Base Time Constant (V_{CB} = 10 V, I_C = 10 mA, f = 31.8 MHz)	$r_b'C_c$	—	—	40	ps
Charge Storage Time ($I_C \approx I_{B1} \approx I_{B2} \approx$ -10 mA)	t_s	—	—	30	ns
Turn-On Time ($I_C \approx$ 10 mA, $I_{B1} \approx$ 0.5 mA)	t_{on}	—	—	60	ns
Turn-Off Time ($I_C \approx$ 10 mA, $I_{B1} \approx I_{B2} \approx$ -0.5 mA)	t_{off}	—	—	60	ns

TYPICAL AMPLIFIER PERFORMANCE

Noise Figure (V_{CE} = 10 V, I_C = 2 mA, f = 60 MHz, R_S = 200 ohms)	NF	—	2.7	—	dB
AC Current Gain (V_{CE} = 10 V, I_C = 2 mA, f = 1 kHz)	h_{fe}	—	70	—	—
Current Gain — Bandwidth Product (V_{CE} = 10 V, I_C = 2 mA, f = 100 MHz)	f_T	—	700	—	MHz
Collector-Base Time Constant (V_{CB} = 10 V, I_C = 2 mA)	$r_b'C_c$	—	15	—	ps

**Measured in guarded circuit

*Pulse Conditions: PW ≤ 300 μs, Duty Cycle ≤ 2%.

MFE2000 (SILICON)
MFE2001

Silicon N-channel junction field-effect transistor designed for VHF/UHF amplifier applications.

CASE 20(1)
(TO-72)

Active elements isolated from case

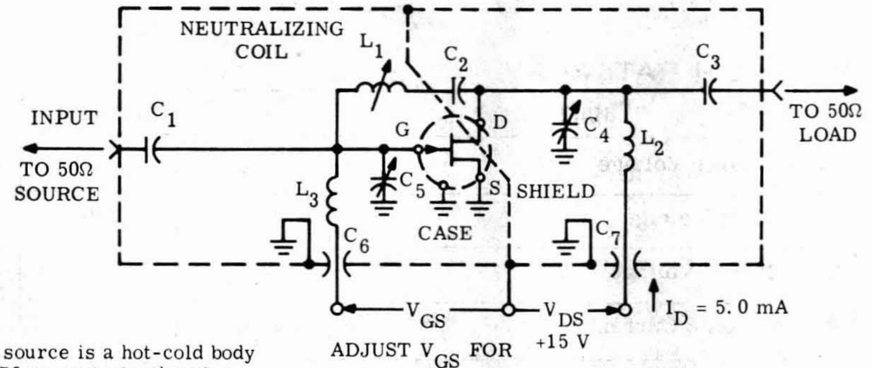
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	25	Vdc
Gate-Source Voltage	V_{GS}	25	Vdc
Drain Current	I_D	30	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 2.0	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Gate-Source Breakdown Voltage ($I_G = -1.0\ \mu Adc$, $V_{DS} = 0$)		$V_{(BR)GSS}$	25	-	-	Vdc
Gate-Source Voltage ($I_D = 0.5$ mAdc, $V_{DS} = 15$ Vdc)	MFE2000 MFE2001	V_{GS}	0.5 3.0	- -	4.0 7.5	Vdc
Gate Reverse Current ($V_{GS} = -20$ Vdc, $V_{DS} = 0$)		I_{GSS}	-	-	100	pAdc
($V_{GS} = -20$ Vdc, $V_{DS} = 0$, $T_A = 150°C$)			-	-	200	nAdc
ON CHARACTERISTICS						
Zero-Gate Voltage Drain Current ($V_{DS} = 15$ Vdc, $V_{GS} = 0$)	MFE2000 MFE2001	I_{DSS}	4.0 8.0	- -	10 20	mAdc
SMALL-SIGNAL CHARACTERISTICS						
Forward Transfer Admittance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1.0 kHz)	MFE2000 MFE2001	$\|y_{fs}\|$	2500 4000	- -	6000 8000	µmhos
Output Admittance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1.0 kHz)	MFE2000 MFE2001	$\|y_{os}\|$	- -	- -	50 75	µmhos
Input Capacitance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1.0 MHz)		C_{iss}	-	-	5.0	pF
Output Capacitance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1.0 MHz)		C_{oss}	-	-	2.0	pF
Reverse Transfer Capacitance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1.0 MHz)		C_{rss}	-	-	1.0	pF
Small-Signal Power Gain (Figure 1) ($V_{DS} = 15$ Vdc, $I_D = 4.0$ mAdc, f = 100 MHz)		G_{ps}	18	23	-	dB
($V_{DS} = 15$ Vdc, $I_D = 4.0$ mAdc, f = 400 MHz)			10	14	-	
Noise Figure (Figure 1) ($V_{DS} = 15$ Vdc, $I_D = 4.0$ mAdc, f = 100 MHz, $R_G \approx 1.0$ k ohm)		NF	-	1.6	2.0	dB
($V_{DS} = 15$ Vdc, $I_D = 4.0$ mAdc, f = 400 MHz, $R_G \approx 1.0$ k ohm)			-	3.3	4.0	

FIGURE 1 — 100 MHz and 400 MHz NEUTRALIZED AMPLIFIER


NEUTRALIZING COIL
L_1
C_2
C_3
INPUT
C_1
TO 50Ω SOURCE
G
D
C_4
L_2
TO 50Ω LOAD
L_3
C_5
S
SHIELD
C_6
CASE
C_7
V_{GS}
V_{DS}
+15 V
I_D = 5.0 mA

ADJUST V_{GS} FOR
I_D = 5.0 mA
$V_{GS} < 0$ VOLTS

NOTE:

The noise source is a hot-cold body (AIL type 70 or equivalent) with a test receiver (AIL type 136 or equivalent).

Reference Designation	VALUE	
	100 MHz	400 MHz
C_1	7.0 pF	1.8 pF
C_2	1000 pF	27 pF
C_3	3.0 pF	1.0 pF
C_4	1-12 pF	0.8-8.0 pF
C_5	1-12 pF	0.8-8.0 pF
C_6	0.0015 μF	0.001 μF
C_7	0.0015 μF	0.001 μF
L_1	3.0 μH*	0.2 μH**
L_2	0.25 μH*	0.03 μH**
L_3	0.14 μH*	0.022 μH**

* L_1 17 turns (approximately - depending on circuit layout), AWG #28 enameled copper wire, close wound on 9/32" ceramic coil form. Tuning provided by a powdered iron slug.

L_2 4-1/2 turns, AWG #18 enameled copper wire, 5/16" long, 3/8" I. D.

L_3 3-1/2 turns, AWG #18 enameled copper wire, 1/4" long, 3/8" I. D.

** L_1 6 turns approximately -(depending on circuit layout), AWG #24 enameled copper wire, close wound on 7/32" ceramic coil form. Tuning provided by an aluminum slug.

L_2 1 turn, AWG #16 enameled copper wire, 3/8" I. D.

L_3 1/2 turn, AWG #16 enameled copper wire, 1/4" I. D.

MFE2004 (SILICON)
MFE2005
MFE2006

Silicon N-channel depletion mode (Type A) junction field-effect transistors designed for chopper applications.

CASE 22(4)
(TO-18)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	30	Vdc
Forward Gate Current	$I_{G(f)}$	10	mAdc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.8 10	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage $(I_G = 1.0\ \mu Adc,\ V_{DS} = 0)$		$V_{(BR)GSS}$	30	-	Vdc
Gate Reverse Current $(V_{GS} = 20\ Vdc,\ V_{DS} = 0$		I_{GSS}	-	0.2	nAdc
$(V_{GS} = 20\ Vdc,\ V_{DS} = 0,\ T_A = 150°C)$			-	0.4	μAdc
Drain Cutoff Current $(V_{DS} = 20\ Vdc,\ V_{GS} = 12\ Vdc)$		$I_{D(off)}$	-	0.2	nAdc
$(V_{DS} = 20\ Vdc,\ V_{GS} = 12\ Vdc,\ T_A = 150°C)$			-	0.4	μAdc
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current* $(V_{DS} = 20\ Vdc,\ V_{GS} = 0)$	MFE2004	I_{DSS}*	8.0	-	mAdc
	MFE2005		15	-	
	MFE2006		30	-	
Gate-Source Voltage $(V_{DS} = 20\ Vdc,\ I_D = 50\ \mu Adc)$	MFE2004	V_{GS}	1.0	6.0	Vdc
	MFE2005		2.0	8.0	
	MFE2006		5.0	10	
Gate-Source Forward Voltage $(I_G = 1.0\ mAdc,\ V_{DS} = 0)$		VGSF	-	1.0	Vdc
Drain-Source "ON" Voltage $(I_D = 3.0\ mAdc,\ V_{GS} = 0)$	MFE2004	$V_{DS(on)}$	-	0.4	Vdc
$(I_D = 6.0\ mAdc,\ V_{GS} = 0)$	MFE2005		-	0.4	
$(I_D = 10\ mAdc,\ V_{GS} = 0)$	MFE2006		-	0.4	
Static Drain-Source "ON" Resistance $(I_D = 1.0\ mAdc,\ V_{GS} = 0)$	MFE2004	$r_{DS(on)}$	-	80	Ohms
	MFE2005		-	50	
	MFE2006		-	30	

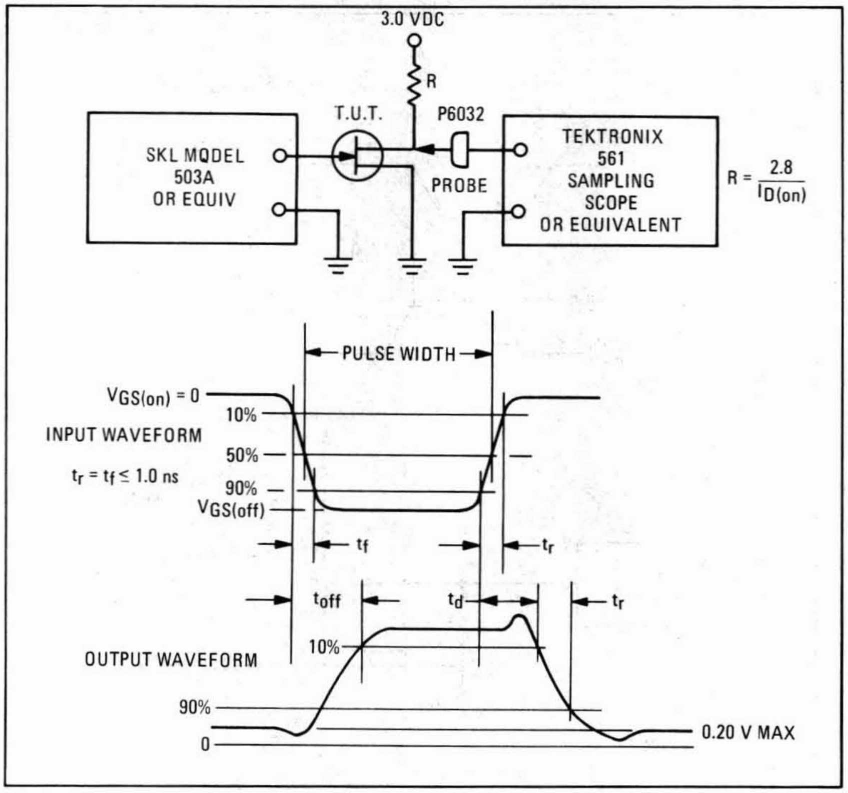
*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 3.0%.

MFE2004, MFE2005, MFE2006 (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Max	Unit
SMALL-SIGNAL CHARACTERISTICS					
Static Drain-Source "ON" Resistance (V_{GS} = 0, I_D = 0, f = 1.0 kHz)	MFE2004	$r_{ds(on)}$	-	80	Ohms
	MFE2005		-	50	
	MFE2006		-	30	
Input Capacitance (V_{DS} = 0, V_{GS} = -12 Vdc, f = 1.0 MHz)		C_{iss}	-	16	pF
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 6.0 Vdc, f = 1.0 MHz)	MFE2004	C_{rss}	-	5.0	pF
(V_{DS} = 0, V_{GS} = 8.0 Vdc, f = 1.0 MHz)	MFE2005		-	5.0	
(V_{DS} = 0, V_{GS} = 12 Vdc, f = 1.0 MHz)	MFE2006		-	5.0	
SWITCHING CHARACTERISTICS					
Turn-On Delay Time (See Figure 1) (V_{DD} = 3.0 Vdc, I_D = 3.0 mAdc, V_{GS} = 0)	MFE2004	$t_{d(on)}$	-	20	ns
(V_{DD} = 3.0 Vdc, I_D = 6.0 mAdc, V_{GS} = 0)	MFE2005		-	15	
(V_{DD} = 3.0 Vdc, I_D = 10 mAdc, V_{GS} = 0)	MFE2006		-	10	
Rise Time (See Figure 1) (V_{DD} = 3.0 Vdc, I_D = 3.0 mAdc, V_{GS} = 0)	MFE2004	t_r	-	40	ns
(V_{DD} = 3.0 Vdc, I_D = 6.0 mAdc, V_{GS} = 0)	MFE2005		-	20	
(V_{DD} = 3.0 Vdc, I_D = 10 mAdc, V_{GS} = 0)	MFE2006		-	10	
Turn-Off Time (See Figure 1) (V_{DD} = 3.0 Vdc, I_D = 3.0 mAdc, $V_{GS(off)}$ = 6.0 Vdc)	MFE2004	t_{off}	-	80	ns
(V_{DD} = 3.0 Vdc, I_D = 6.0 mAdc, $V_{GS(off)}$ = 8.0 Vdc)	MFE2005		-	60	
(V_{DD} = 3.0 Vdc, I_D = 10 mAdc, $V_{GS(off)}$ = 12 Vdc)	MFE2006		-	40	

FIGURE 1 – SWITCHING TIMES TEST CIRCUIT


3.0 VDC
R
T.U.T.
P6032
SKL MODEL 503A OR EQUIV
PROBE
TEKTRONIX 561 SAMPLING SCOPE OR EQUIVALENT
R = 2.8 / $I_{D(on)}$
PULSE WIDTH
$V_{GS(on)}$ = 0
10%
INPUT WAVEFORM
50%
$t_r = t_f \leq 1.0$ ns
90%
$V_{GS(off)}$
t_f
t_r
t_{off}
t_d
t_r
10%
OUTPUT WAVEFORM
90%
0
0.20 V MAX

MFE2007 (SILICON)
MFE2008
MFE2009

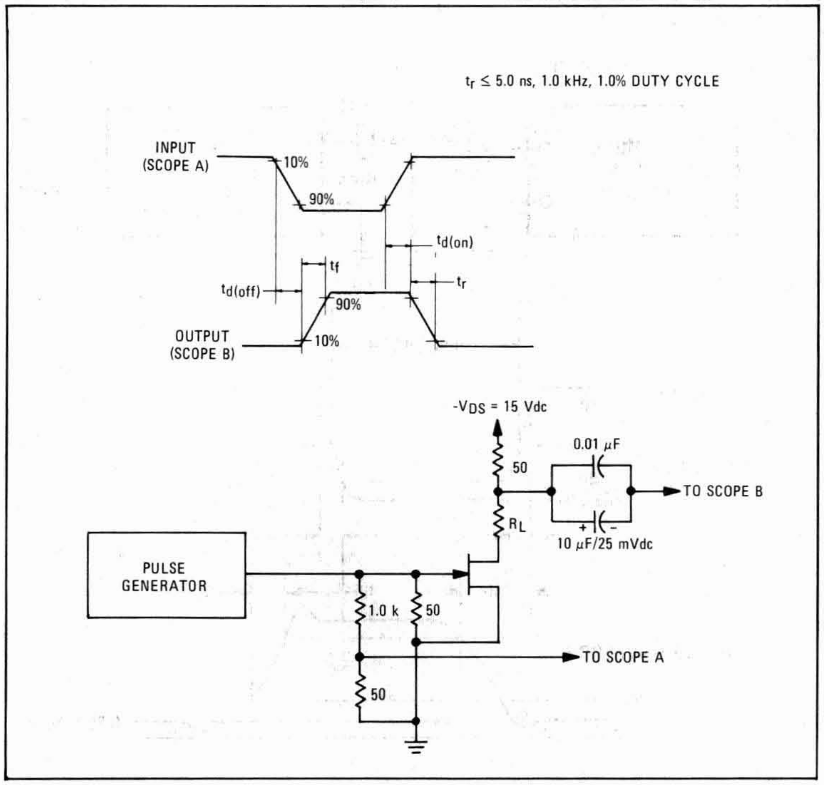
Silicon N-channel depletion mode (Type A) junction field-effect transistors designed for chopper applications.

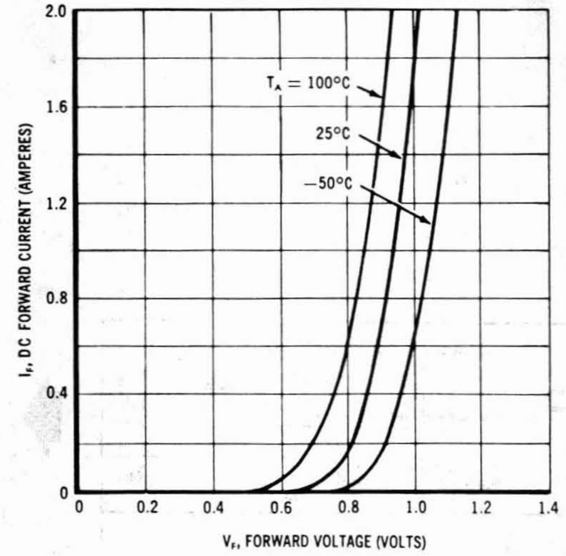
CASE 22 (4)
(TO-18)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	25	Vdc
Gate-Source Voltage	V_{GS}	25	Vdc
Forward Gate Current	$I_{G(f)}$	50	mAdc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.8 10	Watts mW/°C
Operating Junction Temperature Range	T_J	-65 to + 175	°C
Storage Temperature Range	T_{stg}	-65 to + 200	°C

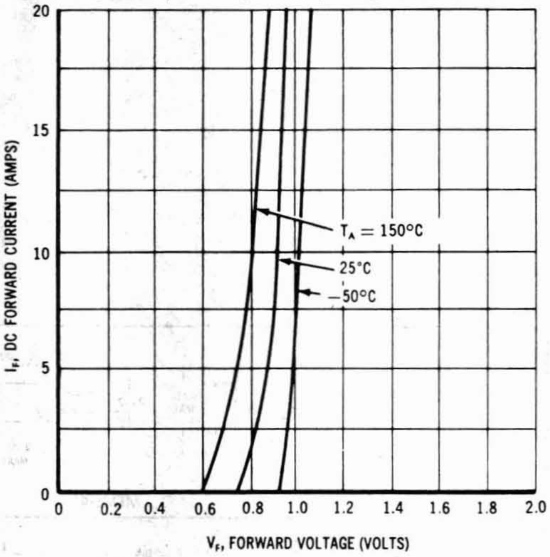
FIGURE 1 – SWITCHING TIMES TEST CIRCUIT


$t_r \le 5.0$ ns, 1.0 kHz, 1.0% DUTY CYCLE
INPUT (SCOPE A)
10%
90%
$t_{d(on)}$
t_f
t_r
$t_{d(off)}$
90%
OUTPUT (SCOPE B)
10%
$-V_{DS}$ = 15 Vdc
50
0.01 μF
TO SCOPE B
R_L
10 μF/25 mVdc
PULSE GENERATOR
1.0 k
50
TO SCOPE A
50



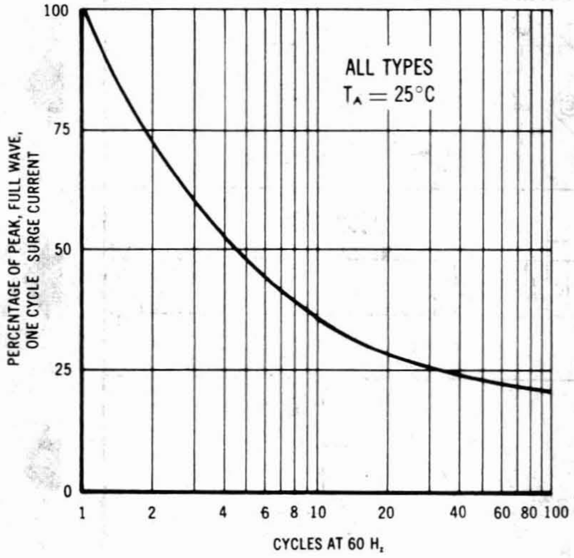
TYPICAL FORWARD CHARACTERISTICS

PER CELL (MDA942 & MDA1491 SERIES)

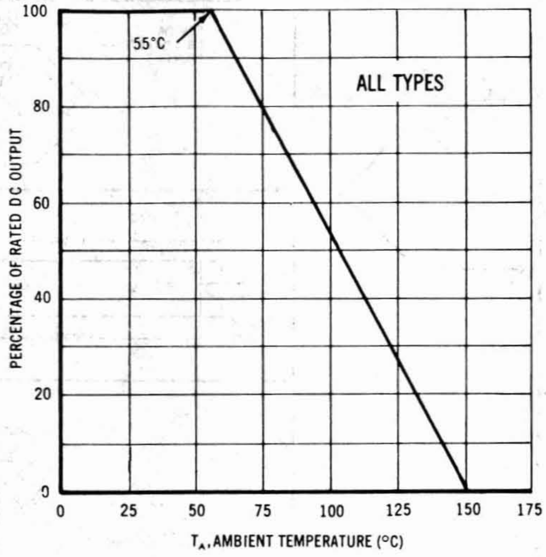


TYPICAL FORWARD CHARACTERISTICS

PER CELL (MDA952, MDA962, MDA972, MDA1505 & MDA1591 SERIES)



MAXIMUM ALLOWABLE FULL WAVE SURGE CURRENT AT RATED LOAD CONDITIONS



MAXIMUM ALLOWABLE DC OUTPUT

(RESISTIVE OR INDUCTIVE LOAD)

MECHANICAL CHARACTERISTICS

CASE: Molded plastic encapsulation, hermetically sealed individual rectifier cells.

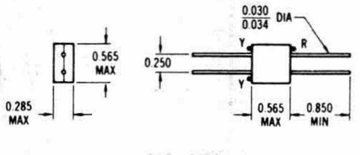
FINISH: All external surfaces are corrosion-resistant, terminals are readily solderable.

POLARITY: Terminal designation by color dots:
AC input — yellow
+DC output — red
−DC output — not marked

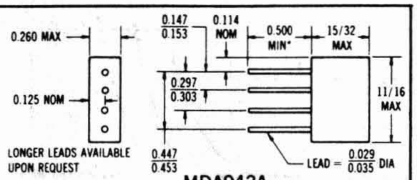
MOUNTING POSITION: Any

WEIGHT: **(approx.)**
MDA942, MDA942A — 3.8 grams
MDA952 — 35 grams
MDA962, MDA1505 — 92 grams
MDA972 — 340 grams
MDA1491 — 33 grams
MDA1591 — 39 grams

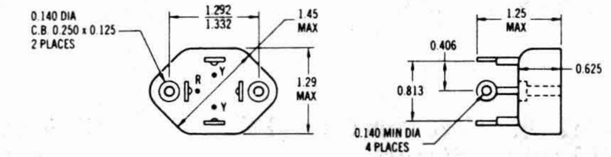
RECTIFIER BRIDGES (continued)

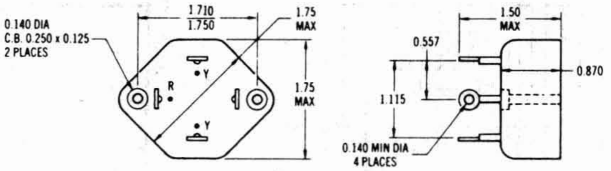

0.565
MAX
0.285
MAX
0.250
$\frac{0.030}{0.034}$ DIA
Y
R
Y
0.565
MAX
0.850
MIN

MDA942

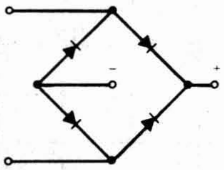

0.260 MAX
0.125 NOM
LONGER LEADS AVAILABLE
UPON REQUEST
$\frac{0.147}{0.153}$
0.114
NOM
0.500
MIN*
15/32
MAX
$\frac{0.297}{0.303}$
11/16
MAX
$\frac{0.447}{0.453}$
LEAD = $\frac{0.029}{0.035}$ DIA

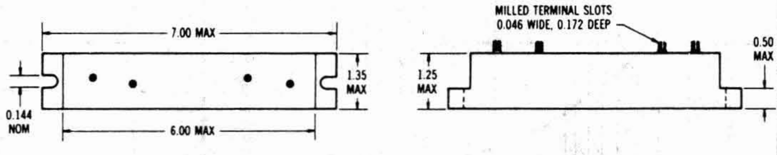
MDA942A

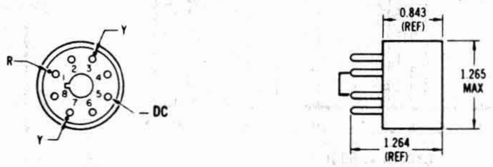

0.140 DIA
C.B. 0.250 x 0.125
2 PLACES
$\frac{1.292}{1.332}$
1.45
MAX
1.29
MAX
R
Y
Y
1.25
MAX
0.406
0.625
0.813
0.140 MIN DIA
4 PLACES

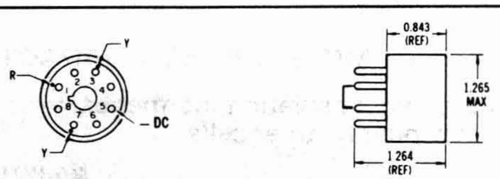

0.140 DIA
C.B. 0.250 x 0.125
2 PLACES
$\frac{1.710}{1.750}$
1.75
MAX
1.75
MAX
R
Y
Y
1.50
MAX
0.557
0.870
1.115
0.140 MIN DIA
4 PLACES

SINGLE-PHASE FULL-WAVE BRIDGE

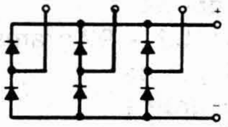


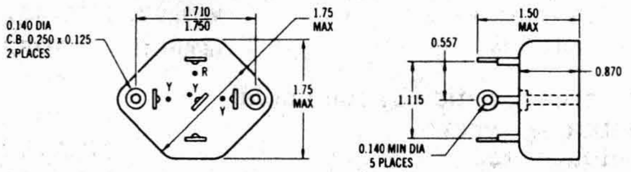

7.00 MAX
1.35
MAX
0.144
NOM
6.00 MAX
MILLED TERMINAL SLOTS
0.046 WIDE, 0.172 DEEP
0.50
MAX
1.25
MAX


Y
R
1
2
3
4
5
6
7
8
DC
Y
0.843
(REF)
1.265
MAX
1.264
(REF)


Y
R
1
2
3
4
5
6
7
8
DC
Y
0.843
(REF)
1.265
MAX
1.264
(REF)

THREE-PHASE FULL-WAVE BRIDGE




0.140 DIA
C.B. 0.250 x 0.125
2 PLACES
$\frac{1.710}{1.750}$
1.75
MAX
1.75
MAX
R
Y
Y
Y
1.50
MAX
0.557
0.870
1.115
0.140 MIN DIA
5 PLACES

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	25	-	Vdc
Gate Reverse Current (V_{GS} = 15 Vdc, V_{DS} = 0)	I_{GSS}	-	2.0	nAdc
(V_{GS} = 15 Vdc, V_{DS} = 0, T_A = 150°C)		-	4.0	μAdc
Drain Cutoff Current (V_{DS} = 15 Vdc, V_{GS} = 12 Vdc)	$I_{D(off)}$	-	2.0	nAdc
(V_{DS} = 15 Vdc, V_{GS} = 12 Vdc, T_A = 150°C)		-	4.0	μAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current* (V_{DS} = 20 Vdc, V_{GS} = 0) MFE2007	I_{DSS}*	8.0	-	mAdc
MFE2008		20	-	
MFE2009		50	-	
Gate-Source Voltage (V_{DS} = 15 Vdc, I_D = 1.0 μAdc) MFE2007	V_{GS}	0.5	10	Vdc
MFE2008		1.0	10	
MFE2009		3.0	10	
Gate-Source Forward Voltage (I_G = 1.0 mAdc, V_{DS} = 0)	VGSF	-	1.0	Vdc
Drain-Source "ON" Voltage (I_D = 5.0 mAdc, V_{GS} = 0) MFE2007	$V_{DS(on)}$	-	0.75	Vdc
(I_D = 10 mAdc, V_{GS} = 0) MFE2008		-	0.75	
(I_D = 20 mAdc, V_{GS} = 0) MFE2009		-	0.75	
Static Drain-Source "ON" Resistance (I_D = 1.0 mAdc, V_{GS} = 0) MFE2007	$r_{DS(on)}$	-	40	Ohms
MFE2008		-	30	
MFE2009		-	20	
SMALL-SIGNAL CHARACTERISTICS				
Static Drain-Source "ON" Resistance (V_{GS} = 0, I_D = 0, f = 1.0 kHz) MFE2007	$r_{ds(on)}$	-	40	Ohms
MFE2008		-	30	
MFE2009			20	
Input Capacitance (V_{DS} = 0, V_{GS} = 10 Vdc, f = 1.0 MHz)	C_{iss}	-	30	pF
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 12 Vdc, f = 1.0 MHz)	C_{rss}	-	15	pF
SWITCHING CHARACTERISTICS				
Turn-On Delay Time (See Figure 1)	$t_{d(on)}$	-	10	ns
Rise Time (See Figure 1)	t_r	-	6.0	ns
Turn-Off Delay Time (See Figure 1) (V_{DD} = 15 Vdc, I_D = 5.0 mAdc) MFE2007	$t_{d(off)}$	-	35	ns
(V_{DD} = 15 Vdc, I_D = 10 mAdc) MFE2008		-	20	
(V_{DD} = 15 Vdc, I_D = 20 mAdc) MFE2009		-	12	
Fall Time (See Figure 1) (V_{DD} = 15 Vdc, I_D = 5.0 mAdc) MFE2007	t_f	-	65	ns
(V_{DD} = 15 Vdc, I_D = 10 mAdc) MFE2008		-	40	
(V_{DD} = 15 Vdc, I_D = 20 mAdc) MFE2009		-	25	

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 3.0%.

MFE2010 (SILICON)
MFE2011
MFE2012

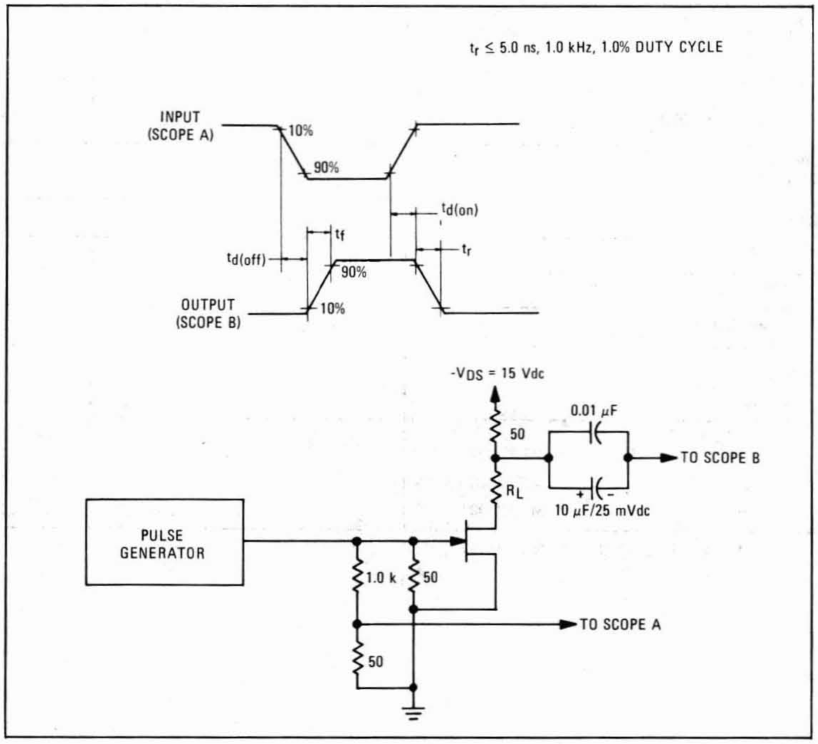
Silicon N-channel depletion mode (Type A) junction field-effect transistors designed for chopper applications.

CASE 22 (4)
(TO-18)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	25	Vdc
Gate-Source Voltage	V_{GS}	25	Vdc
Forward Gate Current	$I_{G(f)}$	50	mAdc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25° C	P_D	1.8 10	Watt mW/° C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

FIGURE 1 – SWITCHING TIMES TEST CIRCUIT


$t_r \leq 5.0$ ns, 1.0 kHz, 1.0% DUTY CYCLE
INPUT (SCOPE A)
10%
90%
$t_{d(on)}$
t_f
t_r
$t_{d(off)}$
90%
OUTPUT (SCOPE B)
10%
$-V_{DS} = 15$ Vdc
50
0.01 μF
TO SCOPE B
R_L
+ −
10 μF/25 mVdc
PULSE GENERATOR
1.0 k
50
TO SCOPE A
50

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	25	-	Vdc
Gate Reverse Current (V_{GS} = 15 Vdc, V_{DS} = 0) (V_{GS} = 15 Vdc, V_{DS} = 0, T_A = 150°C)		I_{GSS}	- -	3.0 6.0	nAdc μAdc
Drain Cutoff Current (V_{DS} = 15 Vdc, V_{GS} = 12 Vdc) (V_{DS} = 15 Vdc, V_{GS} = 12 Vdc, T_A = 150°C)		$I_{D(off)}$	- -	3.0 6.0	nAdc μAdc
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current* (V_{DS} = 20 Vdc, V_{GS} = 0)	MFE2010 MFE2011 MFE2012	I_{DSS}*	15 40 100	- - -	mAdc
Gate-Source Voltage (V_{DS} = 15 Vdc, I_D = 1.0 μAdc)	MFE2010 MFE2011 MFE2012	V_{GS}	0.5 1.0 3.0	10 10 10	Vdc
Gate-Source Forward Voltage (I_G = 1.0 mAdc, V_{DS} = 0)		VGSF	-	1.0	Vdc
Drain-Source "ON" Voltage (I_D = 8.0 mAdc, V_{GS} = 0) (I_D = 15 mAdc, V_{GS} = 0) (I_D = 30 mAdc, V_{GS} = 0)	MFE2010 MFE2011 MFE2012	$V_{DS(on)}$	- - -	0.75 0.75 0.75	Vdc
Static Drain-Source "ON" Resistance (I_D = 1.0 mAdc, V_{GS} = 0)	MFE2010 MFE2011 MFE2012	$r_{DS(on)}$	- - -	25 15 10	Ohms
SMALL-SIGNAL CHARACTERISTICS					
Static Drain-Source "ON" Resistance (V_{GS} = 0, I_D = 0, f = 1.0 kHz)	MFE2010 MFE2011 MFE2012	$r_{ds(on)}$	- - -	25 15 10	Ohms
Input Capacitance (V_{DS} = 0, V_{GS} = 10 Vdc, f = 1.0 MHz)		C_{iss}	-	50	pF
Reverse Transfer Capacitance (V_{DS} = 0, V_{GS} = 12 Vdc, f = 1.0 MHz)		C_{rss}	-	20	pF
SWITCHING CHARACTERISTICS					
Turn-On Delay Time (See Figure 1)		$t_{d(on)}$	-	10	ns
Rise Time (See Figure 1)		t_r	-	6.0	ns
Turn-Off Delay Time (See Figure 1) (V_{DD} = 15 Vdc, I_D = 8.0 mAdc) (V_{DD} = 15 Vdc, I_D = 15 mAdc) (V_{DD} = 15 Vdc, I_D = 30 mAdc)	MFE2010 MFE2011 MFE2012	$t_{d(off)}$	- - -	35 20 12	ns
Fall Time (See Figure 1) (V_{DD} = 15 Vdc, I_D = 8.0 mAdc) (V_{DD} = 15 Vdc, I_D = 15 mAdc) (V_{DD} = 15 Vdc, I_D = 30 mAdc)	MFE2010 MFE2011 MFE2012	t_f	- - -	75 45 25	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 3.0%.

MFE2093 (SILICON)
MFE2094
MFE2095

CASE 20(3)
(TO-72)

Silicon N-channel junction field-effect transistors, designed for low-power audio-amplifier and switching applications. Drain and source interchangeable.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	50	Vdc
Drain-Gate Voltage	V_{DG}	50	Vdc
Gate-Source Voltage	V_{GS}	50	Vdc
Drain Current	I_D	3	mAdc
Power Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 2	mW mW/°C
Operating Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

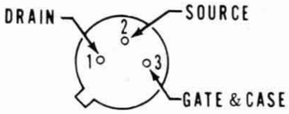
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Gate-Source Breakdown Voltage ($I_G = -10\ \mu Adc$, $V_{DS} = 0$)		$V_{(BR)GSS}$	50	-	-	Vdc
Gate Reverse Current ($V_{GS} = -15$ Vdc, $V_{DS} = 0$)		I_{GSS}	-	-	0.1	nAdc
($V_{GS} = -15$ Vdc, $V_{DS} = 0$, $T_A = 150°C$)			-	-	100	
Gate-Source Cutoff Voltage ($I_D = 0.1$ nAdc, $V_{DS} = 15$ Vdc)	MFE2093	$V_{GS(off)}$	-	1.5	2.5	Vdc
	MFE2094		-	3.0	4.5	
	MFE2095		-	4.5	5.5	
ON CHARACTERISTICS						
Zero-Gate-Voltage Drain Current* ($V_{DS} = 15$ Vdc, $V_{GS} = 0$)	MFE2093	I_{DSS}*	0.1	0.35	0.7	mAdc
	MFE2094		0.4	0.7	1.4	
	MFE2095		1.0	1.5	3.0	
DYNAMIC CHARACTERISTICS						
Forward Transfer Admittance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1 kHz)*	MFE2093	$\|y_{fs}\|$	250	400	500	µmhos
	MFE2094		350	500	700	
	MFE2095		400	600	800	
($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 100 MHz)	MFE2093		150	-	-	
	MFE2094		250	-	-	
	MFE2095		300	-	-	
Output Admittance* ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1 kHz)	MFE2093	$\|y_{os}\|$*	-	0.5	1.5	µmhos
	MFE2094		-	1.0	3.0	
	MFE2095		-	4.0	10.0	
Drain-Source Resistance ($V_{DS} = 0$, $V_{GS} = 0$)	MFE2093	$r_{ds(on)}$	-	2500	-	Ohms
	MFE2094		-	1600	-	
	MFE2095		-	1300	-	
Input Capacitance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 140 kHz)		C_{iss}	-	4.0	6.0	pF
Reverse Transfer Capacitance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 140 kHz)		C_{rss}	-	1.2	2.0	pF

*Pulse Test: Pulse Width ≦ 630 ms, Duty Cycle ≦ 10%

MFE2097 (SILICON)
MFE2098

CASE 79
(TO-39 with 1½″ leads)



N-channel junction silicon field-effect transistors designed for general purpose amplifier and audio driver applications.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

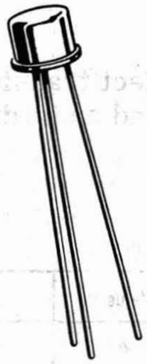
Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	50	Vdc
Drain-Gate Voltage	V_{DG}	50	Vdc
Gate-Source Voltage	V_{GS}	50	Vdc
Gate Current	I_G	10	mAdc
Total Device Dissipation @ T_C = 25° C Derate Above 25°C	P_D	1.5 10	W mW/°C
Operating Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = -10 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	50	—	—	Vdc
Gate Reverse Current (V_{GS} = -15 Vdc, V_{DS} = 0)	I_{GSS}	—	—	1.0	nAdc
(V_{GS} = -15 Vdc, V_{DS} = 0, T_A = 150°C)		—	—	1000	
Gate-Source Cutoff Voltage (I_D = 1.0 nAdc, V_{DS} = 15 Vdc) MFE2097	$V_{GS(off)}$	—	—	7	Vdc
MFE2098		—	—	10	
Gate-Source Voltage (I_D = 1.5 mAdc, V_{DS} = 15 Vdc) MFE2097	V_{GS}	0.5	—	5.0	Vdc
(I_D = 4.0 mAdc, V_{DS} = 15 Vdc) MFE2098		2.0	—	8	
ON CHARACTERISTICS					
Zero-Gate-Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0) MFE2097	I_{DSS}*	15	—	50	mAdc
MFE2098		40	—	100	
DYNAMIC CHARACTERISTICS					
Forward Transfer Admittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 kHz) MFE2097	$\lvert y_{fs} \rvert$*	10,000	—	20,000	μmhos
MFE2098		14,000	—	25,000	
Output Admittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 kHz) MFE2097	$\lvert y_{os} \rvert$*	—	—	200	μmhos
MFE2098		—	—	400	
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)	C_{iss}	—	14	20	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)	C_{rss}	—	3	5.0	pF
Output Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)	C_{osp}	—	5	—	pF

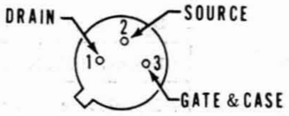
*Pulse Test: Pulse Width ≦ 630 ms; Duty Cycle ≦ 10%

MFE2133 (SILICON)



CASE 79 A
(TO-39 with 1½" leads)

N-channel junction silicon field-effect transistor designed for high-level chopper applications.



MAXIMUM RATINGS (T

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	**30**	**Vdc**
Drain-Gate Voltage	V_{DG}	**30**	**Vdc**
Gate-Source Voltage	V_{GS}	**30**	**Vdc**
Gate-Drain Current	I_G	**10**	**mAdc**
Total Device Dissipation @ T_C = 25°C **Derate Above 25°C**	P_D	**1.5** **10**	**W** **mW/°C**
Operating Junction Temperature	T_J	**175**	**°C**
Storage Temperature Range	T_{stg}	**-65 to +200**	**°C**

ELECTRICAL CHARACTERISTICS (T

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = -1 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	30	—	—	Vdc
Drain Cutoff Current (V_{DG} = 15 Vdc, I_S = 0) (V_{DG} = 15 Vdc, I_S = 0, T_A = 150°C)	I_{DGO}	— —	— —	1.0 1000	nAdc
ON CHARACTERISTICS					
Zero-Gate-Voltage Drain Current* (V_{DS} = 10 Vdc, V_{GS} = 0)	I_{DSS}*	25	—	—	mAdc
Drain Cutoff Current (V_{DS} = 10 Vdc, V_{GS} = -10 Vdc) (V_{DS} = 10 Vdc, V_{GS} = -10 Vdc, T_A = 150°C)	$I_{D(off)}$	— —	— —	1.0 1000	nAdc
DYNAMIC CHARACTERISTICS					
Forward Transfer Admittance* (V_{DS} = 10 Vdc, V_{GS} = 0, f = 1 kHz)	y_{fs} *	12000	—	—	μmhos
Drain-Source Resistance (V_{GS} = 0, I_D = 0, f = 1 kHz)	$r_{ds(on)}$	—	40	60	ohms
Input Capacitance (V_{DS} = 10 Vdc, V_{GS} = 0, f = 1 MHz)	C_{iss}	—	14	20	pF
Reverse Transfer Capacitance (V_{GS} = -10 Vdc, V_{DS} = 0, f = 1 MHz)	C_{rss}	—	3	5	pF

*Pulse Test: Pulse Width ≤ 630 ms; Duty Cycle = 10%

FIGURE 1 — DRAIN-SOURCE SATURATION REGION

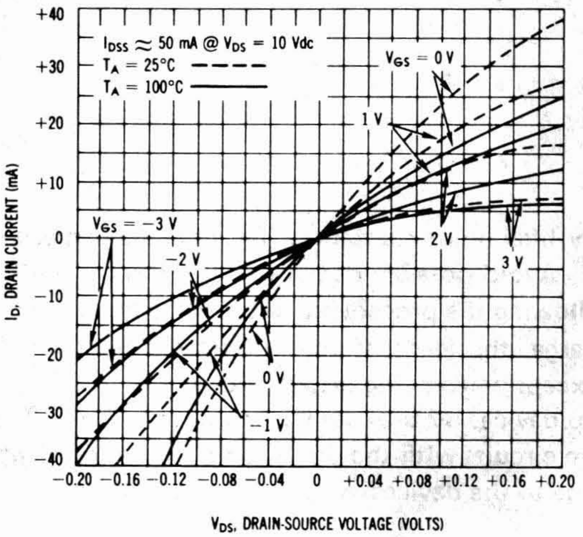
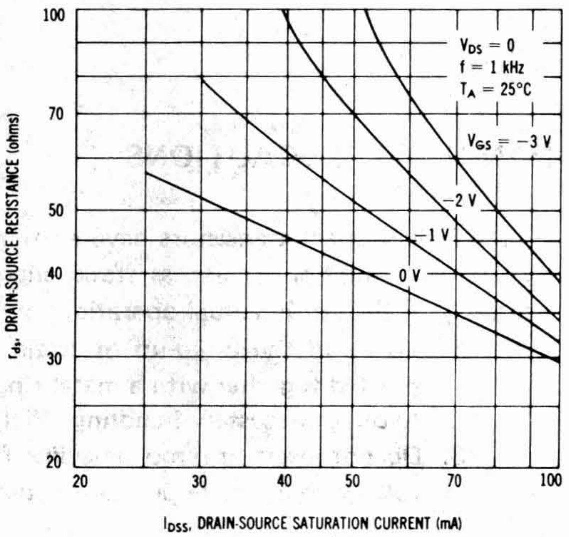


FIGURE 2 — DRAIN-SOURCE RESISTANCE



MFE3001 (SILICON)

CASE 20 (2)
(TO-72)

Silicon N-channel insulated-gate field-effect transistor designed for low-power applications in the audio frequency range.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	20	Vdc
Gate-Source Voltage	V_{GS}	±30	Vdc
Drain Current	I_D	20	mAdc
Power Dissipation at T_A = 25°C Derating Factor above 25°C	P_D	300 2.0	mW mW/°C
Operating Junction Temperature	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Drain-Source Breakdown Voltage (V_{GS} = -8 V, I_D = 10 μAdc)	BV_{DSX}	20	—	Vdc
Zero-Gate-Voltage Drain Current (V_{GS} = 0 Vdc, V_{DS} = 10 Vdc)	I_{DSS}	0.5	6.0	mAdc
Gate-Source Voltage Cutoff (I_{DS} = 1 μAdc, V_{DS} = 10 Vdc)	$V_{GS(off)}$	—	-8.0	Vdc
ON CHARACTERISTICS				
"On" Drain Current (V_{GS} = 3.5 Vdc, V_{DS} = 10 Vdc)	$I_{D(on)}$	5.0	—	mAdc
Gate-Reverse Current* (V_{GS} = -10 Vdc, V_{DS} = 0)	I_{GSS}*	—	10	pAdc
DYNAMIC CHARACTERISTICS				
Forward Transfer Admittance (V_{DS} = 10 Vdc, V_{GS} = 0, f = 1 kHz)	$\|y_{fs}\|$	700	3500	μmhos
Output Admittance (V_{DS} = 10 Vdc, V_{GS} = 0, f = 1 kHz)	$\|y_{os}\|$	—	100	μmhos
Input Capacitance (V_{DS} = 10 Vdc, V_{GS} = 0, f = 1 MHz)	C_{iss}	—	5.0	pF
Reverse Transfer Capacitance (V_{DS} = 10 Vdc, V_{GS} = 0, f = 1 MHz)	C_{rss}	—	1.5	pF

*This value of current includes both the FET leakage current as well as the leakage current associated with the test socket and fixture when measured under best attainable conditions.

MFE3002 (SILICON)

Active Elements Isolated From Case

CASE 20(7)
(TO-72)

Silicon N-channel MOS field-effect transistor designed for chopper applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	15	Vdc
Drain-Gate Voltage	V_{DG}	20	Vdc
Gate-Source Voltage	V_{GS}	±30	Vdc
Drain Current	I_D	30	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 2.0	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. **To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.**
2. **Avoid unnecessary handling. Pick up devices by the case instead of the leads.**
3. **Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.**

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Drain-Source Breakdown Voltage ($V_{GS} = 0$, $I_D = 10\ \mu Adc$)	BV_{DSS}	15	-	Vdc
Gate Leakage Current ($V_{GS} = 10$ Vdc, $V_{DS} = 0$)	I_{GSS}	-	100	pAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current ($V_{DS} = 10$ Vdc, $V_{GS} = 0$) ($V_{DS} = 10$ Vdc, $V_{GS} = 0$, $T_C = 125°C$)	I_{DSS}	- -	10 100	nAdc
Gate-Source Threshold Voltage ($V_{DS} = 10$ Vdc, $I_D = 10\ \mu Adc$)	$V_{GS(TH)}$	-	3.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Drain-Source Resistance ($V_{GS} = 10$ Vdc, $I_D = 0$, f = 1.0 kHz)	$r_{ds(on)}$	-	100	Ohms
Drain-Substrate Capacitance ($V_{D(SUB)} = 10$ Vdc, f = 1.0 MHz)	$C_{d(sub)}$	-	4.0	pF
Input Capacitance ($V_{DS} = 10$ Vdc, $V_{GS} = 0$, f = 1.0 MHz)	C_{iss}	-	5.0	pF
Reverse Transfer Capacitance ($V_{DS} = 0$, $V_{GS} = 0$, f = 1.0 MHz)	C_{rss}	-	1.0	pF

MFE3003 (SILICON)

Silicon P-channel MOS field-effect transistor designed for chopper applications.

CASE 20 (7)
(TO-72)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	15	Vdc
Drain-Gate Voltage	V_{DG}	20	Vdc
Gate-Source Voltage	V_{GS}	±30	Vdc
Drain Current	I_D	30	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 2.0	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Drain-Source Breakdown Voltage ($V_{GS} = 0$, $I_D = -10\ \mu Adc$)	$V_{(BR)DSS}$	15	-	Vdc
Gate Leakage Current ($V_{GS} = \pm 10$ Vdc, $V_{DS} = 0$)	I_{GSS}	-	100	pAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current ($V_{DS} = -10$ Vdc, $V_{GS} = 0$) ($V_{DS} = -10$ Vdc, $V_{GS} = 0$, $T_C = 125°C$)	I_{DSS}	- -	10 100	nAdc
Gate-Source Threshold Voltage ($V_{DS} = -10$ Vdc, $I_D = -10\ \mu Adc$)	$V_{GS(TH)}$	-	4.0	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Drain-Source Resistance ($V_{GS} = -10$ Vdc, $I_D = 0$, f = 1.0 kHz)	$r_{ds(on)}$	-	200	Ohms
Drain-Substrate Capacitance ($V_{D(SUB)} = -10$ Vdc, f = 1.0 MHz)	$C_{d(sub)}$	-	4.0	pF
Input Capacitance ($V_{DS} = -10$ Vdc, $V_{GS} = 0$, f = 1.0 MHz)	C_{iss}	-	5.0	pF
Reverse Transfer Capacitance ($V_{DS} = 0$, $V_{GS} = 0$, f = 1.0 MHz)	C_{rss}	-	1.0	pF

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

MFE3004 (SILICON)
MFE3005

CASE 20(7)
(TO-72)

Active Elements Isolated From Case

Silicon N-channel MOS field-effect transistors designed for VHF/UHF amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	20	Vdc
Drain-Gate Voltage	V_{DG}	20	Vdc
Gate-Source Voltage	V_{GS}	±30	Vdc
Drain Current	I_D	10	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 2.0	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
ON CHARACTERISTICS				
Drain-Source Breakdown Voltage (V_{GS} = -5.0 Vdc, I_D = 10 µAdc)	BV_{DSX}	20	-	Vdc
Gate-Source Cutoff Voltage (I_D = 10 µAdc, V_{DS} = 15 Vdc)	$V_{GS(off)}$	-	5.0	Vdc
Gate Reverse Current (V_{GS} = ±15 Vdc, V_{DS} = 0)	I_{GSS}	-	50	pAdc
OFF CHARACTERISTICS				
Zero-Gate Voltage Drain Current (V_{DS} = 15 Vdc, V_{GS} = 0)	I_{DSS}	2.0	10	mAdc
SMALL-SIGNAL CHARACTERISTICS				
Forward Transfer Admittance (V_{DS} = 15 Vdc, I_D = 2.0 mAdc, f = 1.0 kHz)	$\lvert y_{fs} \rvert$	2000	-	µmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	-	4.5	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	-	0.2	pF
Small-Signal Power Gain	G_{ps}			dB
(V_{DS} = 15 Vdc, I_D = 2.0 mAdc, R_S ≈ 1.8 k ohms, f = 200 MHz) (Figure 1) MFE3004		16	-	
(V_{DS} = 15 Vdc, I_D = 2.0 mAdc, R_S ≈ 650 ohms, f = 400 MHz) (Figure 2) MFE3005		10	-	
Noise Figure	NF			dB
(V_{DS} = 15 Vdc, I_D = 2.0 mAdc, R_S ≈ 1.8 k ohms, f = 200 MHz) (Figure 1) MFE3004		-	4.5	
(V_{DS} = 15 Vdc, I_D = 2.0 mAdc, R_S ≈ 650 ohms, f = 400 MHz) (Figure 2) MFE3005		-	4.5	

FIGURE 1 — 200 MHz TEST CIRCUIT NEUTRALIZED

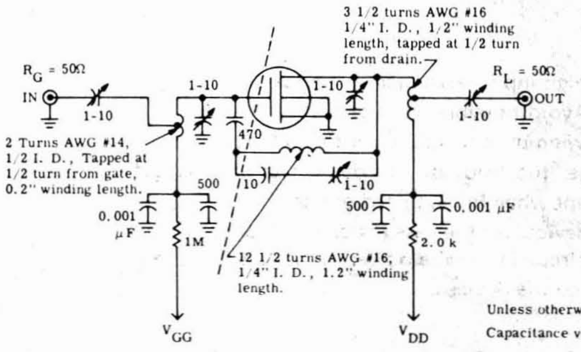
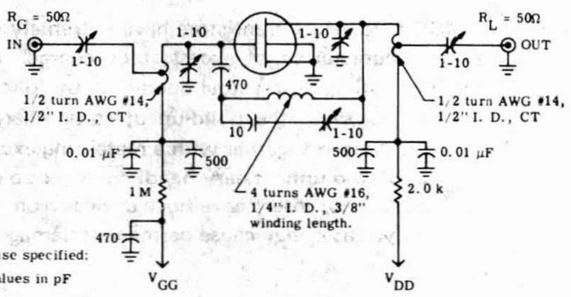
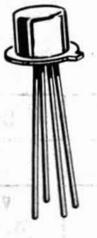

3 1/2 turns AWG #16 1/4" I. D., 1/2" winding length, tapped at 1/2 turn from drain.
R_G = 50Ω
IN
1-10
1-10
1-10
R_L = 50Ω
OUT
1-10
470
2 Turns AWG #14, 1/2 I. D., Tapped at 1/2 turn from gate, 0.2" winding length.
500
10
1-10
500
0.001 µF
0.001 µF
1M
2.0 k
12 1/2 turns AWG #16, 1/4" I. D., 1.2" winding length.
V_{GG}
V_{DD}

FIGURE 2 — 400 MHz TEST CIRCUIT NEUTRALIZED


R_G = 50Ω
IN
1-10
1-10
1-10
R_L = 50Ω
OUT
1-10
470
1/2 turn AWG #14, 1/2" I. D., CT
10
1-10
1/2 turn AWG #14, 1/2" I. D., CT
0.01 µF
500
500
0.01 µF
1 M
2.0 k
4 turns AWG #16, 1/4" I. D., 3/8" winding length.
470
V_{GG}
V_{DD}

Unless otherwise specified:
Capacitance values in pF

MFE3006 (SILICON)



CASE 20(9)
(TO-72)

N-channel dual-gate silicon-nitride passivated MOS field-effect transistor, depletion mode (Type B), designed for VHF amplifier and mixer applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Gate 1 Source Voltage	V_{GS1}	±35	Vdc
Gate 2 Source Voltage	V_{GS2}	±35	Vdc
Drain Current	I_D	30	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	300 1.7	mW mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

HANDLING PRECAUTIONS:

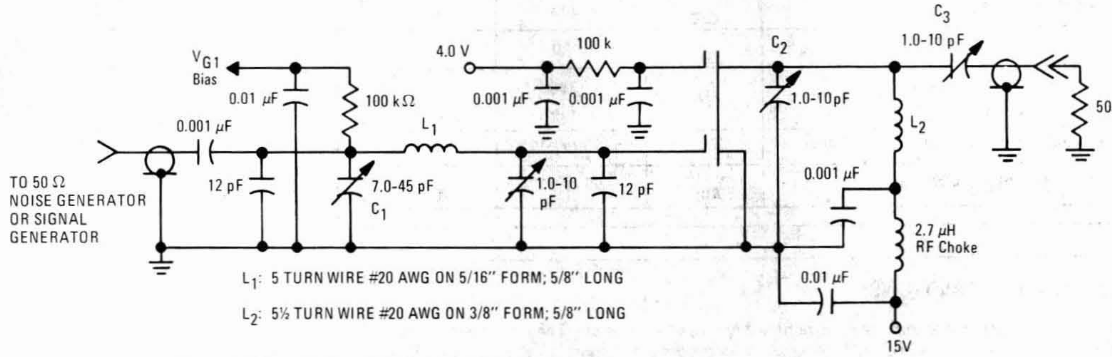
MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Drain-Source Breakdown Voltage (I_D = 10μAdc, V_S = 0, V_{G1} = V_{G2} = -4.0 Vdc)	$V_{(BR)DS}$	25	-	-	Vdc
Gate 1 to Source Cutoff Voltage (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 200 μAdc)	$V_{G1S(off)}$	-	-	3.0	Vdc
Gate 1 Reverse Leakage Current (V_{G1S} = -10 Vdc, V_{G2S} = 0, V_{DS} = 0)	I_{G1SS}	-	-	1.0	nAdc
Gate 2 Reverse Leakage Current (V_{G2S} = -10 Vdc, V_{G1S} = 0, V_{DS} = 0)	I_{G2SS}	-	-	1.0	nAdc
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current (V_{DS} = +15 Vdc, V_{G1S} = 0, V_{G2S} = +4.0 Vdc)	I_{DSS}	2.0	7.0	18	mAdc
SMALL-SIGNAL CHARACTERISTICS					
Forward Transadmittance (Gate 1 to Drain) (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, f = 1.0 kHz)	y_{fs}	8,000	-	18,000	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, f = 1.0 MHz)	C_{iss}	-	-	6.0	pF
Output Capacitance (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, f = 1.0 MHz)	C_{oss}	-	-	4.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, f = 1.0 MHz)	C_{rss}	-	0.02	-	pF
Common-Source Noise Figure (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, f = 100 MHz)	NF	-	3.0	4.5	dB
Common-Source Power Gain (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, f = 100 MHz)	G_{ps}	20	24	-	dB

FIGURE 1 — 100 MHz NOISE AND POWER GAIN TEST CIRCUIT


V_{G1} Bias
0.01 μF
100 kΩ
0.001 μF
4.0 V
100 k
0.001 μF
0.001 μF
L_1
C_2
1.0-10 pF
C_3
1.0-10 pF
L_2
50Ω
TO 50 Ω NOISE GENERATOR OR SIGNAL GENERATOR
12 pF
7.0-45 pF
C_1
1.0-10 pF
12 pF
0.001 μF
2.7 μH RF Choke
0.01 μF
15V

L_1: 5 TURN WIRE #20 AWG ON 5/16" FORM; 5/8" LONG

L_2: 5½ TURN WIRE #20 AWG ON 3/8" FORM; 5/8" LONG

NOTE1. ADJUST THE V_{G1} FOR 10 mA DRAIN CURRENT.

NOTE 2. ADJUST C_2 & C_3 FOR MAXIMUM OUTPUT & C_1 FOR MINIMUM NOISE FIGURE. THEN, MEASURE THE POWER GAIN

MFE3007 (SILICON)

N-CHANNEL DUAL-GATE SILICON-NITRIDE PASSIVATED MOS FIELD-EFFECT TRANSISTOR

. . . depletion mode (Type B) dual gate transistor designed for VHF amplifier and mixer applications.

- Silicon-Nitride Passivation for Excellent Long Term Stability
- High Common-Source Power Gain —
  G_{ps} = 18 dB (Min) @ f = 200 MHz
- Low Reverse Transfer Capacitance —
  C_{rss} = 0.02 pF (Typ) @ V_{DS} = 15 Vdc

N-CHANNEL

DUAL GATE
MOS FIELD-EFFECT
TRANSISTOR

TYPE B

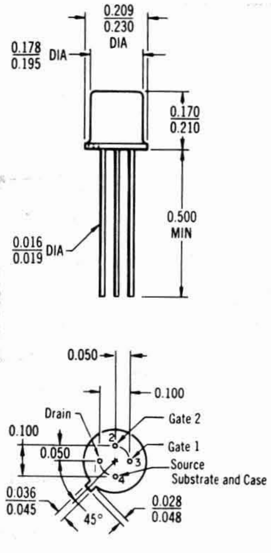
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	+25	Vdc
Gate 1 Source Voltage	V_{GS1}	±35	Vdc
Gate 2 Source Voltage	V_{GS2}	±35	Vdc
Drain Current	I_D	30	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 1.7	mW mW/°C
Operating Junction Temperature Range	T_J	-65 to +175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

HANDLING PRECAUTIONS:

MOS field-effect transistors have extremely high input resistance. They can be damaged by the accumulation of excess static charge. Avoid possible damage to the devices while handling, testing, or in actual operation, by following the procedures outlined below:

1. To avoid the build-up of static charge, the leads of the devices should remain shorted together with a metal ring except when being tested or used.
2. Avoid unnecessary handling. Pick up devices by the case instead of the leads.
3. Do not insert or remove devices from circuits with the power on because transient voltages may cause permanent damage to the devices.



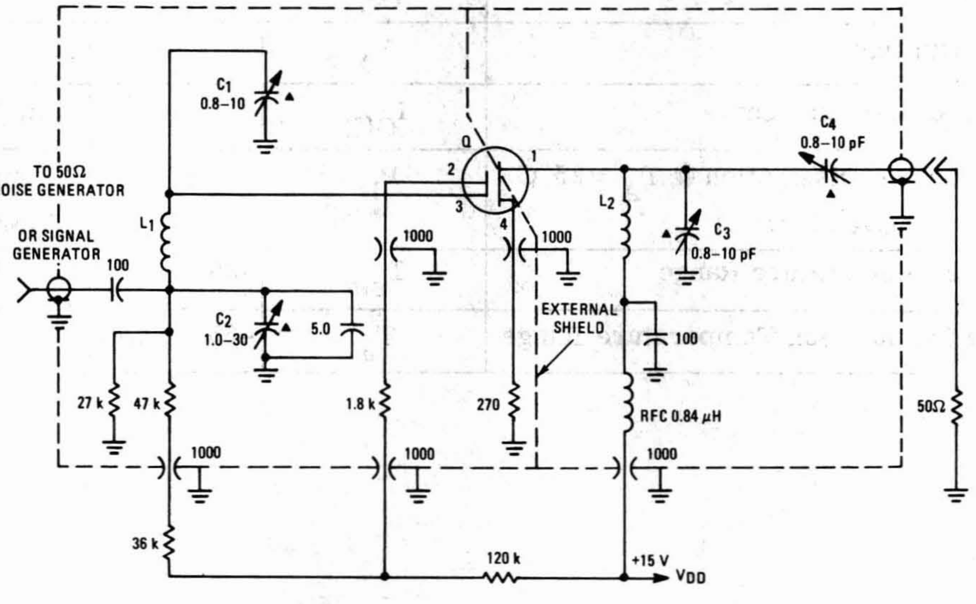
CASE 20 (9)
TO-72

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Substrate Connected to Source

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Drain-Source Breakdown Voltage (I_D = 10μAdc, V_S = 0, V_{G1} = V_{G2} = -4.0 Vdc)	$V_{(BR)DSX}$	25	-	-	Vdc
Gate 1 to Source Cutoff Voltage (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 200 μAdc)	$V_{G1S(off)}$	-	-	-3.0	Vdc
Gate 2 to Source Cutoff Voltage (V_{DS} = 15 Vdc, V_{G1S} = 0, I_D = 200 μAdc)	$V_{G2S(off)}$	-	-	-3.0	Vdc
Gate 1 Reverse Leakage Current (V_{G1S} = -10 Vdc, V_{G2S} = 0, V_{DS} = 0)	I_{G1SS}	-	-	1.0	nAdc
Gate 2 Reverse Leakage Current (V_{G2S} = -10 Vdc, V_{G1S} = 0, V_{DS} = 0)	I_{G2SS}	-	-	1.0	nAdc
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current (V_{DS} = +15 Vdc, V_{G1S} = 0, V_{G2S} = +4.0 Vdc)	I_{DSS}	5.0	10	20	mAdc
SMALL-SIGNAL CHARACTERISTICS					
Forward Transadmittance (Gate 1 to Drain) (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, f = 1.0 kHz)	y_{fs}	10,000	-	18,000	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, f = 1.0 MHz)	C_{iss}	-	4.5	5.5	pF
Output Capacitance (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, f = 1.0 MHz)	C_{oss}	-	2.5	3.5	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, f = 1.0 MHz)	C_{rss}	-	0.02	-	pF
Common-Source Noise Figure (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, R_S ≈ 1000 Ohms, f = 200 MHz)	NF	-	3.0	4.0	dB
Common-Source Power Gain (V_{DS} = 15 Vdc, V_{G2S} = +4.0 Vdc, I_D = 10 mAdc, f = 200 MHz)	G_{ps}	18	24	-	dB

FIGURE 1 — 200 MHz NOISE AND POWER GAIN TEST CIRCUIT


TO 50Ω
NOISE GENERATOR
OR SIGNAL
GENERATOR
100
C1
0.8–10
L1
C2
1.0–30
5.0
27 k
47 k
36 k
1000
1000
1000
1.8 k
Q
1
2
3
4
1000
1000
270
EXTERNAL
SHIELD
L2
C3
0.8–10 pF
100
RFC 0.84 μH
1000
C4
0.8–10 pF
50Ω
120 k
+15 V
VDD

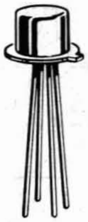
▲ JOHANSON CAPACITORS

L_1: 4 Turns #16 AWG Wire (Internal diameter 1/4" Length 3/4".)

L_2: 5 Turns #16 AWG Wire (Internal diameter 1/4" Length 3/4".)

NOTE: Adjust C_1 and C_3 for maximum output and C_1 for minimum noise figure and measure the power gain.

MFE4007 (SILICON)
thru
MFE4012



CASE 20 (5)
(TO-72)

P-channel junction field-effect transistors, depletion mode (Type A) designed for general-purpose amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	40	Vdc
Drain-Gate Voltage	V_{DG}	40	Vdc
Reverse Gate-Source Voltage	$V_{GS(r)}$	40	Vdc
Drain Current	I_D	20	mAdc
Forward Gate Current	$I_{G(f)}$	10	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 2.0	mW mW/°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Operating Junction Temperature Range	T_J	-65 to +175	°C

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)		$V_{(BR)GSS}$	40	-	Vdc
Gate-Source Cutoff Voltage (V_{DS} = 15 Vdc, I_D = 1.0 μAdc)	MFE4007, MFE4008 MFE4009, MFE4010 MFE4011, MFE4012	$V_{GS(off)}$	- - -	3.0 6.0 8.0	Vdc
Gate Reverse Current (V_{GS} = 20 Vdc, V_{DS} = 0) (V_{GS} = 20 Vdc, V_{DS} = 0, T_A = 150°C)		I_{GSS}	- -	2.0 2.0	nAdc μAdc
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current (V_{DS} = 15 Vdc, V_{GS} = 0)	MFE4007 MFE4008 MFE4009 MFE4010 MFE4011 MFE4012	I_{DSS}	0.5 0.8 1.5 2.5 4.0 7.0	1.0 1.6 3.0 5.0 8.0 14	mAdc
Gate-Source Voltage (V_{DS} = 15 Vdc, I_D = 50 μAdc) (V_{DS} = 15 Vdc, I_D = 80 μAdc) (V_{DS} = 15 Vdc, I_D = 150 μAdc) (V_{DS} = 15 Vdc, I_D = 250 μAdc) (V_{DS} = 15 Vdc, I_D = 400 μAdc) (V_{DS} = 15 Vdc, I_D = 700 μAdc)	MFE4007 MFE4008 MFE4009 MFE4010 MFE4011 MFE4012	V_{GS}	0.3 0.4 1.0 1.0 2.0 2.0	1.5 2.0 4.0 4.0 6.0 6.0	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Forward Transadmittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	MFE4007 MFE4008 MFE4009 MFE4010 MFE4011 MFE4012	$\|y_{fs}\|$	900 1000 1500 2000 2200 2500	2700 3000 3500 4000 4500 5000	μmhos
Forward Transconductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)	MFE4007 MFE4008 MFE4009 MFE4010 MFE4011 MFE4012	$Re(y_{fs})$	800 900 1400 1700 1900 2100	- - - - - -	μmhos
Output Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)		$\|y_{os}\|$	-	75	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)		C_{iss}	-	7.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)		C_{rss}	-	2.0	pF
Common-Source Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_G = 1.0 Megohm, f = 100 Hz, BW = 1.0 Hz)		NF	-	2.5	dB
Equivalent Short-Circuit Input Noise Voltage (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 Hz, BW = 1.0 Hz)		e_n	-	115	$nV/\sqrt{Hz}$

TRANSFER CHARACTERISTIC CURVES FOR MIN/MAX I_{DSS} LIMITS

FIGURE 1

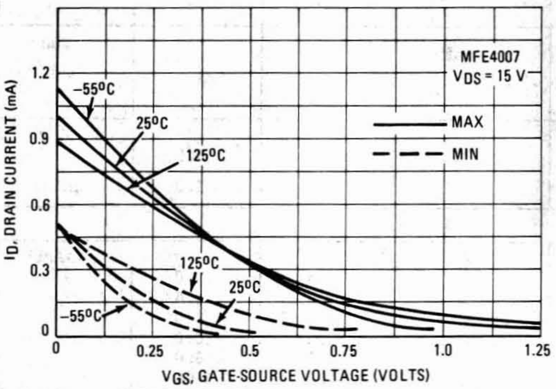


FIGURE 2

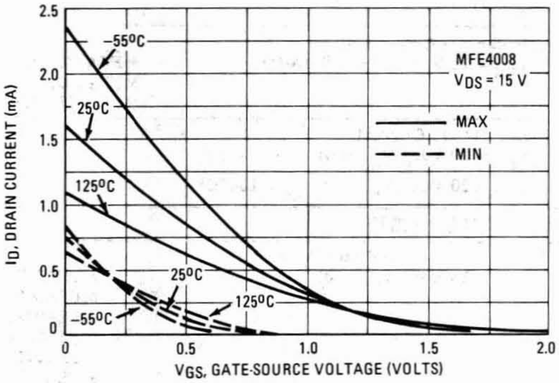


FIGURE 3

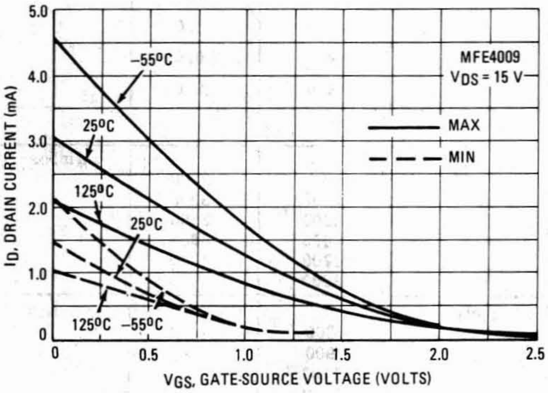


FIGURE 4

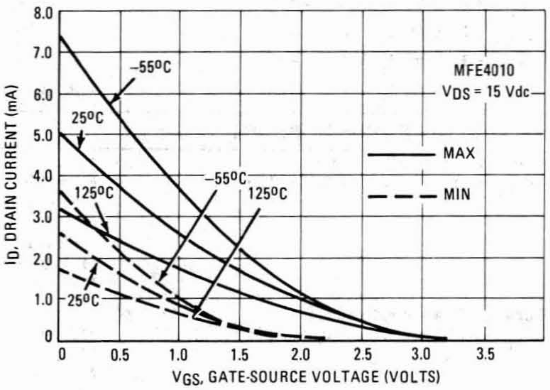


FIGURE 5

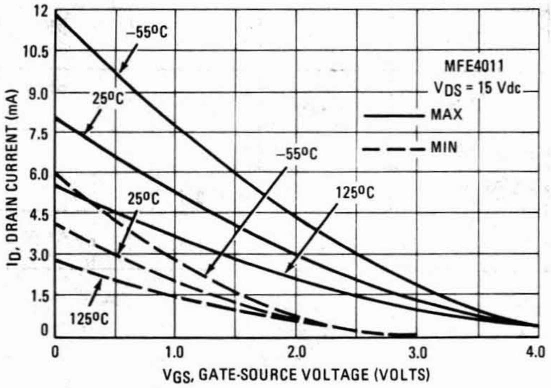
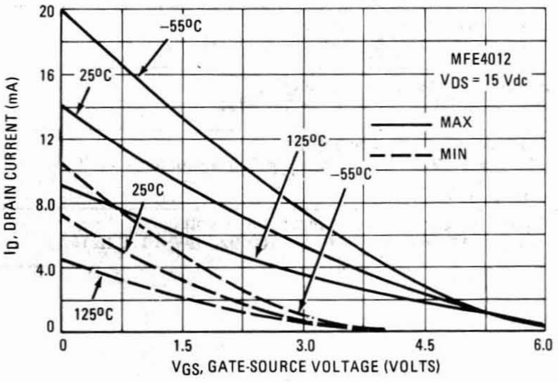


FIGURE 6



TYPICAL AND MINIMUM FORWARD TRANSFER ADMITTANCE

FIGURE 7

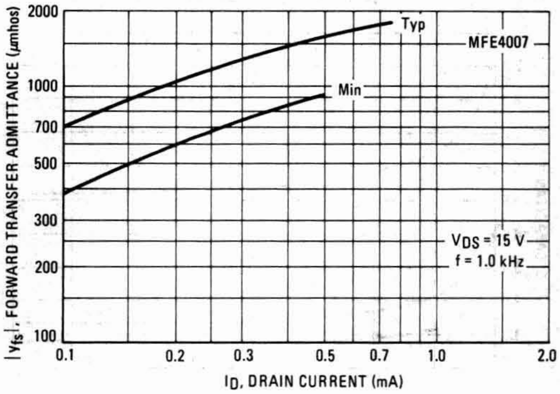


FIGURE 8

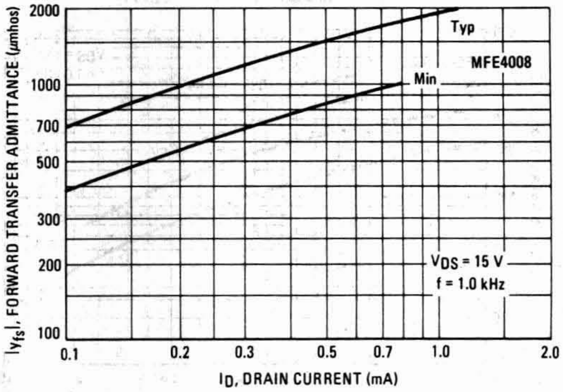


FIGURE 9

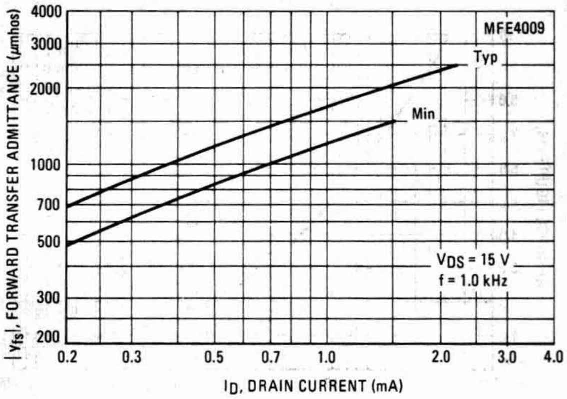


FIGURE 10

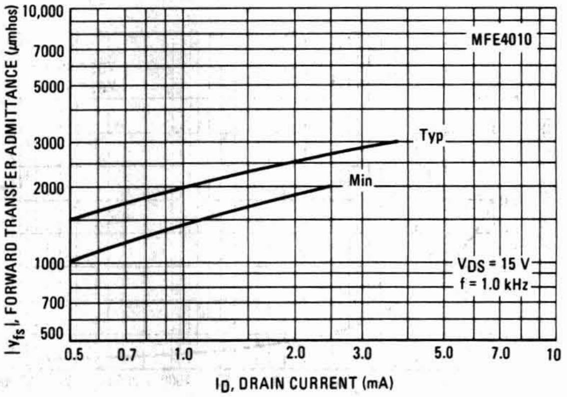


FIGURE 11

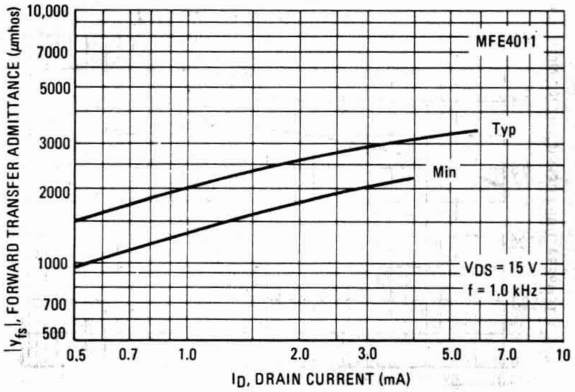
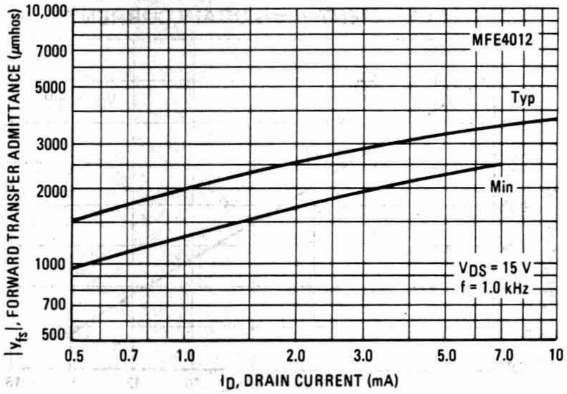


FIGURE 12



TYPICAL CURVES

FIGURE 13 – OUTPUT RESISTANCE versus DRAIN CURRENT

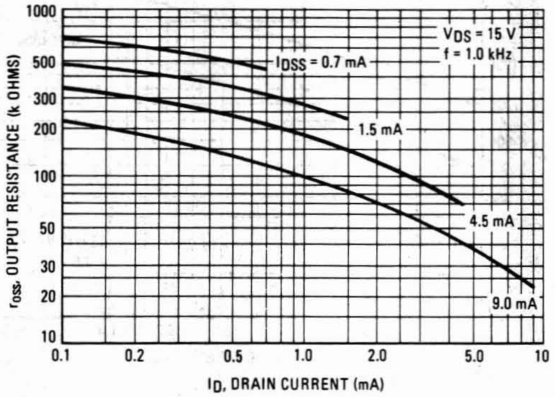


FIGURE 14 – CAPACITANCE versus DRAIN-SOURCE VOLTAGE

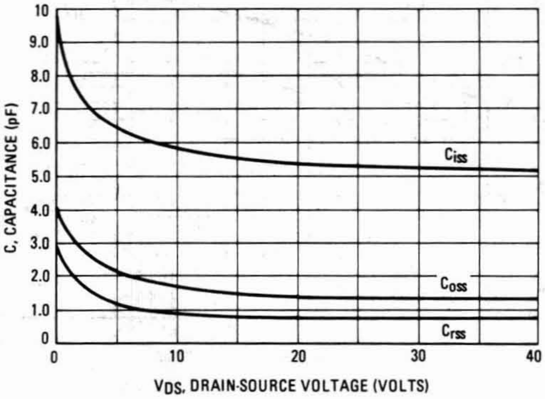


FIGURE 15 – NOISE FIGURE versus FREQUENCY

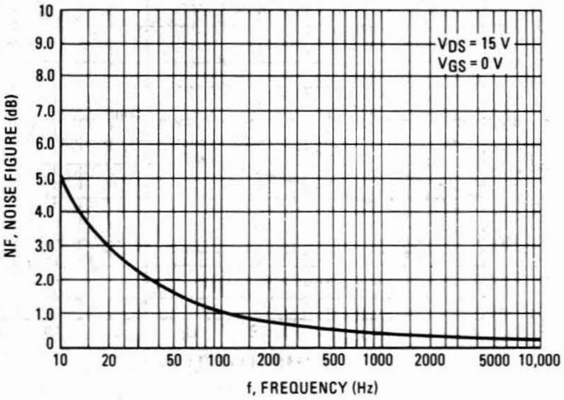


FIGURE 16 – NOISE FIGURE versus SOURCE RESISTANCE

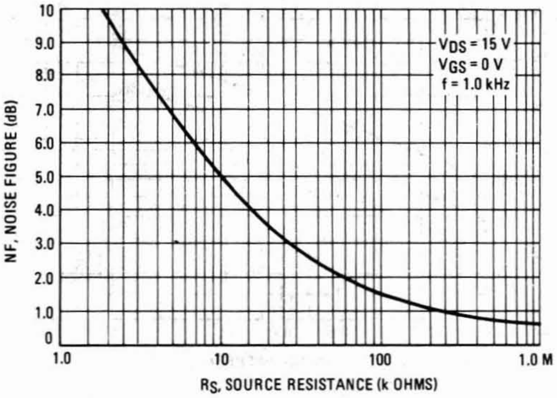


FIGURE 17 – DRAIN CURRENT TEMPERATURE COEFFICIENT versus DRAIN CURRENT

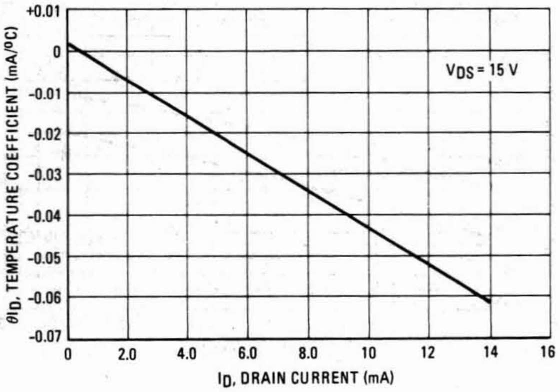


FIGURE 18 – TEMPERATURE COEFFICIEN versus DRAIN CURRENT

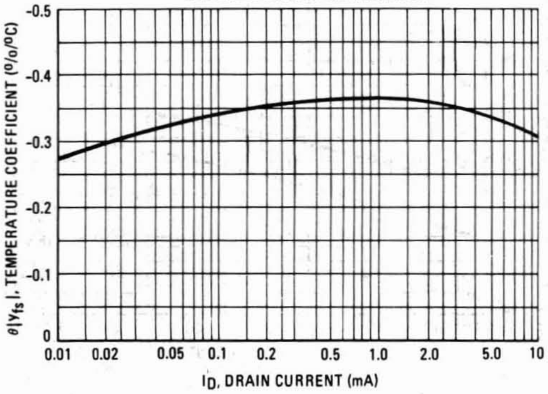
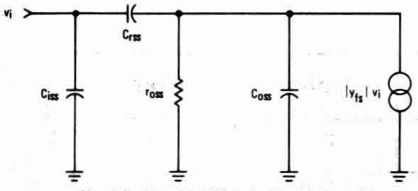


FIGURE 19 – EQUIVALENT LOW FREQUENCY CIRCUIT



Common Source
y Parameters for Frequencies
Below 30 MHz

$y_{is} = j\omega C_{iss}$
$y_{os} = j\omega C_{osp}{}^{*} + 1/r_{oss}$
$y_{fs} = |y_{fs}|$
$y_{rs} = -j\omega C_{rss}$

$^{*}C_{osp}$ is C_{oss} in parallel with Series Combination of C_{iss} and C_{rss}.

BIAS NETWORK DESIGN FOR WORST CASE I_{DSS} VARIANCE

This Designers Data Sheet has been published to assist the circuit designer in optimizing his "worst case" design. The following example illustrates the use of the forward transfer characteristics curves (Pigures 1 thru 6) in the design of a typical bias network.

Given: V_{DD} = -30 Vdc, I_D = 1.0 ± 0.25 mAdc from -55°C to +125°C

Procedure: The MFE4010 "worst case" bias conditions across the temperature range (from Figure 4) are reproduced in Figure A. The first step in the bias network design is to determine the value of the source resistance (R_S) necessary to hold the ± 0.25 mAdc I_D bias tolerance. To solve R_S, plot $I_{D(max)}$ and $I_{D(min)}$ on Figure A and calculate R_S, and V_G.

$$R_S = \frac{V_{GS(max)} - V_{GS(min)}}{I_{D(max)} - I_{D(min)}} = \frac{1.9\ \text{Vdc} - 0.8\ \text{Vdc}}{(1.25\ \text{mA} - 0.75\ \text{mA})} = 2.2\ \text{k Ohms}$$

$$V_G = \frac{I_{D(max)}\,V_{GS(min)} - I_{D(min)}\,V_{GS(max)}}{I_{D(max)} - I_{D(min)}}$$

$$= \frac{1.25 \times 0.80 - 0.75 \times 1.9}{0.5} = -0.9\ \text{Vdc}$$

In Figure B the maximum allowable value for R_1 will be determined by loading due to gate reverse current. Gate reverse current variations with temperature follow the pattern of all silicon devices, and, as a rule, we can assume that it will double with each 15°C temperature rise. Therefore, we can assume a maximum reverse current of approximately 0.5 μAdc at 125°C, based on the specified maximum 2.0 μAdc reverse at 150°C. The variation in V_G bias versus temperature will not be too great if we chose a value for R_1 which results in a bias network current (I_1 in Figure B) greater than 5 times the maximum reverse current. Assuming a value for R_1 of 9.1 Megohms, R_2 can be solved from the equation:

$$V_G = -0.9\ \text{Vdc} \approx \frac{-30\ R_2}{9.1 + R_2}\ \text{(Ignoring } I_G\text{)}$$

$$R_2 \approx 300\ \text{k Ohms}$$

Using the above values of R_1 and R_2, the variation in V_G can be computed for I_G = 0 to I_G = 0.5 μAdc. V_G will vary from 0.81 Vdc at I_G = 0.5 μAdc to 0.96 Vdc @ I_G = 0. This variation will have a minimal effect on I_D, as can be seen from Figure A by plotting load lines with a slope equal to $1/R_S$ from V_G = 0.81 Vdc and 0.96 Vdc respectively.

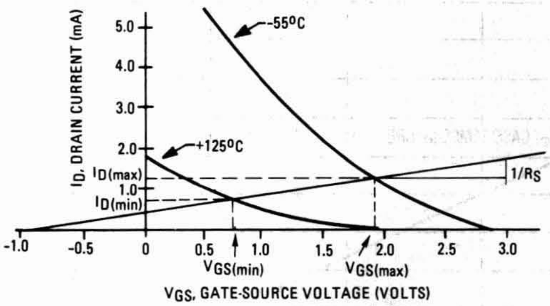


FIGURE A

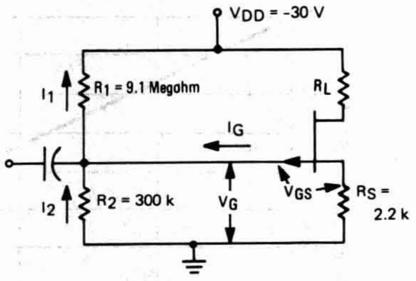
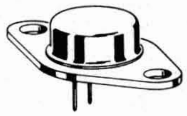


FIGURE B

MJ400 (SILICON)

High-voltage NPN silicon transistor designed for video output circuitry in color television receivers.



CASE 80
(TO-66)

Collector connected to case

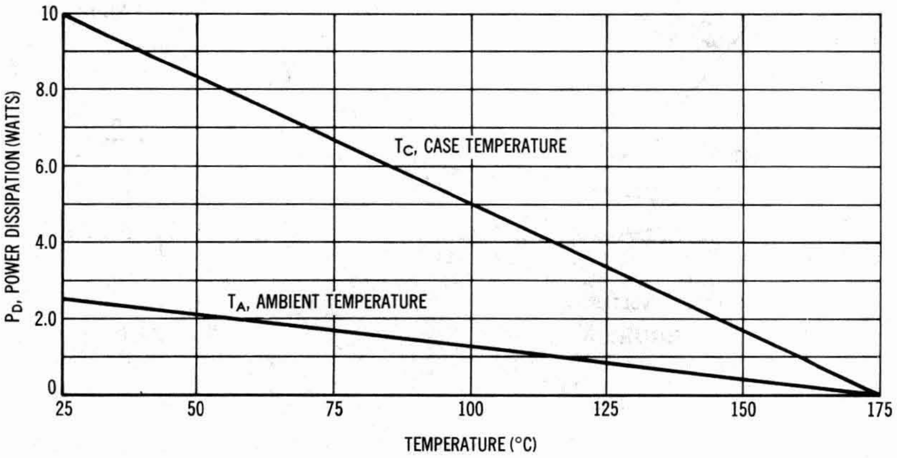
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	325	Vdc
Collector-Base Voltage	V_{CB}	350	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current-Continuous Peak	I_C	250 1000	mAdc
Base Current	I_B	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	2.5 0.0167	Watts W/°C
Total Device Dissipation @ $T_C = 75°C$ Derate above 75°C	P_D	6.67 0.067	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	15	°C/W
Thermal Resistance, Case to Ambient	θ_{CA}	60	°C/W

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 1.0 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	325	—	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	350	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current (V_{CE} = 325 Vdc, I_B = 0)	I_{CEO}	—	1.0	mAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc)	h_{FE}	30	300	—
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 5 mAdc)	$V_{CE(sat)}$	—	5.0	Vdc
Base-Emitter On Voltage (I_C = 50 mAdc, V_{CE} = 10 Vdc)	$V_{BE(on)}$	—	1.0	Vdc
SMALL SIGNAL CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 25 Vdc, f = 10 MHz)	f_T	15	—	MHz
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	10	pF
Small Signal Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{fe}	25	—	—

*Pulse Test: PW ≤ 300 μs, duty cycle ≤ 2%

FIGURE 2 — CURRENT GAIN CHARACTERISTICS

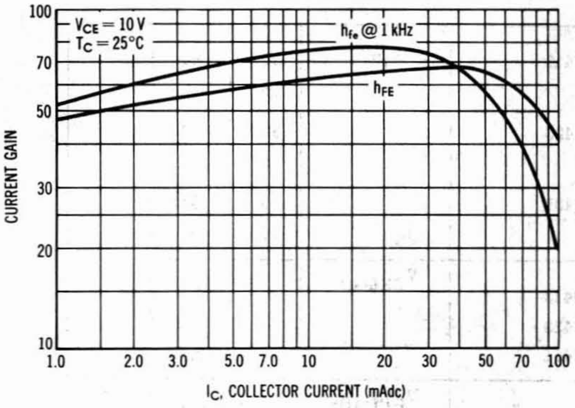
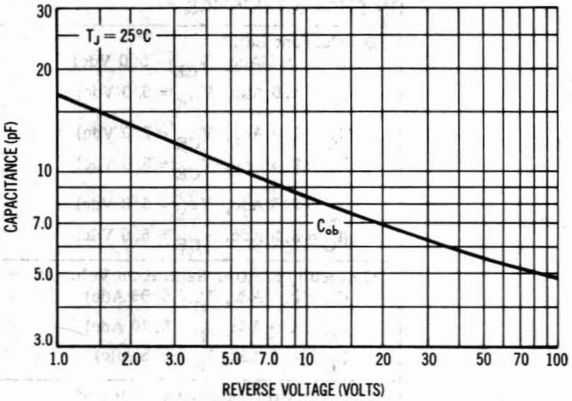
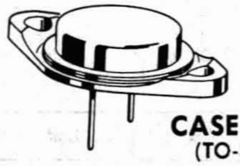


FIGURE 3 — OUTPUT CAPACITANCE



MJ413 (SILICON)
MJ423
MJ431

High-voltage NPN silicon transistors designed for medium-to-high-voltage inverters, converters, regulators and switching circuits.



CASE 11
(TO-3)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	MJ413	MJ423	MJ431	Unit
Collector-Emitter Voltage	V_{CEX}	400	400	400	Vdc
Collector-Base Voltage	V_{CB}	400	400	400	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	5.0	Vdc
Collector Current — Continuous	I_C	10	10	10	Adc
Base Current	I_B	2.0	2.0	2.0	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	125 1.0			Watts W/°C
Operation Junction Temperature Range	T_J	-65 to +150			°C
Storage Temperature Range	T_{stg}	-65 to +200			°C

THERMAL CHARACTERISTICS

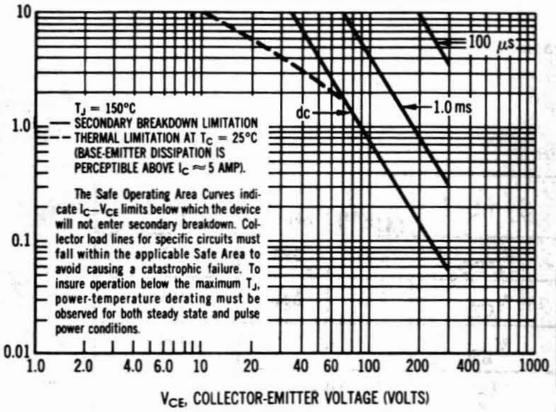
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.0	°C/W

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 100 mAdc, I_B = 0)		$BV_{CEO(sus)}$*	325	—	Vdc
Collector Cutoff Current		I_{CEX}			mAdc
(V_{CE} = 400 Vdc, $V_{EB(off)}$ = 1.5 Vdc)	MJ413, MJ423		—	0.25	
	MJ431		—	2.5	
(V_{CE} = 400 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 125°C)	MJ413, MJ423		—	0.5	mAdc
	MJ431		—	5.0	
Emitter Cutoff Current		I_{EBO}			mAdc
(V_{BE} = 5.0 Vdc, I_C = 0)	MJ413, MJ423		—	5.0	
	MJ431		—	2.0	
ON CHARACTERISTICS					
DC Current Gain*		h_{FE}*			—
(I_C = 0.5 Adc, V_{CE} = 5.0 Vdc)	MJ413		20	80	
(I_C = 1.0 Adc, V_{CE} = 5.0 Vdc)			15	—	
(I_C = 1.0 Adc, V_{CE} = 5.0 Vdc)	MJ423		30	90	
(I_C = 2.5 Adc, V_{CE} = 5.0 Vdc)			10	—	
(I_C = 2.5 Adc, V_{CE} = 5.0 Vdc)	MJ431		15	35	
(I_C = 3.5 Adc, V_{CE} = 5.0 Vdc)			10	—	
Collector-Emitter Saturation Voltage*		$V_{CE(sat)}$*			Vdc
(I_C = 0.5 Adc, I_B = 0.05 Adc)	MJ413		—	0.8	
(I_C = 1.0 Adc, I_B = 0.10 Adc)	MJ423		—	0.8	
(I_C = 2.5 Adc, I_B = 0.5 Adc)	MJ431		—	0.7	
Base-Emitter Saturation Voltage*		$V_{BE(sat)}$*			Vdc
(I_C = 0.5 Adc, I_B = 0.05 Adc)	MJ413		—	1.25	
(I_C = 1.0 Adc, I_B = 0.1 Adc)	MJ423		—	1.25	
(I_C = 2.5 Adc, I_B = 0.5 Adc)	MJ431		—	1.5	
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 200 mAdc, V_{CE} = 10Vdc, f = 1.0 MHz)		f_T	2.5	—	MHz

*PW ≤ 300 μs, Duty Cycle ≤ 2.0%

FIGURE 1 — ACTIVE-REGION SAFE-OPERATING AREA



The Safe Operating Area Curves indicate I_C–V_{CE} limits below which the device will not enter secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a catastrophic failure. To insure operation below the maximum T_J, power-temperature derating must be observed for both steady state and pulse power conditions.

FIGURE 2 — POWER-TEMPERATURE DERATING CURVE

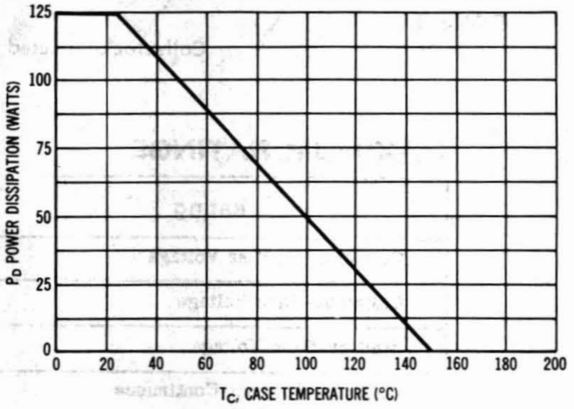


FIGURE 3 — SUSTAINING VOLTAGE TEST LOAD LINE

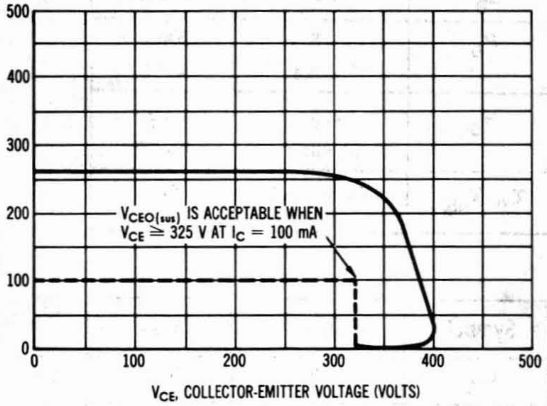


FIGURE 4 — SUSTAINING VOLTAGE TEST CIRCUIT

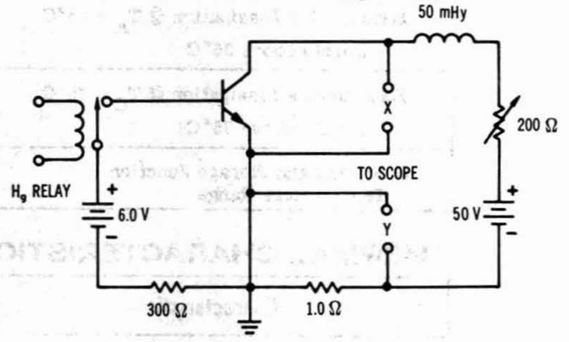


FIGURE 5 — CURRENT GAIN

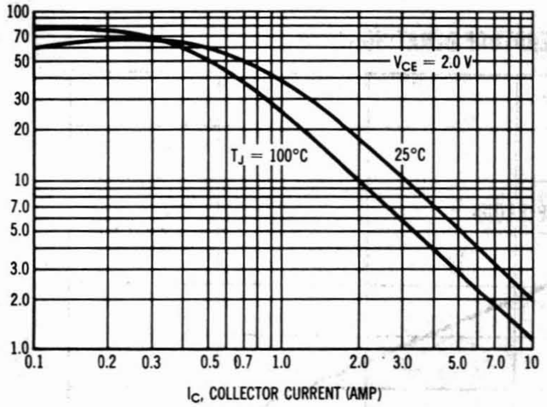
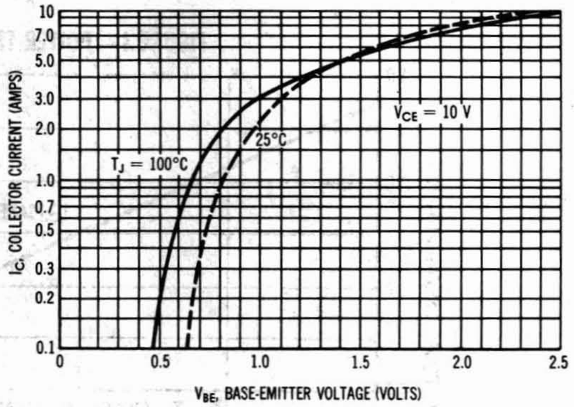
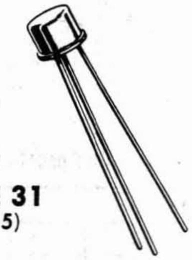


FIGURE 6 — TRANSCONDUCTANCE



MJ420 (SILICON)
MJ421



CASE 31
(TO-5)

NPN silicon high-voltage transistors designed for video output circuitry in transistorized television receivers.

Collector connected to case

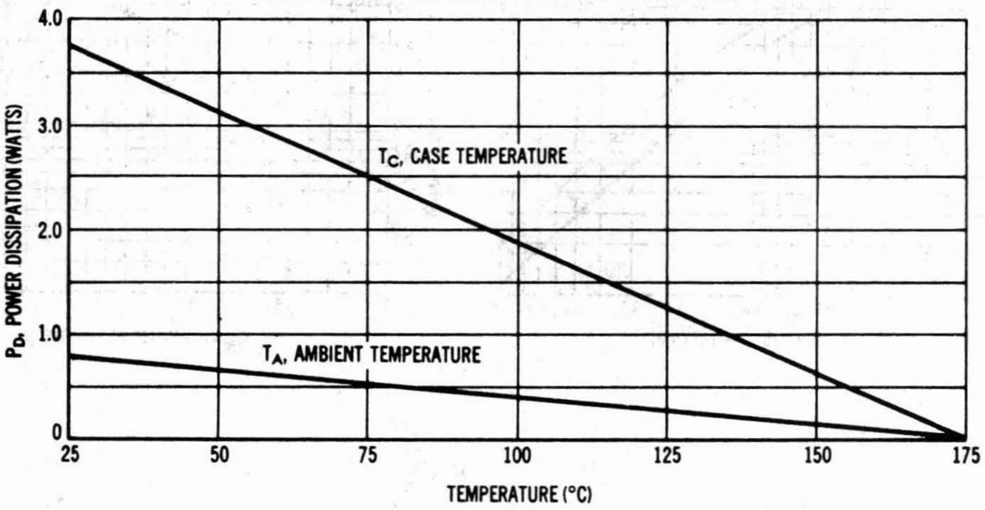
MAXIMUM RATINGS

Rating	Symbol	Value		Unit
		MJ420	MJ421	
Collector-Emitter Voltage	V_{CEO}	250	325	Vdc
Collector-Base Voltage	V_{CB}	275	350	Vdc
Emitter-Base Voltage	V_{EB}	6		Vdc
Collector Current-Continuous Peak	I_C	100 500		mAdc
Base Current	I_B	50		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.8 0.0053		Watts W/°C
Total Device Dissipation @ $T_C = 75°C$ Derate above 75°C	P_D	2.5 0.025		Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	40	°C/W
Thermal Resistance, Case to Ambient	θ_{CA}	187	°C/W

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



MJ420, MJ421 (continued)

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0) MJ420 MJ421	$BV_{CEO(sus)}$*	250 325	— —	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0) MJ420 MJ421	BV_{CBO}	275 350	— —	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	6	—	Vdc
Collector Cutoff Current (V_{CE} = rated voltage, I_B = 0)	I_{CEO}	—	1.0	mAdc
Collector Cutoff Current (V_{CB} = rated voltage, I_E = 0)	I_{CBO}	—	0.1	mAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 1.0 mAdc, V_{CE} = 20 Vdc) (I_C = 10 mAdc, V_{CE} = 20 Vdc) (I_C = 30 mAdc, V_{CE} = 20 Vdc)	h_{FE}	 15 25 25	 — — 250	—
Collector-Emitter Saturation Voltage (I_C = 30 mAdc, I_B = 3.0 mAdc)	$V_{CE(sat)}$	—	5.0	Vdc
Base-Emitter On Voltage (I_C = 30 mAdc, V_{CE} = 20 Vdc)	$V_{BE(on)}$	—	1.0	Vdc
SMALL SIGNAL CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 10 MHz)	f_T	15	—	MHz
Common-Emitter Reverse Transfer Capacitance (V_{CE} = 20 Vdc, I_C = 0)	C_{re}	—	12	pF
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	12	pF
Small Signal Current Gain (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 1 kHz)	h_{fe}	25	—	—

*Pulse Test: PW ≤ 300 μs, duty cycle ≤ 2%

FIGURE 2 — CURRENT GAIN CHARACTERISTICS

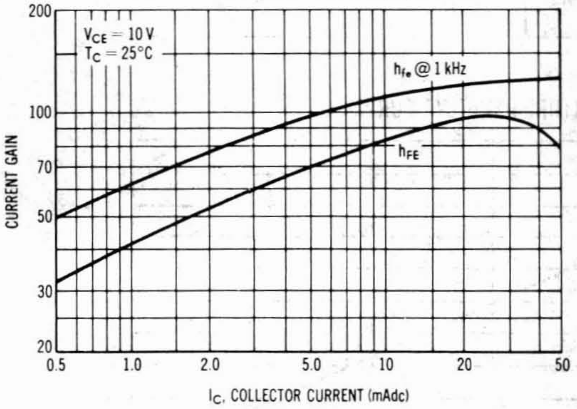
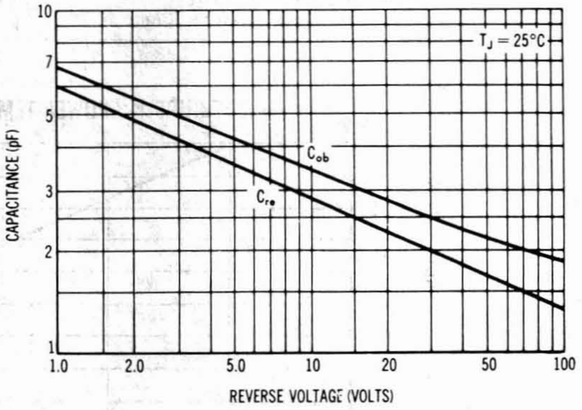


FIGURE 3 — CAPACITANCE versus VOLTAGE



MJ423
MJ431

For Specifications, See MJ413 Data.

MJ2249 (SILICON)
MJ2250
MJ3101

Medium-power NPN silicon transistors ideal for use as drivers, switches, amplifiers.

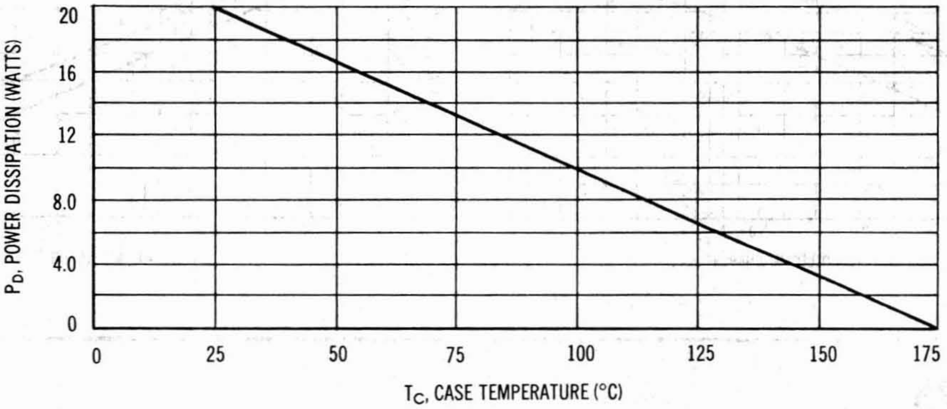
CASE 80
(TO-66)

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	MJ3101	MJ2249	MJ2250	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	80	Vdc
Collector-Base Voltage	V_{CB}	50	60	80	Vdc
Emitter-Base Voltage	V_{EB}	← 6.0 →			Vdc
Collector Current - Continuous Peak	I_C	← 2.0 → ← 3.0 →			Adc
Base Current	I_B	← 0.5 →			Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	← 20 → ← 0.133 →			Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	← -65 to +175 →			°C

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



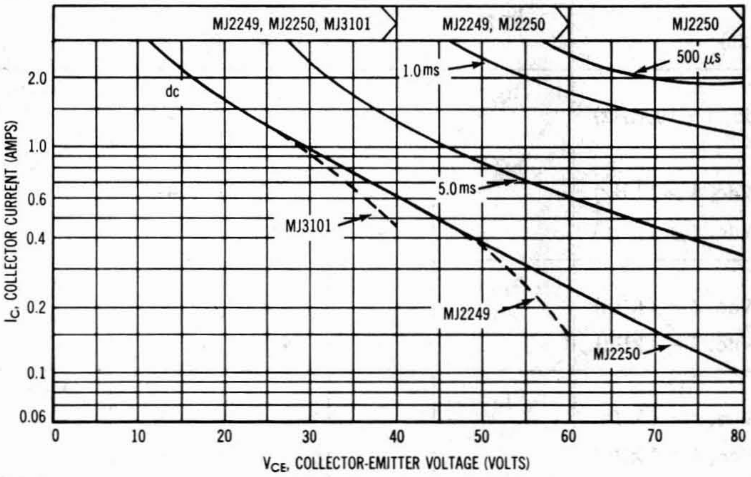
Safe Area Curves are indicated by Figure 2. Both limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Voltage*		BV_{CEO}*			Vdc
(I_C = 100 mAdc, I_B = 0)	MJ3101		40	—	
	MJ2249		60	—	
	MJ2250		80	—	
Collector-Base Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 50 Vdc, I_E = 0)	MJ3101			1.0	
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)			—	2.0	
(V_{CB} = 60 Vdc, I_E = 0)	MJ2249		—	1.0	
(V_{CB} = 60 Vdc, I_E = 0, T_A = 150°C)			—	2.0	
(V_{CB} = 80 Vdc, I_E = 0)	MJ2250		—	1.0	
(V_{CB} = 80 Vdc, I_E = 0, T_A = 150°C)			—	2.0	
Emitter-Base Cutoff Current (V_{EB} = 6.0 Vdc, I_C = 0)		I_{EBO}	—	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			—
(I_C = 50 mAdc, V_{CE} = 4.0 Vdc)			25	—	
(I_C = 100 mAdc, V_{CE} = 4.0 Vdc)†			25	200	
(I_C = 500 mAdc, V_{CE} = 4.0 Vdc)*			25*	200*	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)	All Types		—	1.0	
(I_C = 750 mAdc, I_B = 75 mAdc)	MJ3101		—	2.5	
(I_C = 1.0 Adc, I_B = 0.1 Adc)	MJ2249, MJ2250		—	2.5	
Base-Emitter Saturation Voltages		$V_{BE(sat)}$			Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)	All Types		—	1.2	
(I_C = 750 mAdc, I_B = 75 mAdc)	MJ3101		—	1.5	
(I_C = 1.0 Adc, I_B = 0.1 Adc)	MJ2249, MJ2250		—	1.5	
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 100 mAdc, V_{CE} = 10 Vdc, f = 10 MHz)		f_T	10	—	MHz

*PULSE TEST: PW ≤ 300 μs, Duty Cycle ≤ 2.0% †Color coded h_{FE} groups available at 100 mAdc

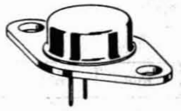
FIGURE 2 — ACTIVE REGION SAFE OPERATING AREAS



The Safe Operating Area Curves indicate the I_C-V_{CE} limits below which the devices will not go into secondary breakdown. These curves can be used as long as the average power derating curve (Figure 1) is also taken into consideration to insure operation below the maximum junction temperature.

NOTE: For additional design curves, please refer to Type 2N3766.

MJ2251 (SILICON)
MJ2252



CASE 80
(TO-66)

High-voltage NPN silicon power transistors, particularly well suited for power output stages in television, radio, phonograph and other consumer product applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage MJ2251 MJ2252	V_{CEO}	 225 300	Vdc
Emitter-Base Voltage	V_{EB}	6	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ T_C = 70°C Derate above 70°C	P_D	 10 0.125	 Watts W/°C
Operating and Storage Temperature Range	T_J, T_{stg}	-65 to +150	°C

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0) MJ2251 MJ2252	BV_{CEO}	 225 300	 — —	 — —	Vdc
Collector Cutoff Current (V_{CB} = 300 Vdc, I_E = 0)	I_{CBO}	—	—	100	μAdc
Emitter-Base Leakage Current (V_{EB} = 6 Vdc, I_C = 0)	I_{EBO}	—	—	100	μAdc
DC Current Gain (I_C = 50 mAdc, V_{CE} = 10 Vdc)	h_{FE}	25	—	200	—
Small Signal Current Gain (I_C = 20 mAdc, V_{CE} = 50 Vdc, f = 10 MHz)	h_{fe}	1.0	—	—	—
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 125 Vdc, f = 1 kHz) (I_C = 30 mAdc, V_{CE} = 125 Vdc, f = 1 kHz)	h_{fe}	 — —	 40 65	 — —	—
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 125 Vdc, f = 1 kHz) (I_C = 30 mAdc, V_{CE} = 125 Vdc, f = 1 kHz)	h_{re}	 — —	 2.5 4.0	 — —	$X10^{-5}$
Input Impedance (I_C = 10 mAdc, V_{CE} = 125 Vdc, f = 1 kHz) (I_C = 30 mAdc, V_{CE} = 125 Vdc, f = 1 kHz)	h_{ie}	 — —	 150 75	 — —	ohms
Output Admittance (I_C = 10 mAdc, V_{CE} = 125 Vdc, f = 1 kHz) (I_C = 30 mAdc, V_{CE} = 125 Vdc, f = 1 kHz)	h_{oe}	 — —	 5 20	 — —	μmhos

COLLECTOR CHARACTERISTICS

FIGURE 1 — MJ2251

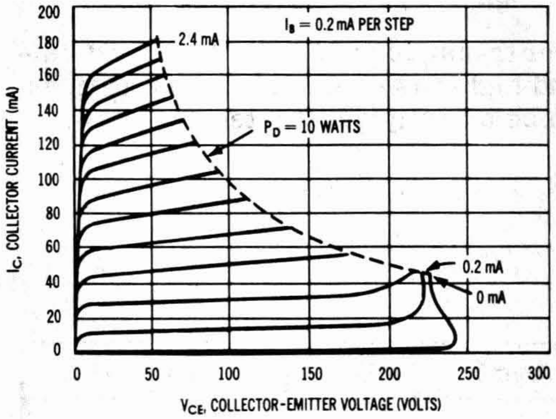


FIGURE 2 — MJ2252

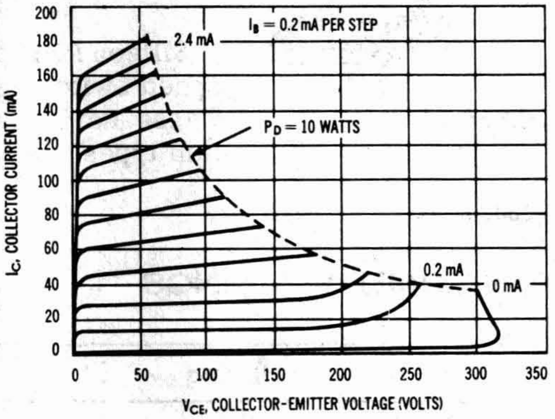


FIGURE 3 — COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE

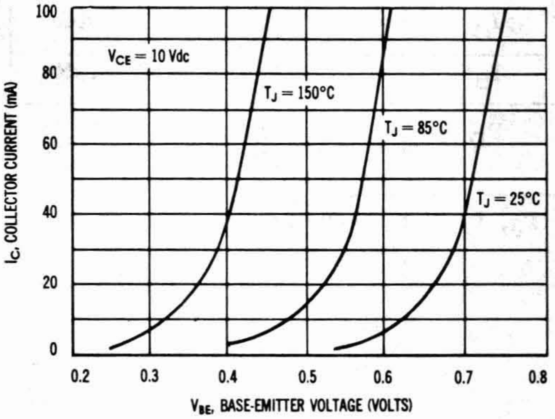


FIGURE 4 — TYPICAL LINE-OPERATED 1.5-WATT AUDIO AMPLIFIER

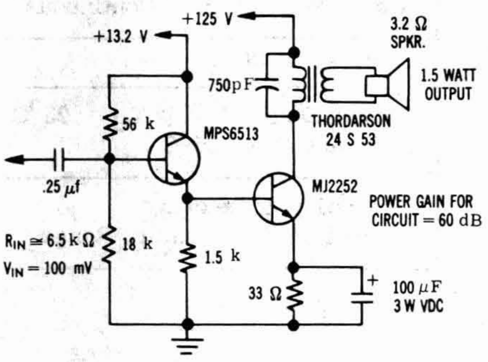

+125 V
+13.2 V
3.2 Ω
SPKR.
1.5 WATT
OUTPUT
750pF
THORDARSON
24 S 53
56 k
MPS6513
.25 µf
MJ2252
POWER GAIN FOR
CIRCUIT = 60 dB
R_IN ≅ 6.5 k Ω
V_IN = 100 mV
18 k
1.5 k
33 Ω
100 µF
3 W VDC

FIGURE 5 — TYPICAL TOTAL HARMONIC DISTORTION versus P_{out}

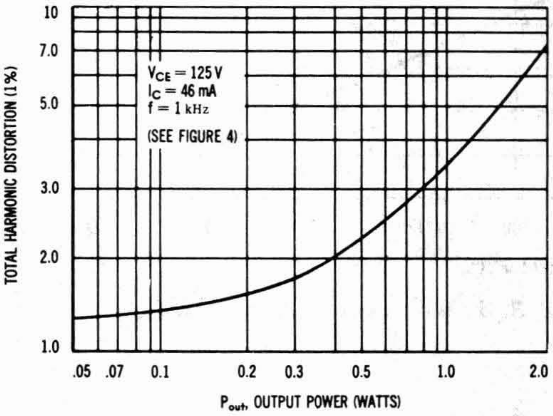
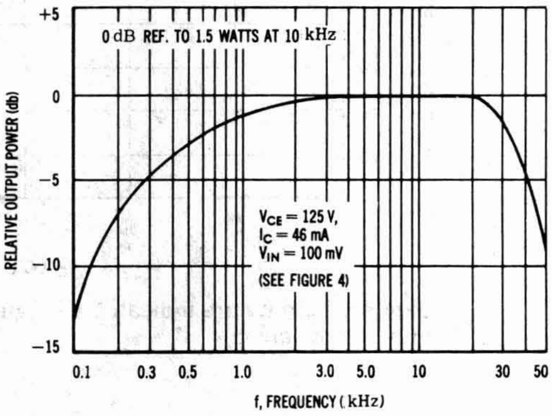
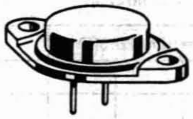


FIGURE 6 — TYPICAL FREQUENCY RESPONSE OF LINE OPERATED AUDIO AMPLIFIER



MJ2267 (SILICON)
MJ2268



CASE 11
(TO-3)

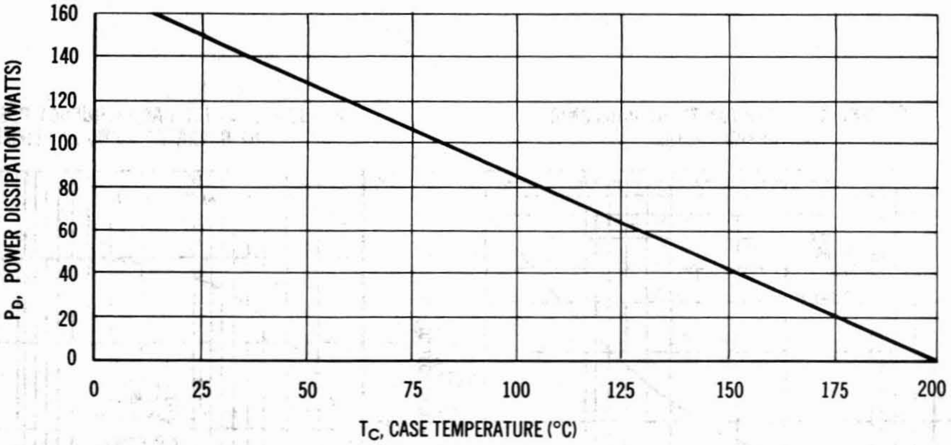
Collector connected to case

Silicon PNP power transistors, designed for medium-speed switching and high-power amplifier applications. These devices can be directly substituted for germanium types.

MAXIMUM RATINGS

Rating	Symbol	MJ2267	MJ2268	Unit
Collector-Emitter Voltage	V_{CEO}	40	55	Vdc
Collector-Base Voltage	V_{CB}	40	55	Vdc
Emitter-Base Voltage	V_{EB}	5.0	5.0	Vdc
Collector Current - Continuous	I_C	5.0		Adc
Base Current	I_B	3		Adc
Power Dissipation @ $T_C = 25^{\circ}C$ Derate above 25°C	P_D	150 0.86		Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



Safe Area Limits are indicated by Figures 2, 3. Both limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristics		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 200 mAdc, I_B = 0)	MJ2267	$BV_{CEO(sus)}$*	40	—	Vdc
	MJ2268		55	—	
Collector Cutoff Current (V_{CE} = 40 Vdc, V_{BE} = 1.5 Vdc)	MJ2267	I_{CEX}	—	1.0	mAdc
(V_{CE} = 60 Vdc, V_{BE} = 1.5 Vdc)	MJ2268		—	1.0	
(V_{CE} = 20 Vdc, V_{BE} = 1.5 Vdc, T_C = 150°C)	MJ2267		—	5.0	
(V_{CE} = 30 Vdc, V_{BE} = 1.5 Vdc, T_C = 150°C)	MJ2268		—	5.0	
Emitter-Base Cutoff Current (V_{EB} = 5.0 Vdc, I_C = 0)		I_{EBO}	—	5.0	mAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)		h_{FE}	20	—	—
(I_C = 4.0 Adc, V_{CE} = 2.0 Vdc)*			20	100	
Collector-Emitter Saturation Voltage* (I_C = 4.0 Adc, I_B = 0.4 Adc)		$V_{CE(sat)}$*	—	1.0	Vdc
Base-Emitter Saturation Voltage* (I_C = 4.0 Adc, I_B = 0.4 Adc)		$V_{BE(sat)}$*	—	1.5	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 0.5 Adc, V_{CE} = 10 Vdc)		f_T	3.0	—	MHz

* Pulse Test: Pulse Width ≦ 300 μs, Duty Cycle ≦ 2.0%.

ACTIVE REGION SAFE OPERATING AREAS

FIGURE 2 — MJ2267

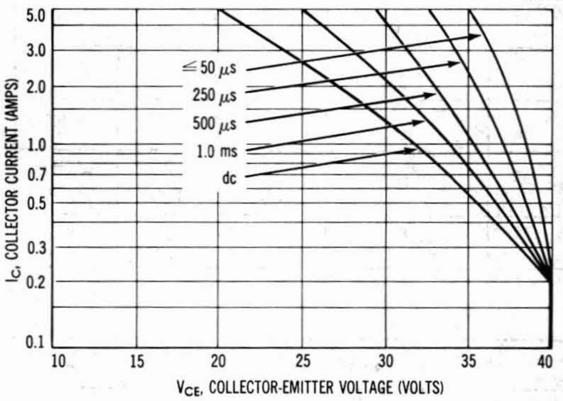
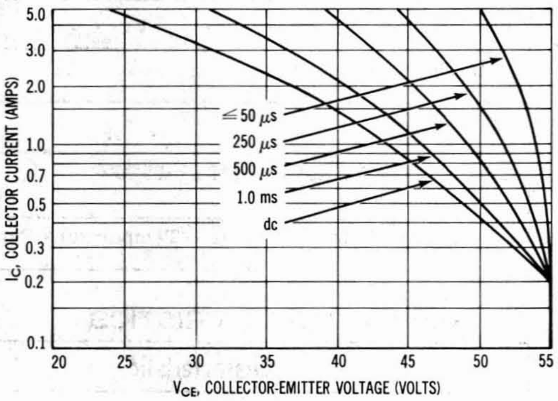


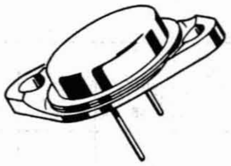
FIGURE 3 — MJ2268



The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

NOTE: For additional design curves, please refer to Type 2N3789.

MJ3029 (SILICON)
MJ3030



CASE 11
(TO-3)

Collector connected to case

NPN power transistors designed for horizontal and vertical deflection amplifier circuits for TV. Also for high power line-operated audio outputs for radio, TV, phonographs and P.A. systems.

MAXIMUM RATINGS

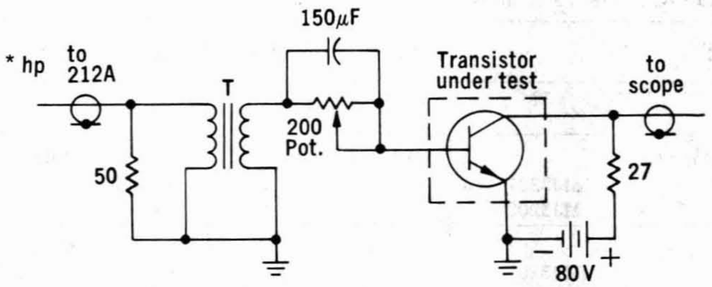
Rating	Symbol	3029	3030	Unit
Collector-Emitter Voltage	V_{CEO}	250	325	Vdc
Collector-Emitter Voltage	V_{CER}	500	-	Vdc
Collector-Emitter Voltage	V_{CEX}	-	700	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current - Continuous	I_C	3.5		Adc
Base Current	I_B	1.0		Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	125 1.0	125 1.0	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150		°C

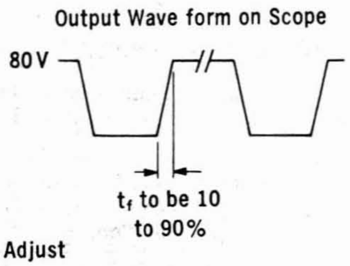
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.0	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 0.1 Adc, I_C = 0)	MJ3029 MJ3030	BV_{CEO}	250 325	- -	Vdc
Collector Cutoff Current (V_{CE} = 500 Vdc, V_{BE} = 0, R_{BE} = 1.5 k ohms)	MJ3029	I_{CER}	-	1.0	mAdc
Collector Cutoff Current (V_{CE} = 700 Vdc, $V_{EB(off)}$ = 1.5 Vdc)	MJ3030	I_{CEX}	-	2.0	mAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 3.0 Adc, V_{CE} = 5.0 Vdc)	MJ3030	h_{FE}	3.75	-	-
DC Current Gain (I_C = 0.4 Adc, V_{CE} = 5.0 Vdc)	MJ3029	h_{FE1}	30	-	-
DC Current Gain (I_C = 0.3 Adc, V_{CE} = 5.0 Vdc)	MJ3029	h_{FE2}	25	-	-
Gain Linearity	MJ3029	$\frac{h_{FE1}}{h_{FE2}}$	0.95		-
Collector-Emitter Saturation Voltage (I_C = 3.0 Adc, I_B = 0.8 Adc)		$V_{CE(sat)}$	-	2.0	Vdc
SWITCHING CHARACTERISTICS					
Fall Time (V_{CC} = 80 Vdc, I_C = 3.0 Adc, I_{B1} = I_{B2} = 0.8 Adc)	MJ3030	t_f	-	1.0	μs


150μF
* hp
to 212A
T
50
200 Pot.
Transistor under test
to scope
27
80 V


Output Wave form on Scope
80 V
t_f to be 10 to 90%

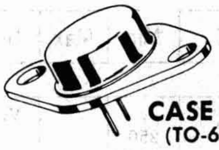
* hp 212A: Set for 10μs wide pulses at 2000 pulses per sec. (500μs intervals) Adjust for I_{B1} = 0.8 A

Bias: Adjust to 1.5 V on a VTVM across the 200Ω Pot.

MJ3101

For Specifications See MJ2249 Data.

MJ3201 (SILICON)
MJ3202



Collector connected to case

High-voltage NPN silicon transistors designed for use in line-operated equipment such as audio output amplifiers; low-current, high-voltage converters; and ac line relays.

MAXIMUM RATINGS

Rating	Symbol	MJ3201	MJ3202	Unit
Collector-Emitter Voltage	V_{CEO}	225	300	Vdc
Collector-Base Voltage	V_{CB}	225	300	Vdc
Emitter-Base Voltage	V_{EB}	3		Vdc
Collector Current-Continuous	I_C	100		mAdc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	15 0.1		Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to + 175		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	10	°C/W

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise specified)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 1.0 mAdc, I_B = 0) MJ3201 MJ3202	BV_{CEO}	225 300	— —	Vdc
Collector Cutoff Current (V_{CB} = 225 Vdc, I_E = 0) MJ3201 (V_{CB} = 300 Vdc, I_E = 0) MJ3202	I_{CBO}	— —	0.1 0.1	mAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)	I_{EBO}	—	0.1	mAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 50 mAdc, V_{CE} = 10 Vdc)	h_{FE}*	30	200	—
Collector-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$*	—	5.0	Vdc
Base-Emitter On Voltage* (I_C = 50 mAdc, V_{CE} = 10 Vdc)	$V_{BE(on)}$*	—	1.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 10 MHz)	f_T	15	—	MHz

*Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2%

FIGURE 1 — DC CURRENT GAIN

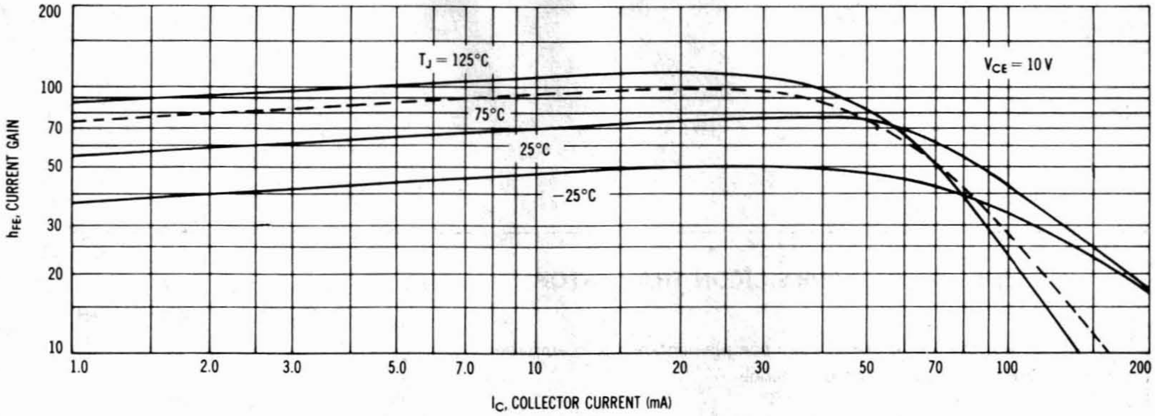


FIGURE 2 — COLLECTOR OUTPUT CHARACTERISTICS

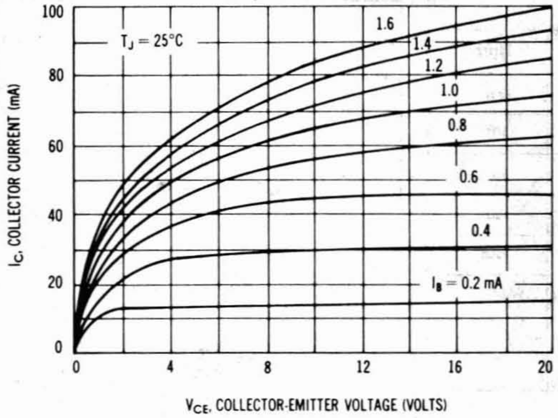


FIGURE 3 — TRANSCONDUCTANCE

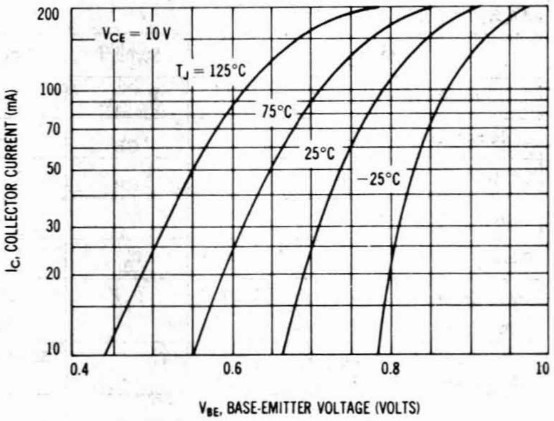
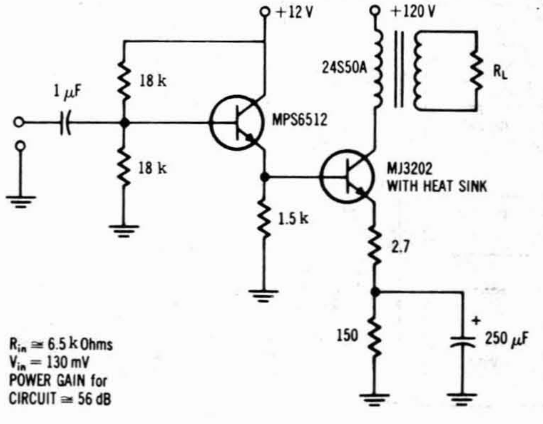
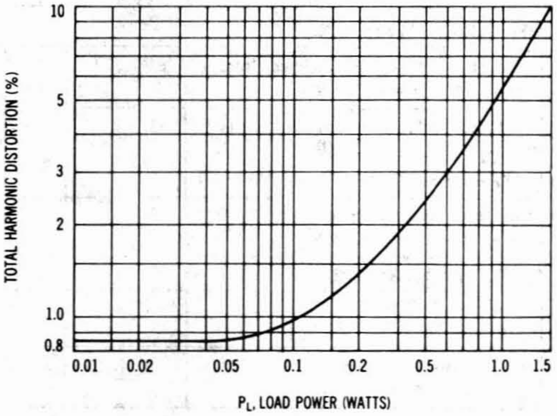


FIGURE 4 — TYPICAL AUDIO AMPLIFIER


+12 V
+120 V
24S50A
R_L
1 μF
18 k
18 k
MPS6512
MJ3202
WITH HEAT SINK
1.5 k
2.7
150
250 μF
+

$R_{in} \cong 6.5$ k Ohms
$V_{in} = 130$ mV
POWER GAIN for
CIRCUIT ≅ 56 dB

FIGURE 5 — AMPLIFIER DISTORTION



MJE105

MEDIUM-POWER PNP SILICON TRANSISTOR

. . . for use as an output device in complementary audio amplifiers up to 20-Watts music power per channel.

- High DC Current Gain – h_{FE} = 25-100 @ I_C = 2.0 A
- Thermopad High-Efficiency Compact Package
- Complementary to NPN MJE205

5 AMPERE
POWER TRANSISTOR

PNP SILICON

50 VOLTS
65 WATTS

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Vdc
Collector-Base Voltage	V_{CB}	50	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	5.0	Adc
Base Current	I_B	2.5	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D†	65 0.522	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

THERMAL CHARACTERISTICS

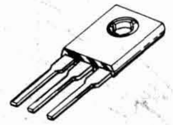
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.92	°C/W

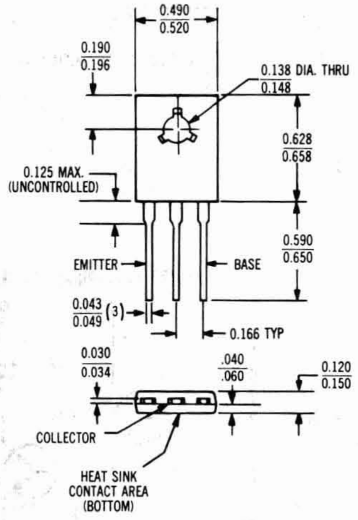
†Safe Area Curves are indicated by Figure 1. Both limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage‡ (I_C = 100 mAdc, I_B = 0)	BV_{CEO}‡	50	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_C = 150°C)	I_{CBO}	 - -	 0.1 2.0	mAdc
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	25	100	-
Base-Emitter Voltage (I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	V_{BE}	-	1.2	Vdc

‡ Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.



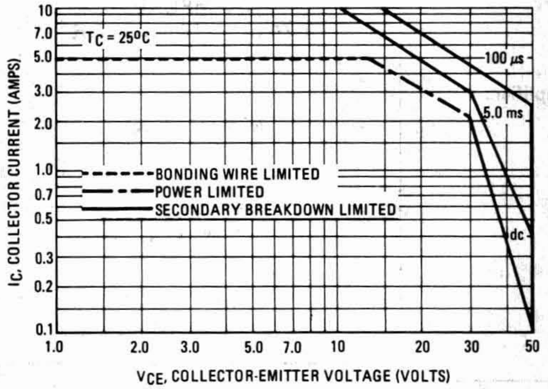

0.490
0.520
0.190
0.196
0.138 DIA. THRU
0.148
0.628
0.658
0.125 MAX.
(UNCONTROLLED)
0.590
0.650
EMITTER
BASE
0.043
0.049
(3)
0.166 TYP
0.030
0.034
.040
.060
0.120
0.150
COLLECTOR
HEAT SINK
CONTACT AREA
(BOTTOM)

CASE 90

When mounting the device, torque not to exceed 8.0 in.-lb.

If lead bending is required, use suitable clamps or other supports between transistor case and point of bend.

FIGURE 1 – ACTIVE REGION DC SAFE OPERATING AREA



The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. To insure operation below the maximum T_J, the power-temperature derating curve, Figure 4, must be observed for both steady state and pulse power conditions.

FIGURE 2 – "ON" VOLTAGES

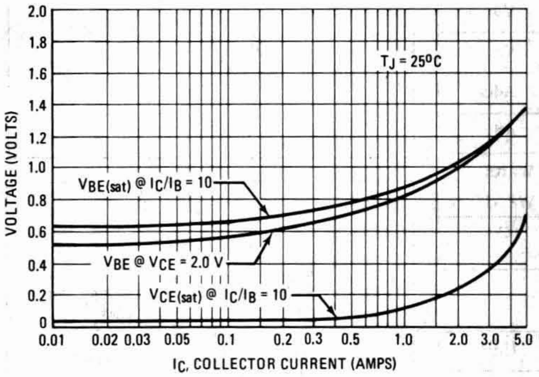


FIGURE 3 – NORMALIZED DC CURRENT GAIN

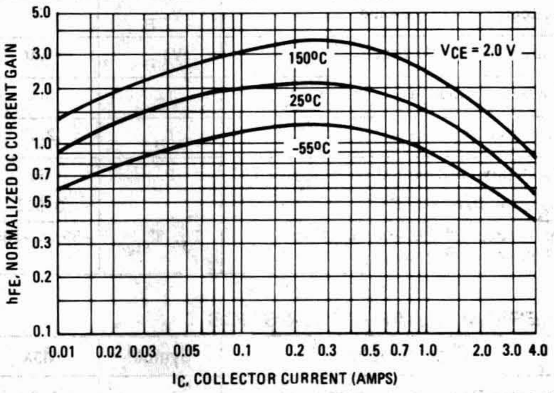
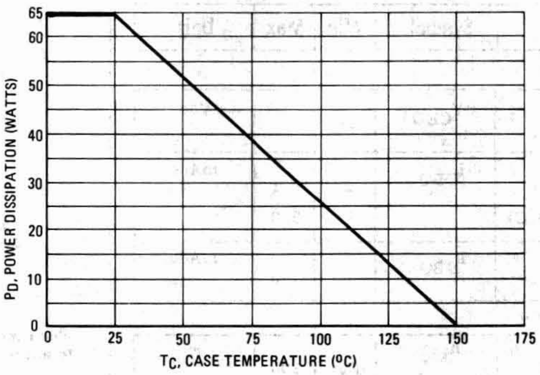


FIGURE 4 – POWER-TEMPERATURE DERATING CURVE



MJE 205

MEDIUM-POWER NPN SILICON TRANSISTOR

. . . for use as an output device in complementary audio amplifiers up to 20-Watts music power per channel.

- High DC Current Gain – h_{FE} = 25-100 @ I_C = 2.0 A
- Thermopad High-Efficiency Compact Package
- Complementary to PNP MJE105

5 AMPERE
POWER TRANSISTOR

NPN SILICON

50 VOLTS
65 WATTS

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Vdc
Collector-Base Voltage	V_{CB}	50	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	5.0	Adc
Base Current	I_B	2.5	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D†	65 0.522	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.92	°C/W

†Safe Area Curves are indicated by Figure 1. Both limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

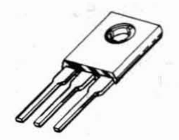
OFF CHARACTERISTICS

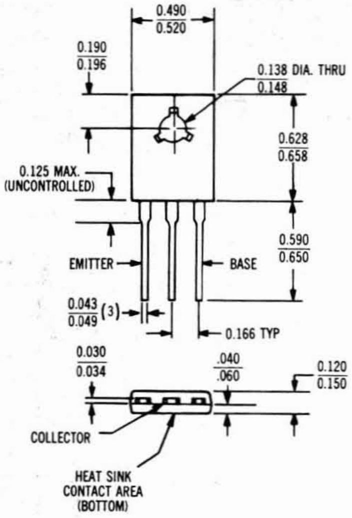
Characteristic	Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage‡ (I_C = 100 mAdc, I_B = 0)	BV_{CEO}‡	50	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_C = 150°C)	I_{CBO}	- -	0.1 2.0	mAdc
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	1.0	mAdc

ON CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
DC Current Gain (I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	25	100	-
Base-Emitter Voltage (I_C = 2.0 Adc, V_{CE} = 2.0 Vdc)	V_{BE}	-	1.2	Vdc

‡ Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.



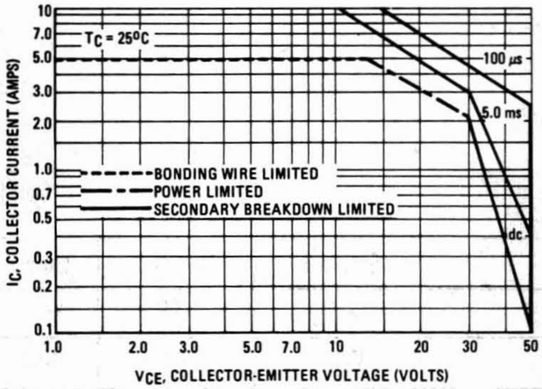

0.490
0.520
0.190
0.196
0.138 DIA. THRU
0.148
0.628
0.658
0.125 MAX.
(UNCONTROLLED)
0.590
0.650
EMITTER
BASE
0.043
0.049
(3)
0.166 TYP
0.030
0.034
.040
.060
0.120
0.150
COLLECTOR
HEAT SINK
CONTACT AREA
(BOTTOM)

CASE 90

When mounting the device, torque not to exceed 8.0 in.-lb.

If lead bending is required, use suitable clamps or other supports between transistor case and point of bend.

FIGURE 1 – ACTIVE REGION DC SAFE OPERATING AREA



The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. To insure operation below the maximum T_J, the power-temperature derating curve, Figure 4, must be observed for both steady state and pulse power conditions.

FIGURE 2 – "ON" VOLTAGES

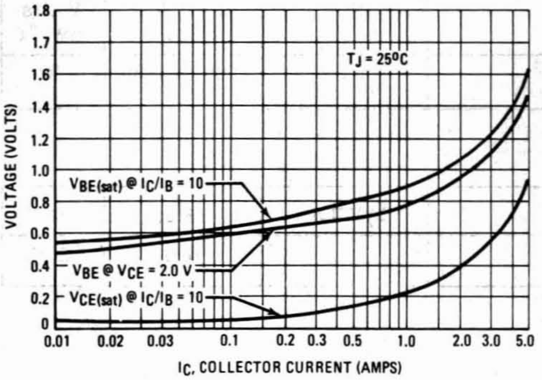


FIGURE 3 – NORMALIZED DC CURRENT GAIN

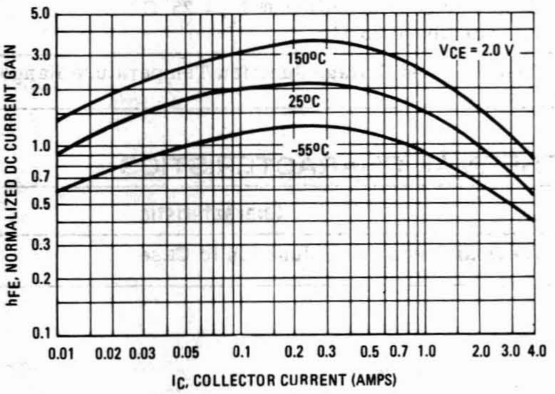
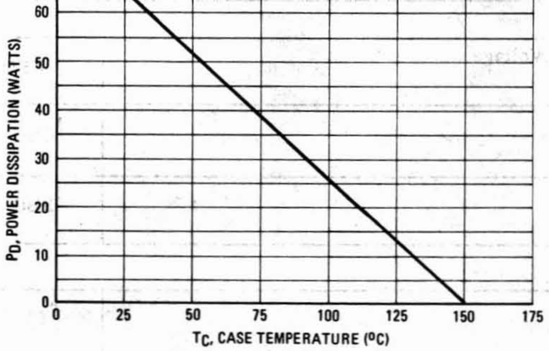
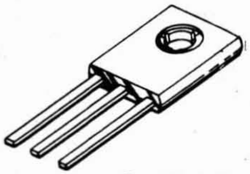


FIGURE 4 – POWER-TEMPERATURE DERATING CURVE



MJE340 (SILICON)



CASE 77

NPN silicon power transistor designed for power output stages for television, radio, phonograph and other consumer product applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	300	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current - Continuous	I_C	500	mAdc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	20.8 167	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Value	Unit
Thermal Resistance, Junction to Case	θ_{JC}	6.0	°C/W

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 1.0$ mAdc, $I_B = 0$)	BV_{CEO}	300	-	Vdc
Collector Cutoff Current ($V_{CB} = 300$ Vdc, $I_E = 0$)	I_{CBO}	-	100	µAdc
Emitter Cutoff Current ($V_{BE} = 3.0$ Vdc, $I_C = 0$)	I_{EBO}	-	100	µAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc)	h_{FE}	30	240	-
DYNAMIC CHARACTERISTICS				
Current-Gain-Bandwidth Product ($I_C = 100$ mAdc, $V_{CE} = 10$ Vdc, f = 1.0 MHz)	f_T	10	-	MHz

FIGURE 1 — COLLECTOR CHARACTERISTICS

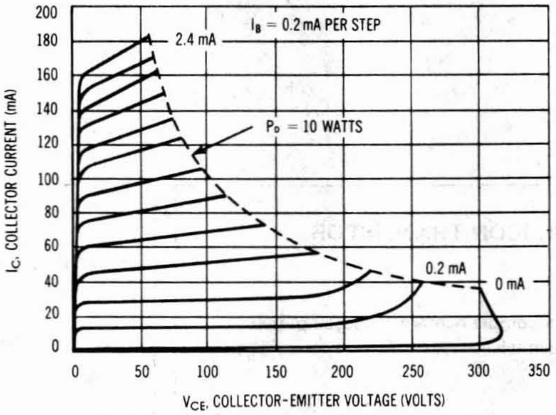


FIGURE 2 — COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE

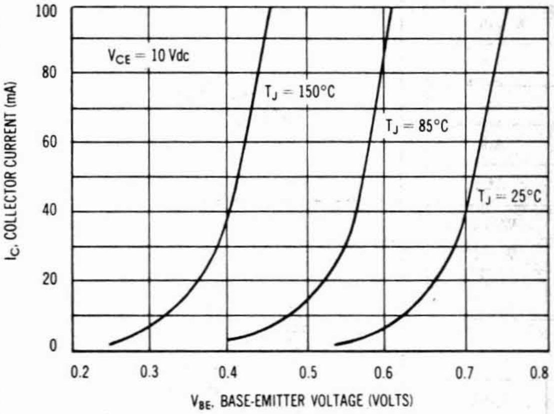


FIGURE 3 — TYPICAL LINE-OPERATED 1.5-WATT AUDIO AMPLIFIER

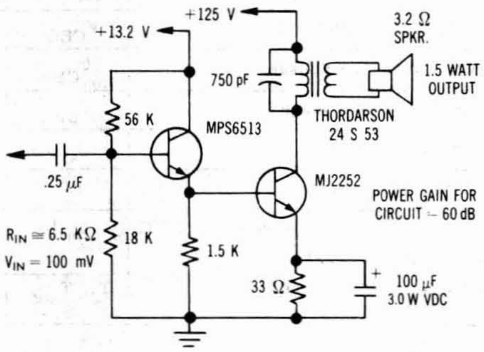

+125 V
+13.2 V
3.2 Ω
SPKR.
1.5 WATT
OUTPUT
750 pF
THORDARSON
24 S 53
56 K
MPS6513
.25 μF
MJ2252
POWER GAIN FOR CIRCUIT — 60 dB
R_{IN} ≅ 6.5 KΩ
V_{IN} = 100 mV
18 K
1.5 K
33 Ω
100 μF
3.0 W VDC

FIGURE 4 — TYPICAL TOTAL HARMONIC DISTORTION versus P_{out}

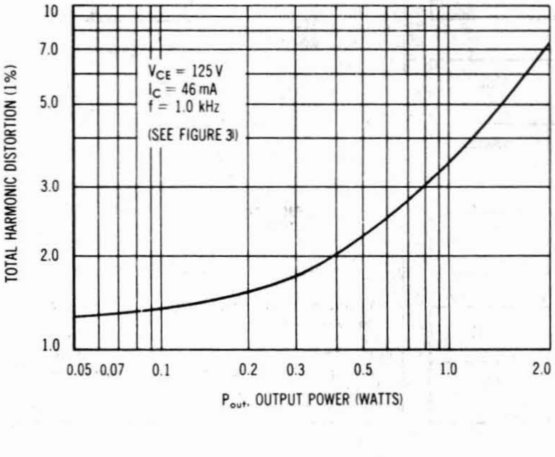
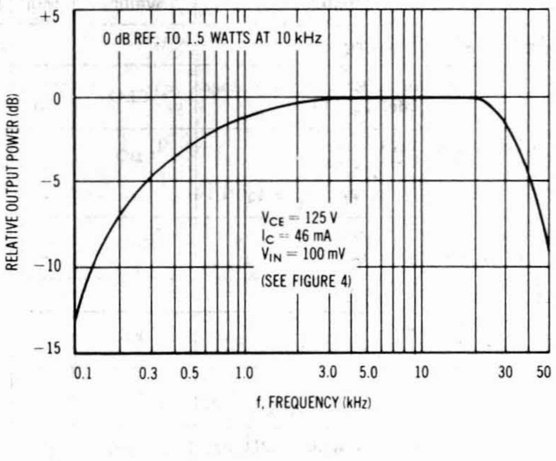


FIGURE 5 — TYPICAL FREQUENCY RESPONSE OF LINE OPERATED AUDIO AMPLIFIER



MJE2801

HIGH-POWER NPN SILICON TRANSISTOR

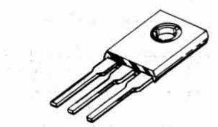
. . . for use as an output device in complementary audio amplifiers up to 35-Watts music power per channel.

- High DC Current Gain – h_{FE} = 25-100 @ I_C = 3.0 A
- Thermopad High-Efficiency Compact Package
- Complementary to PNP MJE2901

10 AMPERE
POWER TRANSISTOR

NPN SILICON

60 VOLTS
90 WATTS



MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	10	Adc
Base Current	I_B	5.0	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D†	90 0.72	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

THERMAL CHARACTERISTICS

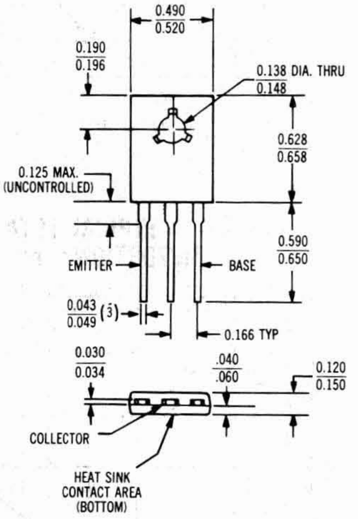
	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.39	°C/W

† Safe Area Curves are indicated by Figure 1. Both limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 200 mAdc, I_B = 0)	BV_{CEO}††	60	-	Vdc
Collector-Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) (V_{CB} = 60 Vdc, I_E = 0, T_C = 150°C)	I_{CBO}	- -	0.1 2.0	mAdc
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	25	100	-
Base-Emitter Voltage (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	V_{BE}	-	1.4	Vdc

†† Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

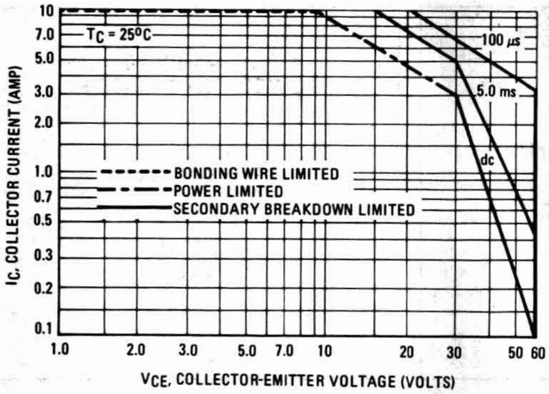

0.490
0.520
0.190
0.196
0.138 DIA. THRU
0.148
0.628
0.658
0.125 MAX.
(UNCONTROLLED)
0.590
0.650
EMITTER
BASE
0.043
0.049
(3)
0.166 TYP
0.030
0.034
.040
.060
0.120
0.150
COLLECTOR
HEAT SINK
CONTACT AREA
(BOTTOM)

CASE 90

When mounting the device, torque not to exceed 8.0 in.-lb.

If lead bending is required, use suitable clamps or other supports between transistor case and point of bend.

FIGURE 1 – ACTIVE REGION DC SAFE OPERATING AREA



The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. To insure operation below the maximum T_J, the power-temperature derating curve, Figure 4, must be observed for both steady state and pulse power conditions.

FIGURE 2 – "ON" VOLTAGES

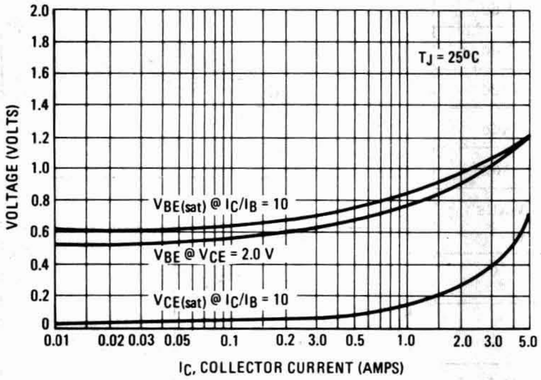


FIGURE 3 – CURRENT GAIN

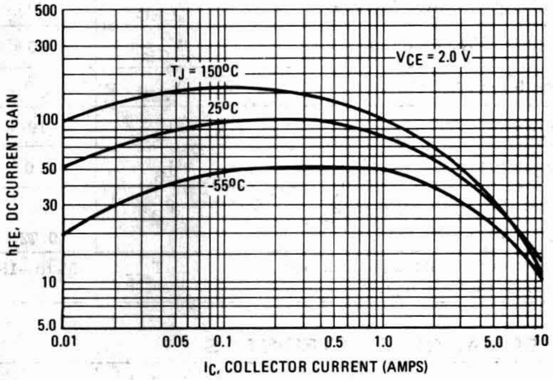
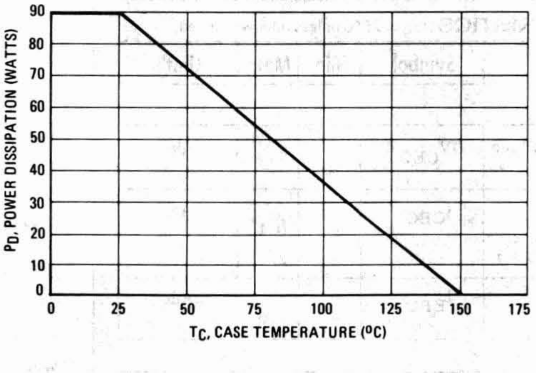


FIGURE 4 – POWER-TEMPERATURE DERATING CURVE



MJE2901

HIGH-POWER PNP SILICON TRANSISTOR

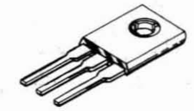
. . . for use as an output device in complementary audio amplifiers up to 35-Watts music power per channel.

- High DC Current Gain – h_{FE} = 25-100 @ I_C = 3.0 A
- Thermopad High-Efficiency Compact Package
- Complementary to NPN MJE2801

10 AMPERE
POWER TRANSISTOR

PNP SILICON

60 VOLTS
90 WATTS



MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	10	Adc
Base Current	I_B	5.0	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D†	90 0.72	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

THERMAL CHARACTERISTICS

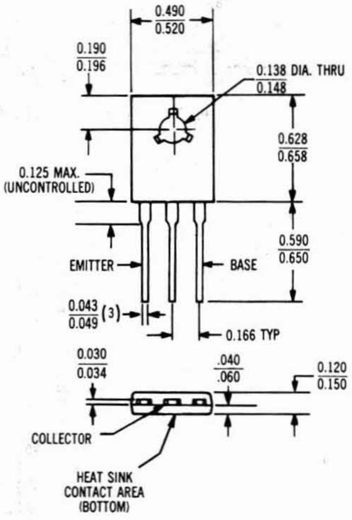
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.39	°C/W

†Safe Area Curves are indicated by Figure 1. Both limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 200 mAdc, I_B = 0)	BV_{CEO}††	60	-	Vdc
Collector-Cutoff Current (V_{CB} = 60 Vdc, I_E = 0) (V_{CB} = 60 Vdc, I_E = 0, T_C = 150°C)	I_{CBO}	 - -	 0.1 2.0	mAdc
Emitter Cutoff Current (V_{BE} = 4.0 Vdc, I_C = 0)	I_{EBO}	-	1.0	mAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	25	100	-
Base-Emitter Voltage (I_C = 3.0 Adc, V_{CE} = 2.0 Vdc)	V_{BE}	-	1.4	Vdc

†† Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

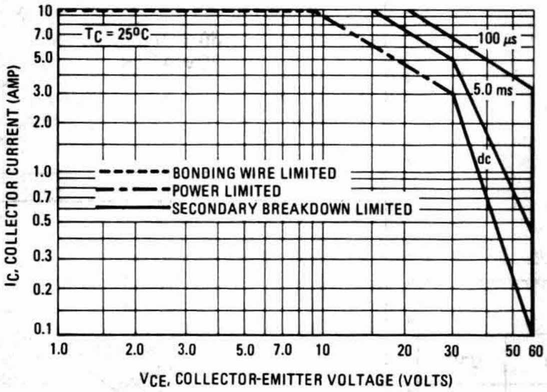

0.490
0.520
0.190
0.196
0.138 DIA. THRU
0.148
0.628
0.658
0.125 MAX.
(UNCONTROLLED)
0.590
0.650
EMITTER
BASE
0.043
0.049
(3)
0.166 TYP
0.030
0.034
.040
.060
0.120
0.150
COLLECTOR
HEAT SINK
CONTACT AREA
(BOTTOM)

CASE 90

When mounting the device, torque not to exceed 8.0 in.-lb.

If lead bending is required, use suitable clamps or other supports between transistor case and point of bend.

FIGURE 1 – ACTIVE REGION DC SAFE OPERATING AREA



The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. To insure operation below the maximum T_J, the power-temperature derating curve, Figure 4, must be observed for both steady state and pulse power conditions.

FIGURE 2 – "ON" VOLTAGES

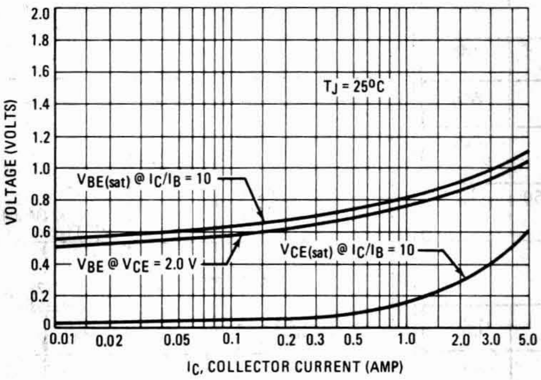


FIGURE 3 – CURRENT GAIN

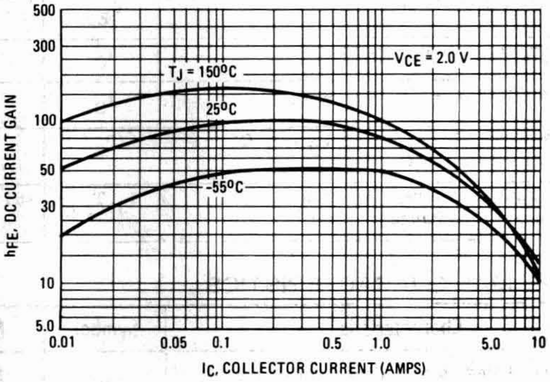
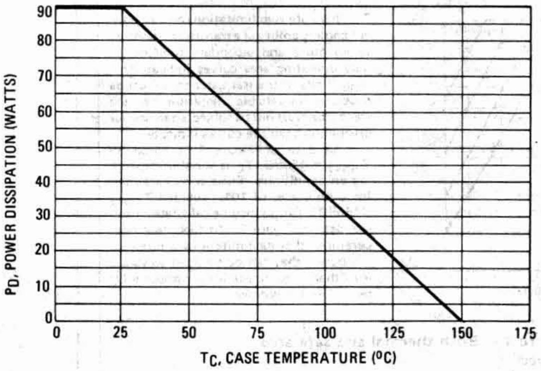


FIGURE 4 – POWER-TEMPERATURE DERATING CURVE



MJE2955

HIGH POWER PNP SILICON TRANSISTOR

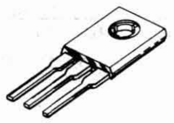
. . . designed for use in general-purpose amplifier and switching applications.

- DC Current Gain Specified to 10 Amperes
- High Current-Gain—Bandwidth Product — f_T = 2.0 MHz (Min) @ I_C = 500 mAdc
- Thermopad High-Efficiency Compact Package
- Complement to NPN MJE3055

10 AMPERE
POWER TRANSISTOR

PNP SILICON

60 VOLTS
90 WATTS

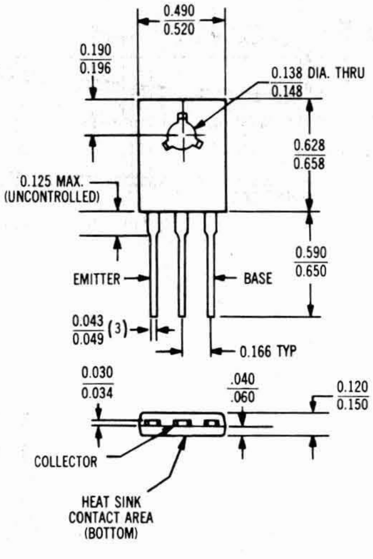


MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Base Voltage	V_{CB}	70	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current - Continuous	I_C	10	Adc
Base Current - Continuous	I_B	6.0	Adc
Total Device Dissipation @T_C = 25°C* Derate above 25°C	P_D*	90 0.718	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.39	°C/W

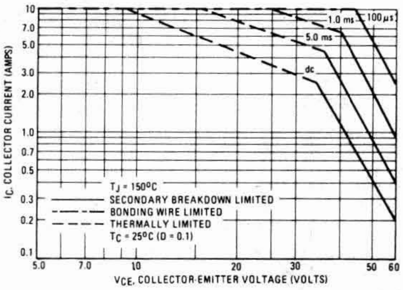


CASE 90

When mounting the device, torque not to exceed 8.0 in.-lb.

If lead bending is required, use suitable clamps or other supports between transistor case and point of bend.

FIGURE 1 — ACTIVE REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate I_C—V_{CE} limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 1 is based on $T_{J(pk)}$ = 150°C; T_C is variable depending on conditions. Pulse curves are valid for duty cycles of 10% provided $T_{J(pk)} \leq 150°C$. $T_{J(pk)}$ may be calculated from the data in Figure 2. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

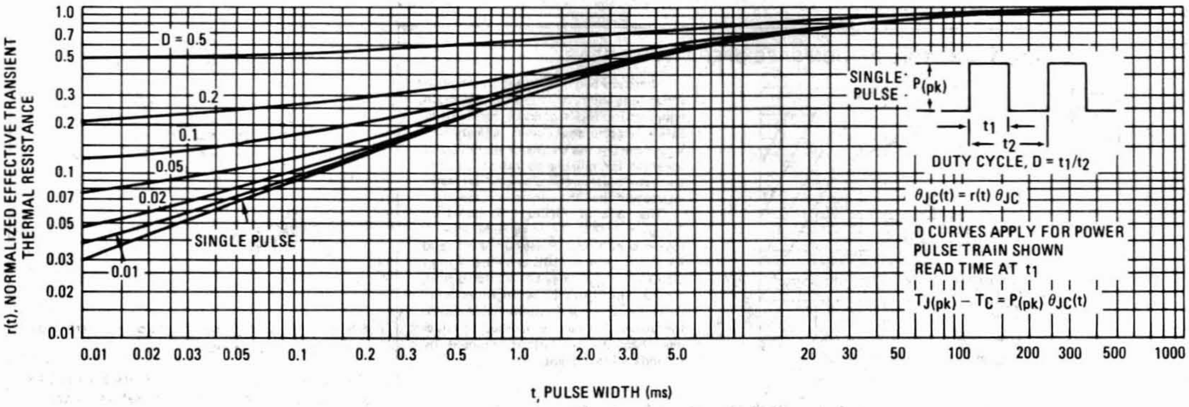
*Safe Area Curves are indicated by Figure 1 — Both thermal and safe area limits are applicable and must be observed.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 200 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	60	-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, I_B = 0)	I_{CEO}	-	700	μAdc
Collector Cutoff Current (V_{CE} = 70 Vdc, $V_{EB(off)}$ = 1.5 Vdc) (V_{CE} = 70 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	I_{CEX}	- -	1.0 5.0	mAdc
Collector Cutoff Current (V_{CB} = 70 Vdc, I_E = 0) (V_{CB} = 70 Vdc, I_E = 0, T_C = 150°C)	I_{CBO}	- -	1.0 10	mAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	5.0	mAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 4.0 Adc, V_{CE} = 4.0 Vdc) (I_C = 10 Adc, V_{CE} = 4.0 Vdc)	h_{FE}*	20 5.0	70 -	-
Collector-Emitter Saturation Voltage* (I_C = 4.0 Adc, I_B = 0.4 Adc) (I_C = 10 Adc, I_B = 3.3 Adc)	$V_{CE(sat)}$*	- -	1.1 8.0	Vdc
Base-Emitter On Voltage* (I_C = 4.0 Adc, V_{CE} = 4.0 Vdc)	$V_{BE(on)}$*	-	1.8	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 500 mAdc, V_{CE} = 10 Vdc, f = 500 kHz)	f_T	2.0	-	MHz

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 2 – THERMAL RESPONSE



MJE 3055 (SILICON)

HIGH POWER NPN SILICON TRANSISTOR

. . . designed for use in general-purpose amplifier and switching applications.

- DC Current Gain Specified to 10 Amperes
- High Current-Gain—Bandwidth Product — f_T = 2.0 MHz (Min) @ I_C = 500 mAdc
- Thermopad High-Efficiency Compact Package
- Plastic Version of 2N3055

10 AMPERE
POWER TRANSISTOR

NPN SILICON

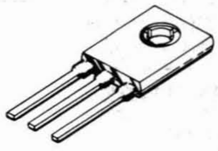
60 VOLTS
90 WATTS

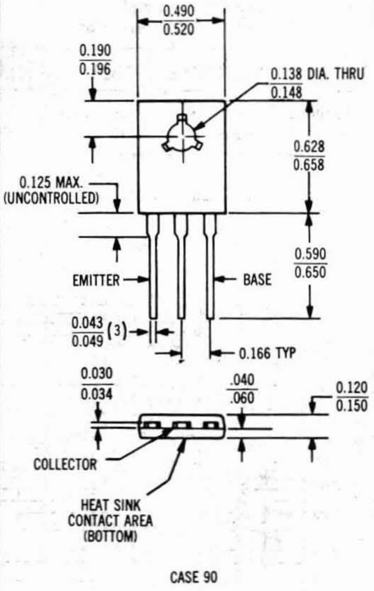
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Base Voltage	V_{CB}	70	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current - Continuous	I_C	10	Adc
Base Current - Continuous	I_B	6.0	Adc
Total Device Dissipation @T_C = 25° C* Derate above 25° C	P_D *	90 0.718	Watts W/° C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	° C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.39	° C/W



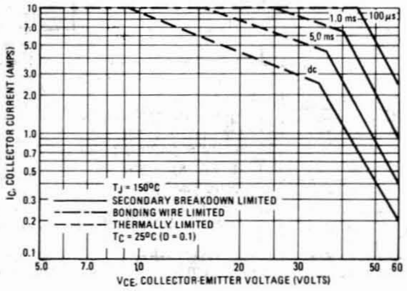


CASE 90

When mounting the device, torque not to exceed 8.0 in.-lb.

If lead bending is required, use suitable clamps or other supports between transistor case and point of bend.

FIGURE 1 — ACTIVE REGION SAFE OPERATING AREAS



There are two limitations on the power handling ability of a transistor: junction temperature and secondary breakdown. Safe operating area curves indicate I_C–V_{CE} limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 1 is based on $T_{J(pk)}$ = 150°C; T_C is variable depending on conditions. Pulse curves are valid for dutv cycles of 10% provided $T_{J(pk)}$ ≤150°C. $T_{J(pk)}$ may be calculated from the data in Figure 2. At high case temperatures, thermal limitations will reduce the power that can be handled to values less than the limitations imposed by secondary breakdown.

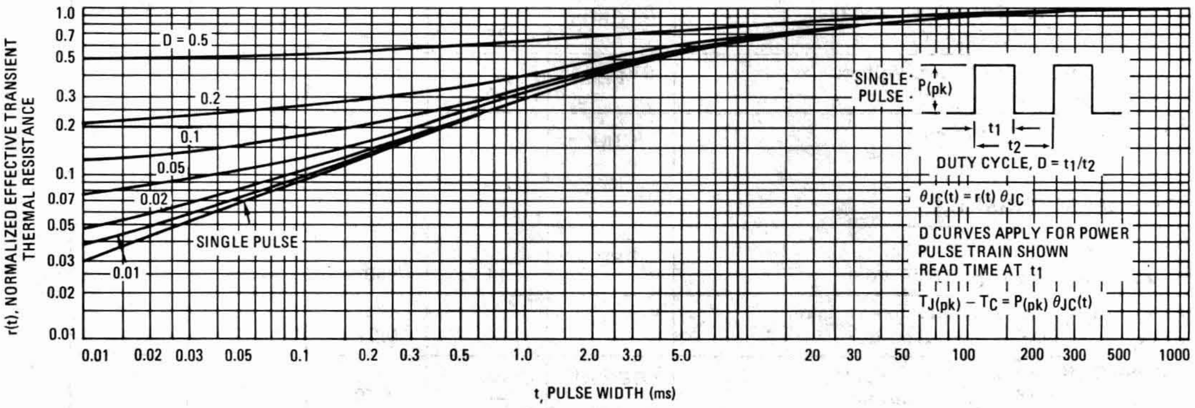
***Safe Area Curves are indicated by Figure 1 — Both thermal and safe area limits are applicable and must be observed.**

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 200 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	60	-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, I_B = 0)	I_{CEO}	-	700	μAdc
Collector Cutoff Current (V_{CE} = 70 Vdc, $V_{EB(off)}$ = 1.5 Vdc) (V_{CE} = 70 Vdc, $V_{EB(off)}$ = 1.5 Vdc, T_C = 150°C)	I_{CEX}	- -	1.0 5.0	mAdc
Collector Cutoff Current (V_{CB} = 70 Vdc, I_E = 0) (V_{CB} = 70 Vdc, I_E = 0, T_C = 150°C)	I_{CBO}	- -	1.0 10	mAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	5.0	mAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 4.0 Adc, V_{CE} = 4.0 Vdc) (I_C = 10 Adc, V_{CE} = 4.0 Vdc)	h_{FE}*	20 5.0	70 -	-
Collector-Emitter Saturation Voltage* (I_C = 4.0 Adc, I_B = 0.4 Adc) (I_C = 10 Adc, I_B = 3.3 Adc)	$V_{CE(sat)}$*	- -	1.1 8.0	Vdc
Base-Emitter On Voltage* (I_C = 4.0 Adc, V_{CE} = 4.0 Vdc)	$V_{BE(on)}$*	-	1.8	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 500 mAdc, V_{CE} = 10 Vdc, f = 500 kHz)	f_T	2.0	-	MHz

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 2 — THERMAL RESPONSE



MM380 (GERMANIUM)

CASE 22
(TO-18)

PNP germanium selective metal etch transistor designed for use in UHF oscillator applications.

Collector connected to case

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	10	Vdc
Collector-Emitter Voltage	V_{CES}	25	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	0.3	Vdc
Total Device Dissipation $T_A = 25^oC$ Derate above 25^oC	P_D	250 3.33	mW mW/^oC
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.300	$^oC/mW$
Thermal Resistance, Junction to Case	θ_{JC}	0.200	$^oC/mW$

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	10	—	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	25	—	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	25	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	0.3	—	—	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	—	—	10	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 3 mAdc, V_{CE} = 10 Vdc)	h_{FE}	15	50	—	—
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$	—	0.07	0.15	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	—	0.40	0.45	Vdc

MM380 (Continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 3 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	400	600	—	MHz
Maximum Frequency of Oscillation (I_C = 3 mAdc, V_{CE} = 10 Vdc)	f_{max}	—	1500	—	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{cb}	—	1.4	1.8	pF
Collector-Base Time Constant (I_E = 3 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)	$r'_b C_c$	—	9	12	ps

COMMON-BASE y PARAMETERS

V_{CB} = 10 Vdc, f = 930 MHz, T_A = 25°C

FIGURE 1 — INPUT ADMITTANCE

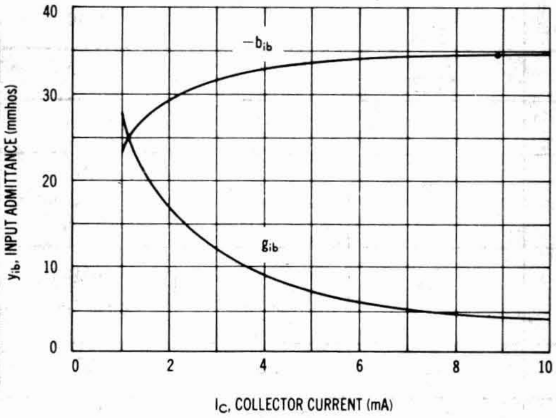


FIGURE 2 — REVERSE TRANSFER ADMITTANCE

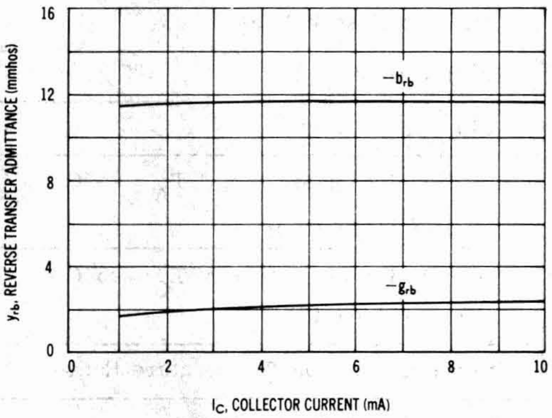


FIGURE 3 — FORWARD TRANSFER ADMITTANCE

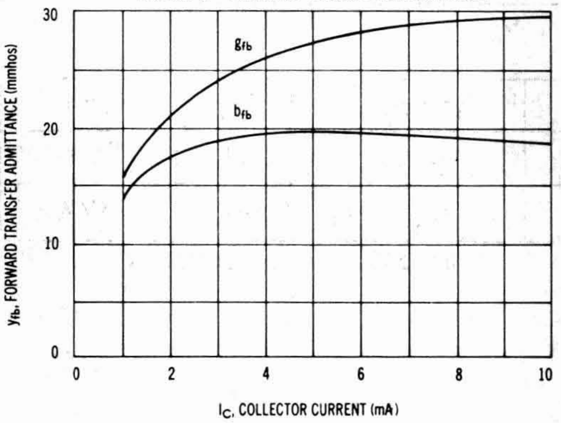


FIGURE 4 — OUTPUT ADMITTANCE

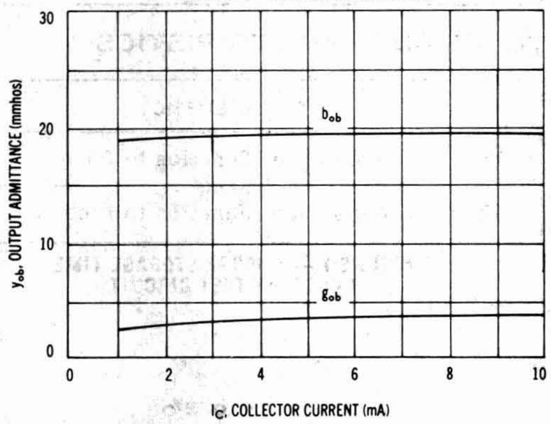
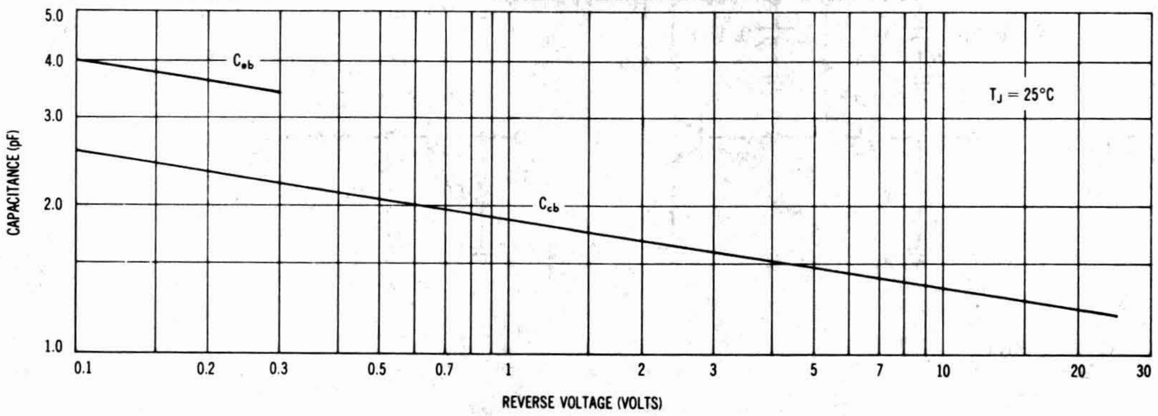
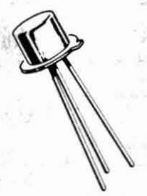


FIGURE 5 — CAPACITANCES



MM709 (SILICON)



Collector connected to case

CASE 27
(TO-52)

NPN silicon annular transistor designed for ultra-high speed switching and amplifier application.

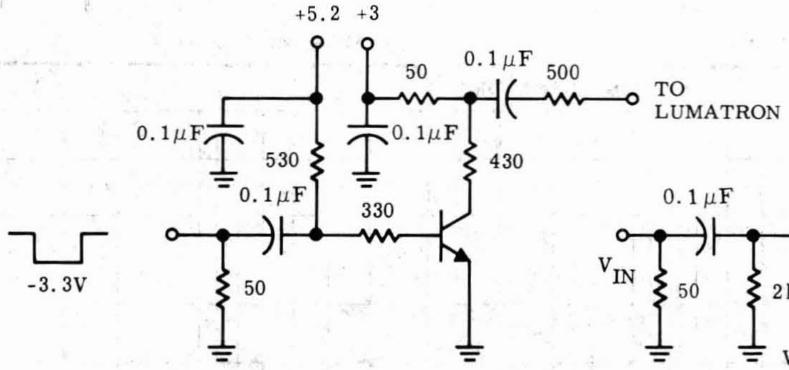
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage (1 to 30 mA)	V_{CEO}	8	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector Current	I_C	100	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	400 2.3	mW mW/^oC
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	750 4.3	mW mW/^oC
Operating Junction Temperature Range	T_J	200	^oC
Storage Temperature Range	T_{stg}	-65 to +200	^oC

THERMAL CHARACTERISTICS

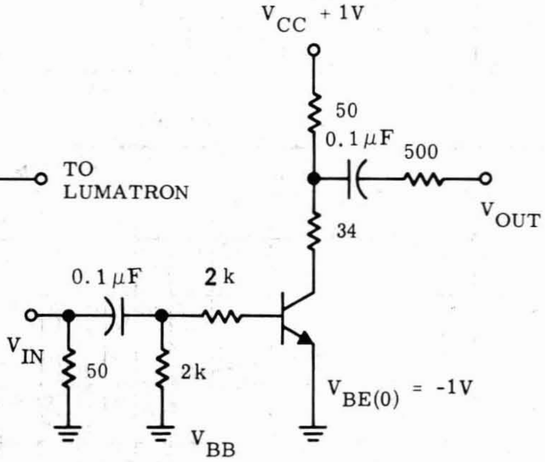
Characteristic	Symbol	Rating	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.233	$^oC/W$
Thermal Resistance, Junction to Ambient	θ_{JA}	0.436	$^oC/W$

FIGURE 1 — CHARGE STORAGE TIME CONSTANT TEST CIRCUIT


+5.2
+3
0.1 μF
50
500
TO LUMATRON
0.1 μF
530
0.1 μF
430
0.1 μF
330
-3.3V
50

SKL
OR
EQUIVALENT
PW≥200 ns

FIGURE 2 — t_{on} & t_{off} TEST CIRCUIT


V_{CC} + 1V
50
0.1 μF
500
V_{OUT}
34
0.1 μF
2 k
V_{IN}
50
2k
V_{BB}
$V_{BE(0)}$ = -1V

ELECTRICAL CHARACTERISTICS

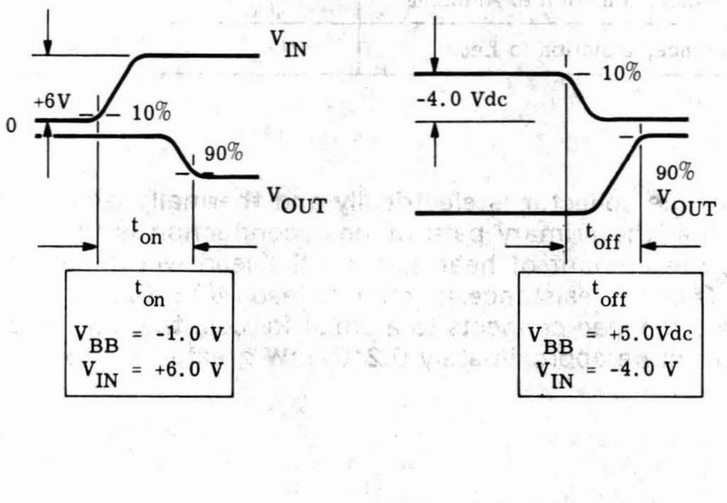
Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	15	-	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	8	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4	-	Vdc
Collector Cutoff Current (V_{CB} = 5 Vdc) (V_{CB} = 5 Vdc, T_A = 125°C)	I_{CBO}	- -	.015 20	μAdc
DC Forward Current Transfer Ratio* (I_C = 10 mAdc, V_{CE} = 0.5 V) (I_C = 30 mAdc, V_{CE} = 1 V) (I_C = 10 mAdc, V_{CE} = 0.5 V, T_A = -55°C)	h_{FE}*	15 12 8	120 - -	-
Collector Saturation Voltage* (I_C = 3 mAdc, I_B = 0.15 mAdc)	$V_{CE(sat)}$*	-	.35	Vdc
Base-Emitter Saturation Voltage* (I_C = 3 mAdc, I_B = 0.15 mAdc)	$V_{BE(sat)}$*	0.70	0.85	Vdc
Current Gain Bandwidth Product (I_C = 5 mAdc, V_{CE} = 4 Vdc)	f_T	300	-	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	3	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_E = 0, f = 100 kHz)	C_{ib}	-	2	pF

SWITCHING CHARACTERISTICS

Charge Storage Time - See Figure 1 (I_C = I_{B1} = $-I_{B2}$ = 5.0 mAdc)	t_s	-	5	ns
Turn-On Time - See Figure 2 (I_C = 10 mAdc, I_B = 2.0 mAdc, I_{B2} = 1.0 mAdc)	t_{on}	-	12	ns
Turn-Off Time - See Figure 2 (I_C = 10 mAdc, I_{B1} = $-I_{B2}$ = 1.0 mAdc)	t_{off}	-	10	ns

*Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2%.

INPUT & OUTPUT PULSE WAVEFORMS V_{in} RISE TIME ≤ 1 ns



MM1139 (GERMANIUM)

CASE 20
(TO-72)

PNP germanium selective metal etch transistor for use in FM mixer and IF amplifier applications.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Emitter Voltage	V_{CES}	30	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	0.3	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	125 1.67	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +100	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}*	0.6	°C/mW
Thermal Resistance, Junction to Lead	θ_{JL}*	0.4	°C/mW

* In this transistor the collector is electrically and thermally isolated from the case with the result that the primary path of heat conduction is through the collector lead; therefore, the amount of heat sink on the lead will determine the thermal characteristics. Thermal resistance, junction to lead (θ_{JL}) = 0.4 °C / mW. In a typical application where the lead connects to a small RF coil, thermal resistance junction to ambient (θ_{JA}) will be approximately 0.2°C/mW greater than θ_{JL}.

MM1139 (Continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, I_B = 0)	BV_{CEO}	15	—	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	30	—	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	30	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	0.3	—	—	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	—	0.7	8	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 2 mAdc, V_{CE} = 10 Vdc)	h_{FE}	15	35	—	—
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 2 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	400	550	—	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)	C_{cb}	—	0.17	0.30	pF
Collector-Base Time Constant (I_E = 2 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)	$r_b'C_c$	—	3.5	6	ps
FUNCTIONAL TEST					
Conversion Gain (108 to 10.7 MHz) (I_C = 3 mAdc, V_{CE} = 10 Vdc, Test Circuit Figure 7)	—	—	22	—	dB

CONVERSION GAIN CHARACTERISTICS

(TEST CIRCUIT FIGURE 7)

FIGURE 1 — VARIATION WITH COLLECTOR CURRENT

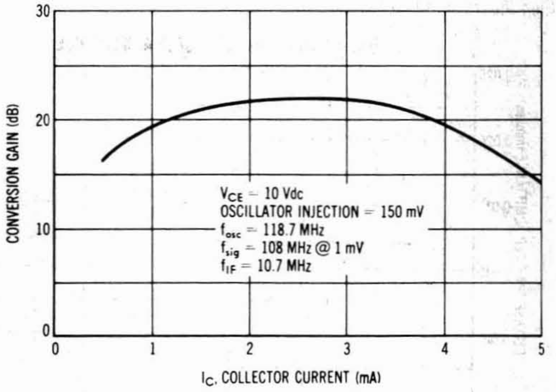
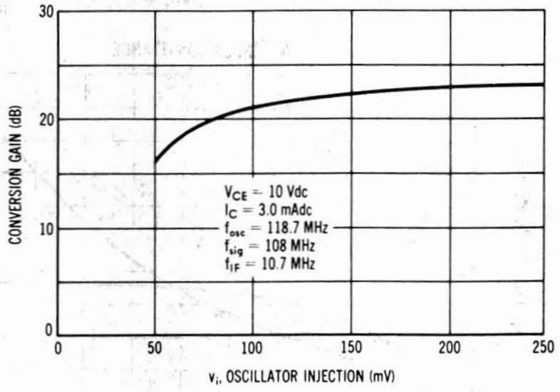


FIGURE 2 — VARIATION WITH INJECTION LEVEL



COMMON-EMITTER y PARAMETERS

V_{CE} = 10 Vdc, f = 105 MHz, T_A = 25°C

FIGURE 3 — INPUT ADMITTANCE

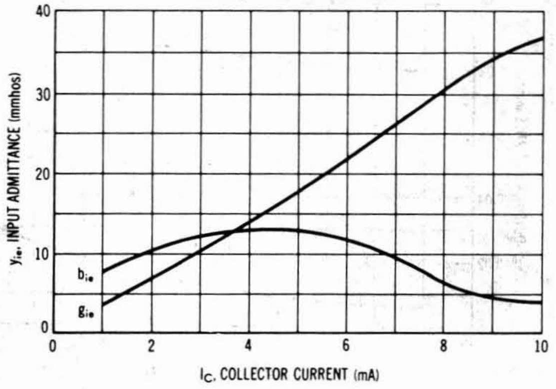


FIGURE 4 — REVERSE TRANSFER ADMITTANCE

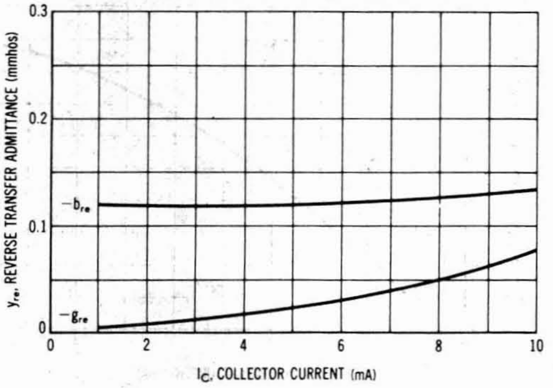


FIGURE 5 — FORWARD TRANSFER ADMITTANCE

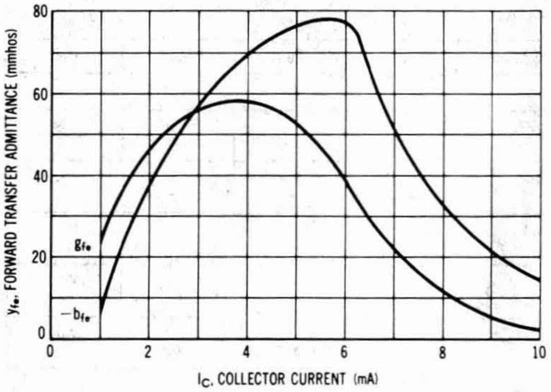


FIGURE 6 — OUTPUT ADMITTANCE

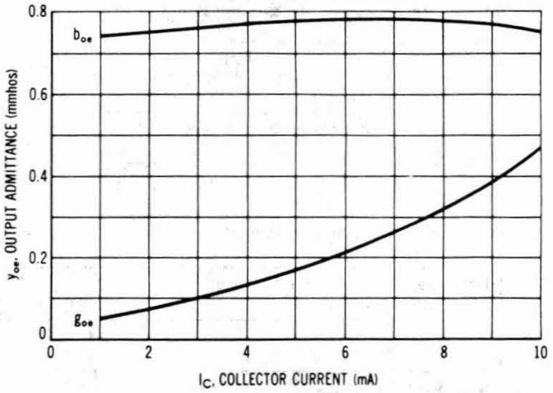
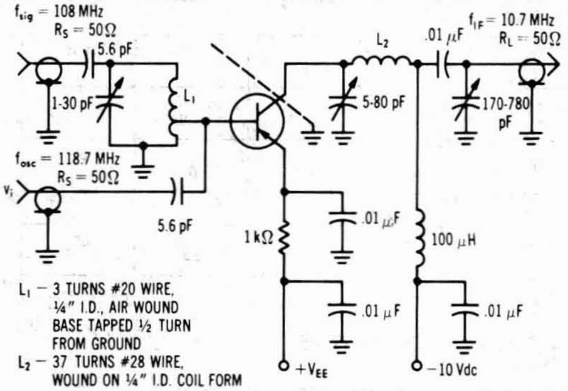


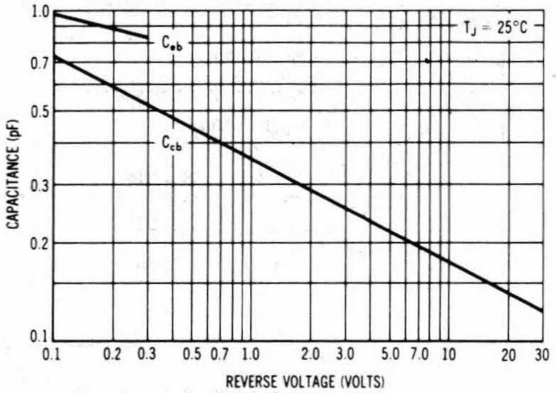
FIGURE 7 — MIXER TEST CIRCUIT


f_{sig} = 108 MHz
R_S = 50Ω
5.6 pF
1-30 pF
L_1
f_{osc} = 118.7 MHz
R_S = 50Ω
V_i
5.6 pF
L_2
.01 μF
f_{IF} = 10.7 MHz
R_L = 50Ω
5-80 pF
170-780 pF
.01 μF
1 kΩ
100 μH
.01 μF
.01 μF
$+V_{EE}$
−10 Vdc

L_1 — 3 TURNS #20 WIRE, ¼" I.D., AIR WOUND BASE TAPPED ½ TURN FROM GROUND

L_2 — 37 TURNS #28 WIRE, WOUND ON ¼" I.D. COIL FORM

FIGURE 8 — CAPACITANCES



COMMON-EMITTER y PARAMETERS

V_{CE} = 10 V, f = 10.7 MHz, T_A = 25°C

FIGURE 9 — INPUT ADMITTANCE

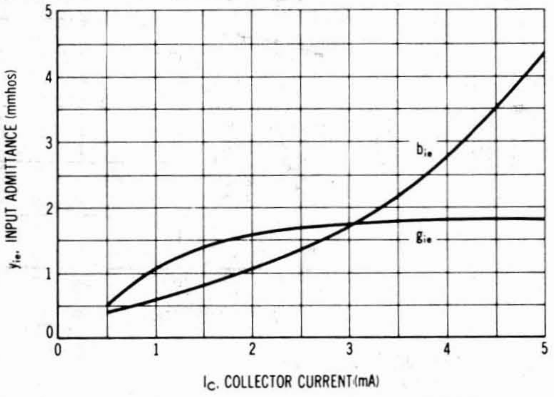


FIGURE 10 — REVERSE TRANSFER ADMITTANCE

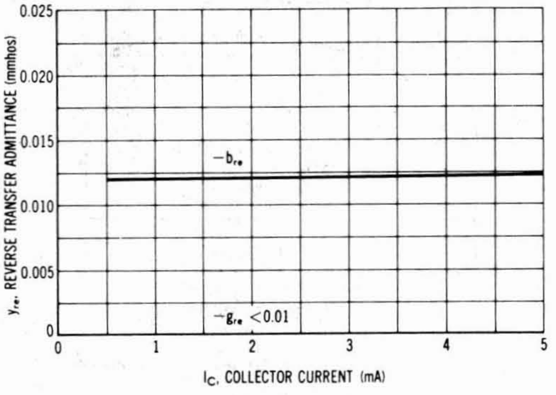


FIGURE 11 — FORWARD TRANSFER ADMITTANCE

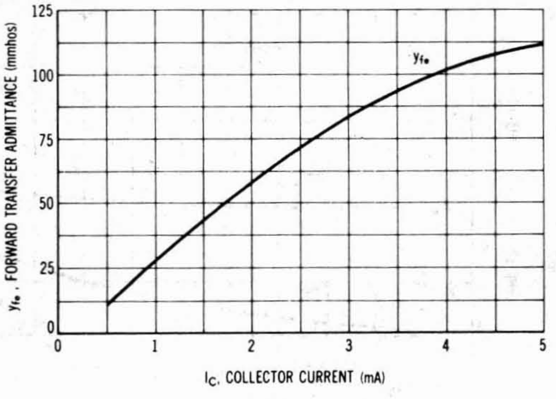
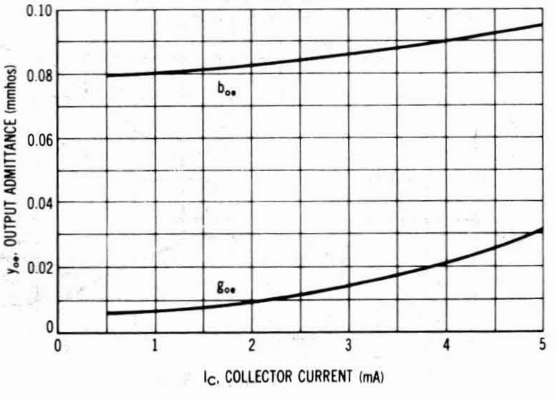


FIGURE 12 — OUTPUT ADMITTANCE



MM1500 (SILICON)
MM1501

NPN silicon RF power transistors designed for UHF amplifier, frequency multiplier, and oscillator applications.

CASE 23
(TO-107)

Collector connected to case
AVAILABLE WITH TO-102 STUD

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltagee	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	3.5 20	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to 200	°C

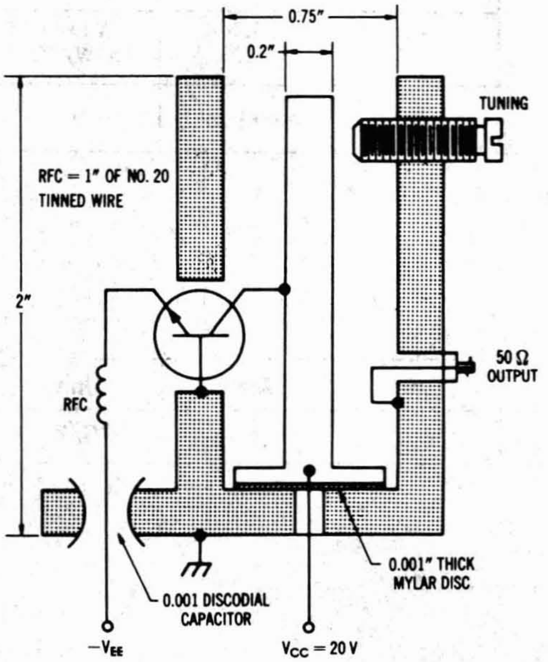
THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	50	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

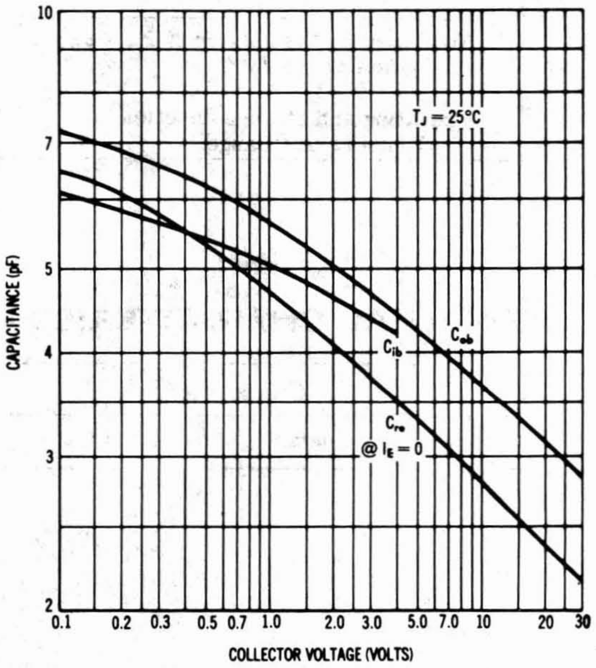
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$	15	—	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	30	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	4	—	—	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0) (V_{CB} = 20 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	— —	— —	0.1 100	μAdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 100 mAdc, V_{CE} = 15 Vdc, f = 200 MHz) MM1500 MM1501	f_T	— —	1500 1000	— —	MHz
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	3.2	5	pF
Collector-Base Time Constant (I_E = 100 mAdc, V_{CB} = 15 Vdc, f = 31.8 MHz) MM1500 MM1501	$r_b'C_c$	— —	7 10	— —	ps
FUNCTIONAL TEST					
Power Output, Figure 1 (V_{CB} = 20 Vdc, R_L = 50 ohms, f = 1500 MHz) MM1500 MM1501	P_{out}	250 150	— —	— —	mW

FIGURE 1 — POWER OUTPUT TEST CIRCUIT



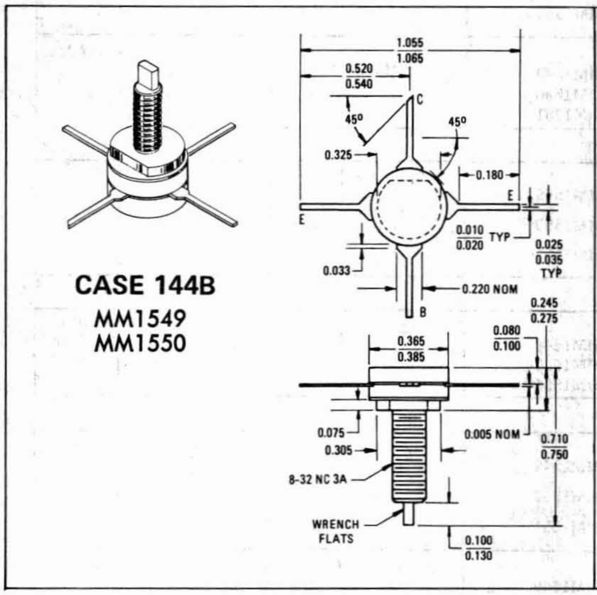
0.75″
0.2″
TUNING
RFC = 1″ OF NO. 20
TINNED WIRE
2″
RFC
50 Ω
OUTPUT
0.001″ THICK
MYLAR DISC
0.001 DISCODIAL
CAPACITOR
$-V_{EE}$
V_{CC} = 20 V

FIGURE 2 — CAPACITANCES

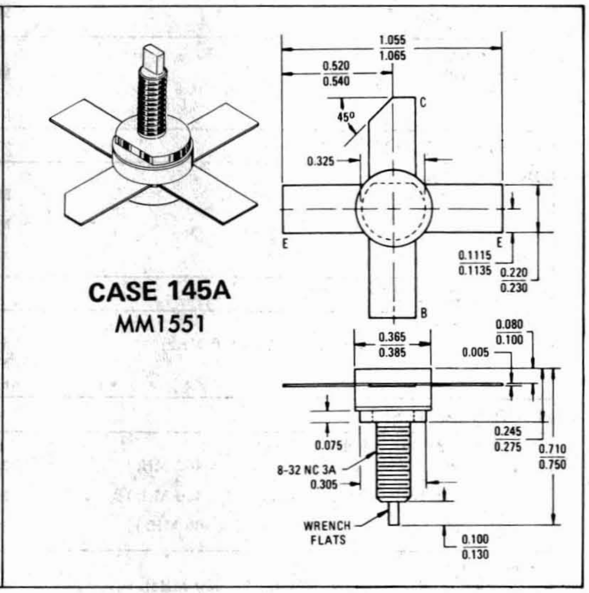


MM1549 (SILICON)
MM1550
MM1551

NPN silicon RF power transistors designed for VHF/UHF amplifier applications. Suitable for use in driver and output stages in 28 volt systems up to 470 MHz. Ideal for 225-400 MHz communications equipment.


1.055
1.065
0.520
0.540
C
45°
45°
0.325
0.180
E
E
0.010
0.020
TYP
0.025
0.035
TYP
0.033
0.220 NOM
B
0.245
0.275
0.365
0.385
0.080
0.100
0.075
0.305
0.005 NOM
0.710
0.750
8-32 NC 3A
WRENCH FLATS
0.100
0.130

CASE 144B
MM1549
MM1550


1.055
1.065
0.520
0.540
45°
C
0.325
E
E
0.1115
0.1135
0.220
0.230
B
0.365
0.385
0.080
0.100
0.005
0.075
0.245
0.275
0.710
0.750
8-32 NC 3A
0.305
WRENCH FLATS
0.100
0.130

CASE 145A
MM1551

MAXIMUM RATINGS

Rating	Symbol	MM1549	MM1550	MM1551	Unit
Collector-Emitter Voltage	V_{CEO}	← 35 →			Vdc
Collector-Base Voltage	V_{CB}	← 60 →			Vdc
Emitter-Base Voltage	V_{EB}	← 4.0 →			Vdc
Collector Current	I_C	1.0	1.5	3.0	Adc
Total Device Dissipation @ $T_C = 25°C$	P_D	7.5	15	30	Watts
Derate above 25°C		43	86	171	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200			°C

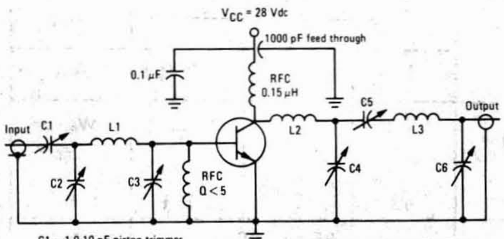
MM1549, MM1550, MM1551 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage*		BV_{CEO}*				Vdc
(I_C = 100 mAdc, I_B = 0)	MM1549		35	-	-	
(I_C = 200 mAdc, I_B = 0)	MM1550, MM1551		35	-	-	
Collector-Emitter Breakdown Voltage		BV_{CES}				Vdc
(I_C = 100 mAdc, V_{BE} = 0)	MM1549		60	-	-	
(I_C = 200 mAdc, V_{BE} = 0)	MM1550, MM1551		60	-	-	
Emitter-Base Breakdown Voltage		BV_{EBO}				Vdc
(I_E = 1.0 mAdc, I_C = 0)	MM1549		4.0	-	-	
(I_E = 5.0 mAdc, I_C = 0)	MM1550		4.0	-	-	
(I_E = 10 mAdc, I_C = 0)	MM1551		4.0	-	-	
Collector Cutoff Current		I_{CBO}				mAdc
(V_{CB} = 30 Vdc, I_E = 0)	MM1549		-	-	0.1	
	MM1550		-	-	1.0	
	MM1551		-	-	1.0	
ON CHARACTERISTICS						
DC Current Gain		h_{FE}				-
(I_C = 100 mAdc, V_{CE} = 5.0 Vdc)	MM1549		5.0	-	-	
(I_C = 200 mAdc, V_{CE} = 5.0 Vdc)	MM1550		5.0	-	-	
(I_C = 500 mAdc, V_{CE} = 5.0 Vdc)	MM1551		5.0	-	-	
DYNAMIC CHARACTERISTICS						
Output Capacitance		C_{ob}				pF
(V_{CB} = 30 Vdc, I_E = 0, f = 0.1 to 1.0 MHz)	MM1549		-	-	10	
	MM1550		-	-	20	
	MM1551		-	-	30	
FUNCTIONAL TEST						
Common-Emitter Amplifier Power Gain		G_{PE}				dB
(P_{out} = 2.5 Watts, V_{CE} = 28 Vdc, f = 400 MHz)	MM1549		6.2	9.2	-	
(P_{out} = 7.5 Watts, V_{CE} = 28 Vdc, f = 400 MHz)	MM1550		5.7	7.0	-	
(P_{out} = 20 Watts, V_{CE} = 28 Vdc, f = 400 MHz)	MM1551		4.6	5.8	-	
Power Output		P_{out}				Watts
(P_{in} = 0.6 Watt, V_{CE} = 28 Vdc, f = 400 MHz)	MM1549		2.5	3.2	-	
(P_{in} = 2.0 Watts, V_{CE} = 28 Vdc, f = 400 MHz)	MM1550		7.5	8.4	-	
(P_{in} = 7.0 Watts, V_{CE} = 28 Vdc, f = 400 MHz)	MM1551		20	22	-	
Collector Efficiency		η				%
(P_{out} = 2.5 Watts, V_{CE} = 28 Vdc, f = 400 MHz)	MM1549		50	-	-	
(P_{out} = 7.5 Watts, V_{CE} = 28 Vdc, f = 400 MHz)	MM1550		50	-	-	
(P_{out} = 20 Watts, V_{CE} = 28 Vdc, f = 400 MHz)	MM1551		60	-	-	

* Pulsed through 25 mH inductor.

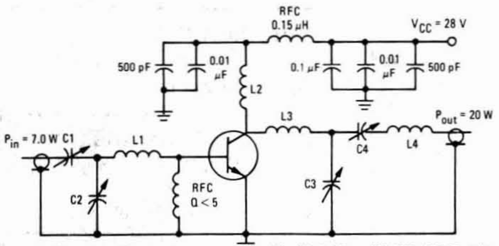
FIGURE 1 – 400 MHz TEST CIRCUIT (MM1549, MM1550)



C1 – 1.0-10 pF piston trimmer
C2, C3, C4, C5 – 1.0-30 pF piston trimmer
C6 – 1.0-20 pF piston trimmer

L1, L2, L3 – 1 turn, #14 AWG, 1/4" dia.

FIGURE 2 – 400 MHz TEST CIRCUIT (MM1551)



C1 – 1.0-30 pF piston trimmer
C2, C3, C4 – 1.0-10 pF piston trimmer
L1 – 12 nH, #14 straight wire, 3/4" long

L2 – 30 nH, 3 Turns #16 AWG, ¼" O. D., ½" L.
L3 – 40 nH, 1 Turn #16 AWG, 3/8 O. D.
L4 – 10 nH, 1/4" wide, 3/8" long Cu Strap

CIRCUIT DESIGN DATA

REAL INPUT IMPEDANCE versus FREQUENCY

FIGURE 3

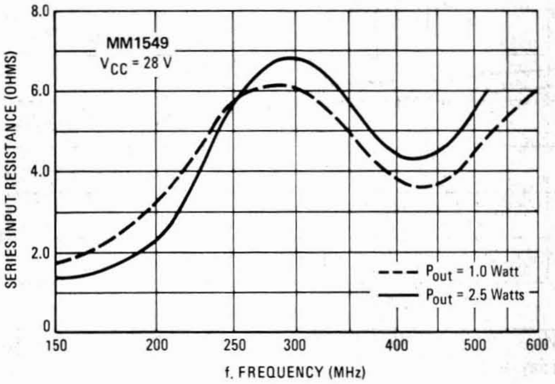


FIGURE 5

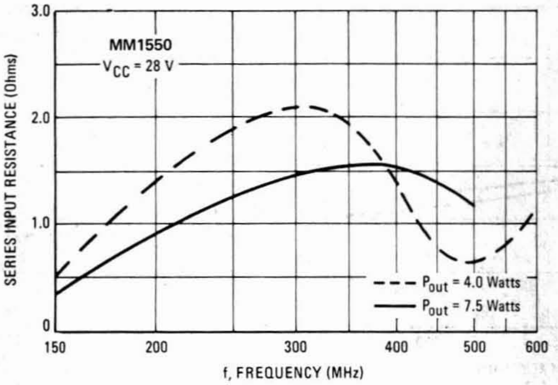
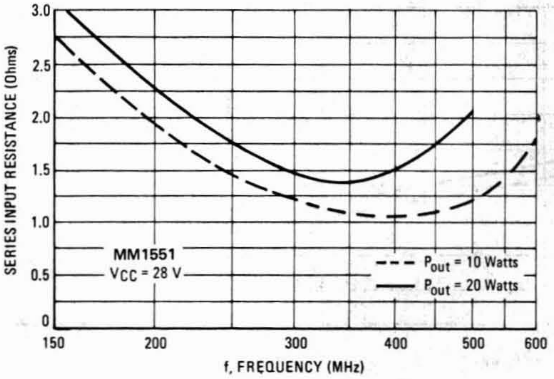


FIGURE 7



IMAGINARY INPUT IMPEDANCE versus FREQUENCY

FIGURE 4

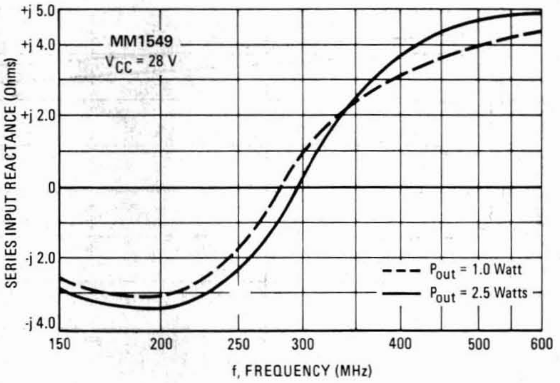


FIGURE 6

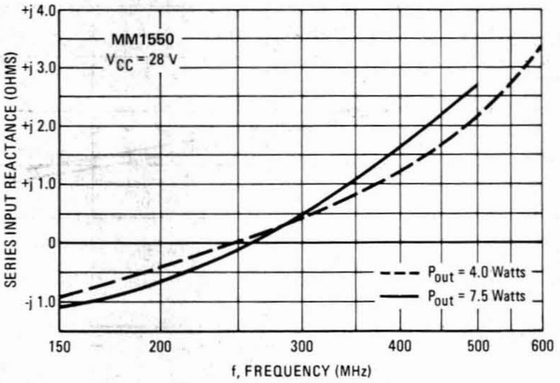
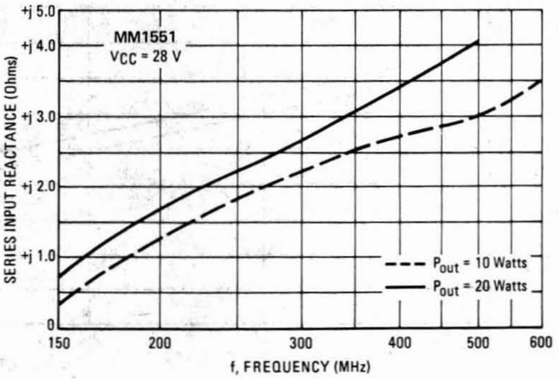


FIGURE 8



CIRCUIT DESIGN DATA

LARGE SIGNAL OUTPUT CAPACITANCE versus FREQUENCY

FIGURE 9

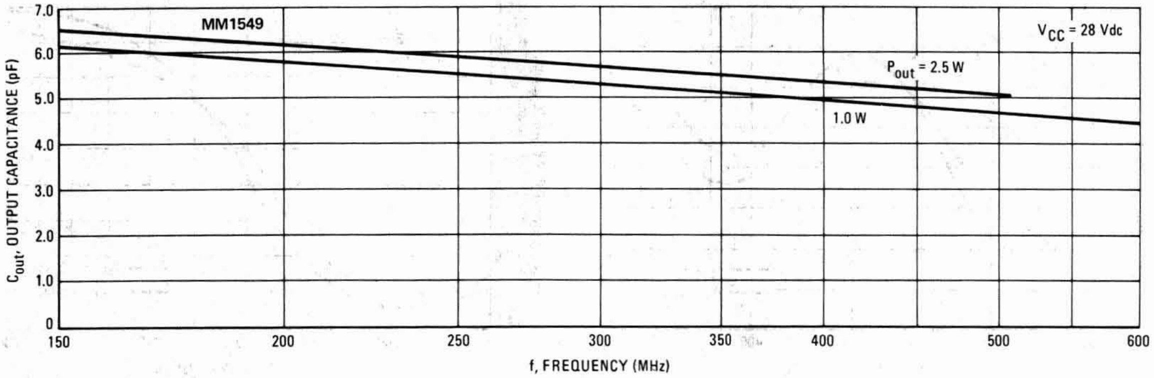


FIGURE 10

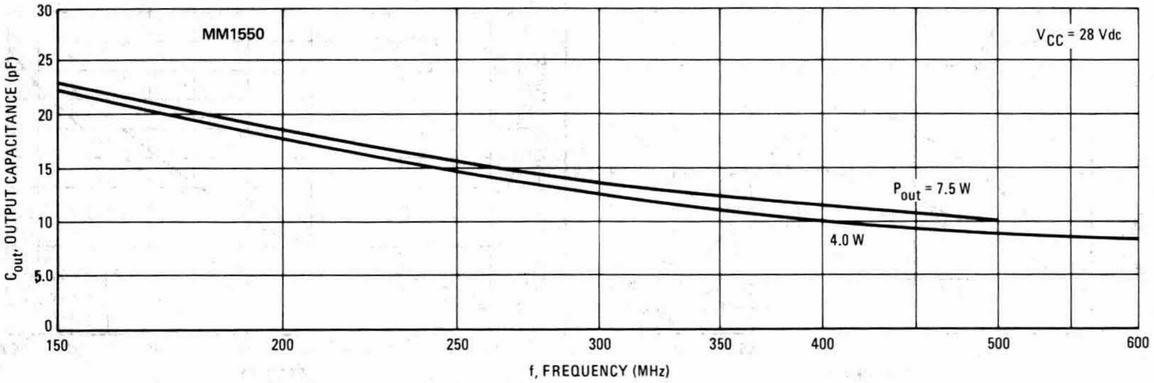
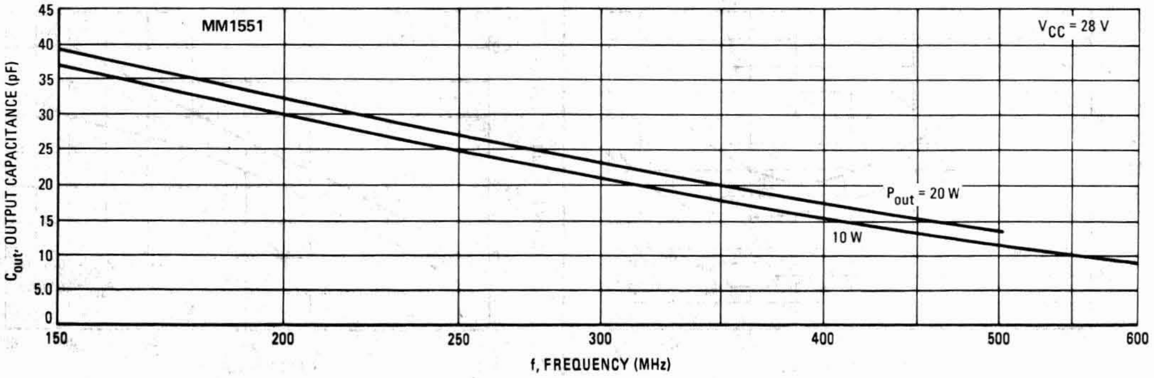


FIGURE 11



TYPICAL PERFORMANCE DATA

POWER OUTPUT versus FREQUENCY

FIGURE 12

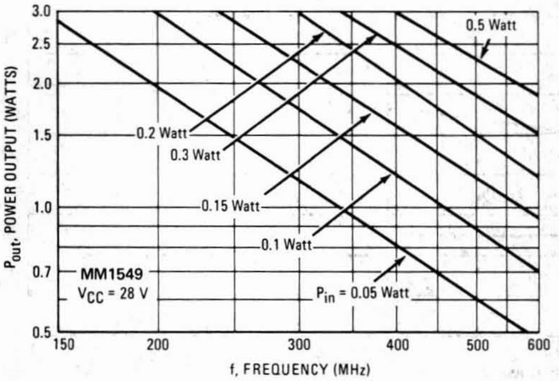


FIGURE 13

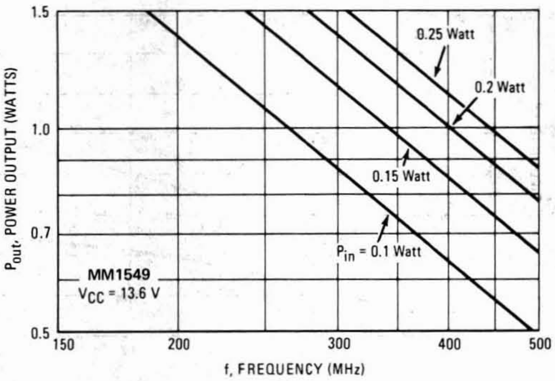


FIGURE 14

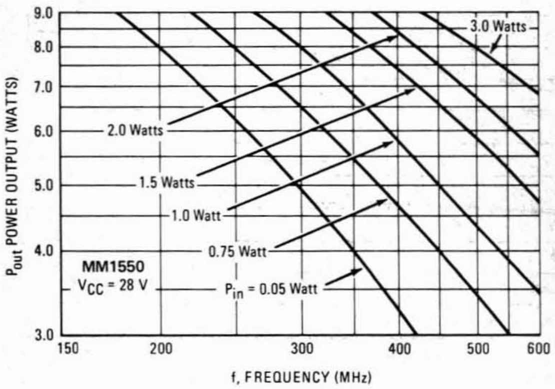


FIGURE 15

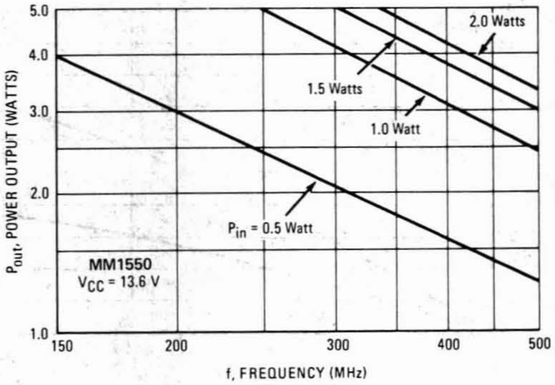


FIGURE 16

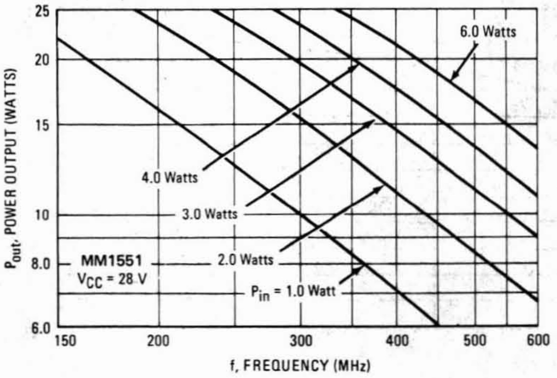
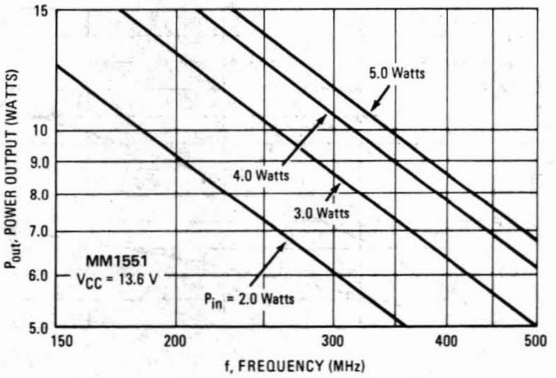


FIGURE 17



TYPICAL PERFORMANCE DATA

POWER OUTPUT versus POWER INPUT

FIGURE 18

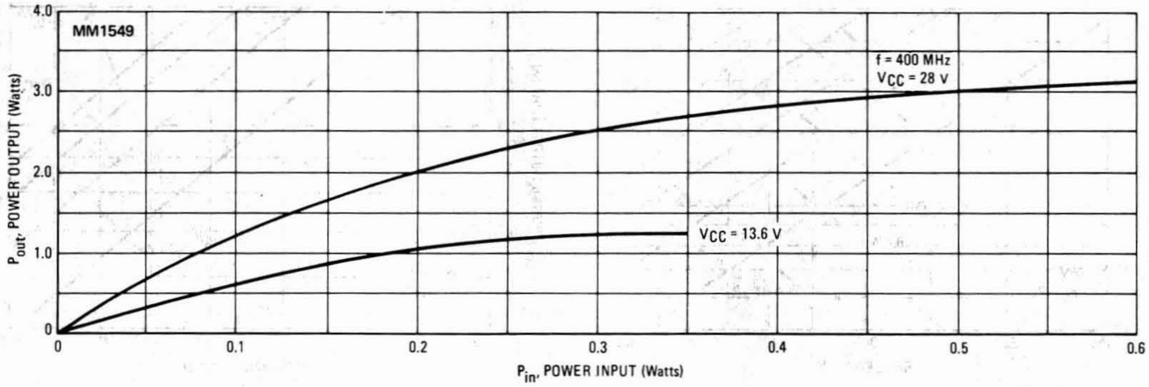


FIGURE 19

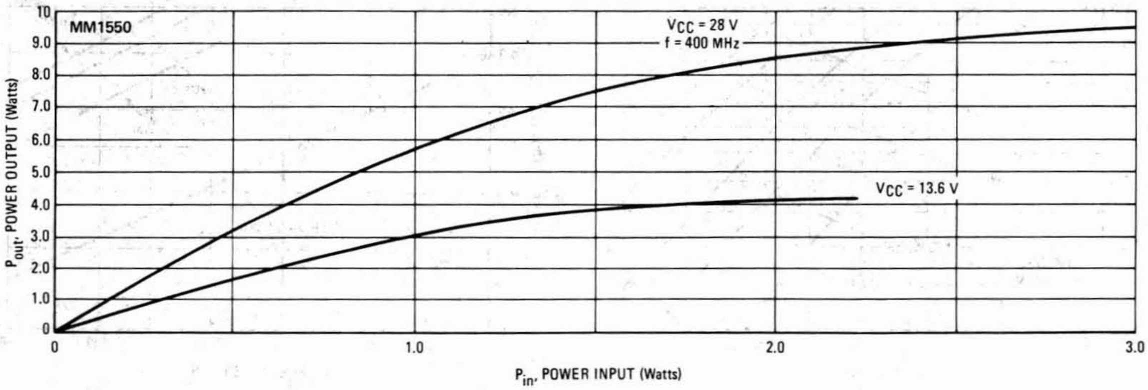
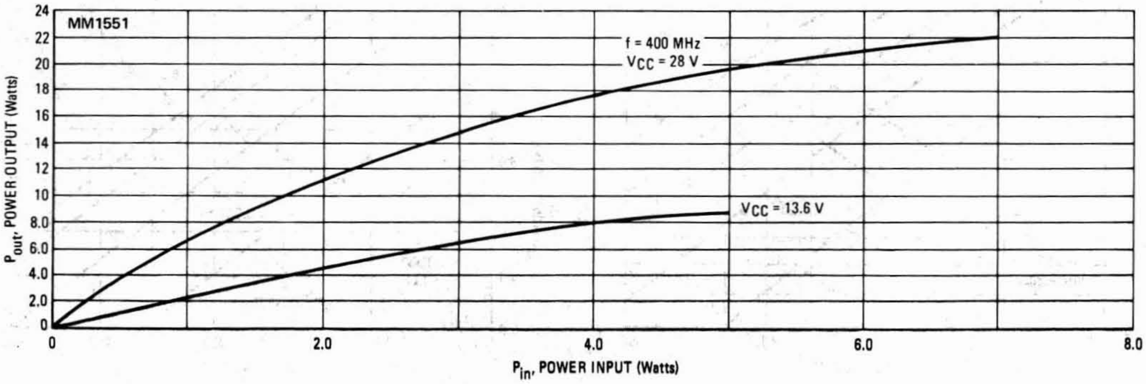


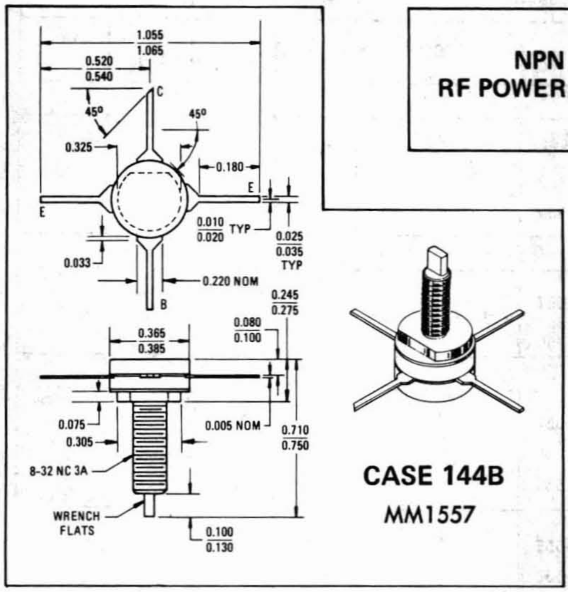
FIGURE 20



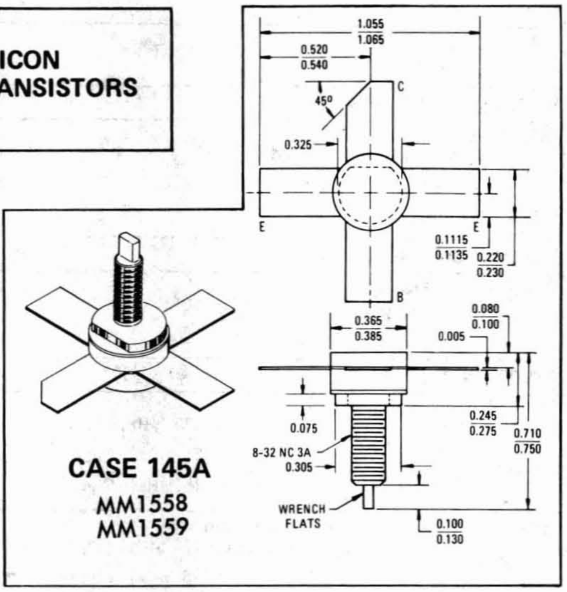
MM1557 (SILICON)
MM1558
MM1559

NPN silicon RF power transistors designed for power amplifier or oscillator applications in military and industrial equipment. Suitable for Class AB, B or C in applications to 400 MHz.

NPN SILICON
RF POWER TRANSISTORS


1.055
1.065
0.520
0.540
C
45°
45°
0.325
0.180
E
E
0.010
0.020
TYP
0.025
0.035
TYP
0.033
0.220 NOM
B
0.245
0.275
0.080
0.100
0.365
0.385
0.075
0.305
0.005 NOM
0.710
0.750
8-32 NC 3A
WRENCH FLATS
0.100
0.130

CASE 144B
MM1557


1.055
1.065
0.520
0.540
C
45°
0.325
E
E
0.1115
0.1135
0.220
0.230
B
0.080
0.100
0.365
0.385
0.005
0.075
8-32 NC 3A
0.305
0.245
0.275
0.710
0.750
WRENCH FLATS
0.100
0.130

CASE 145A
MM1558
MM1559

MAXIMUM RATINGS

Rating	Symbol	MM1557	MM1558	MM1559	Unit
Collector-Emitter Voltage	V_{CEO}	← 35 →			Vdc
Collector-Base Voltage	V_{CB}	← 65 →			Vdc
Emitter-Base Voltage	V_{EB}	← 4.0 →			Vdc
Collector Current	I_C	1.0	3.0	5.0	Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	15 86	30 171	60 342	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200			°C

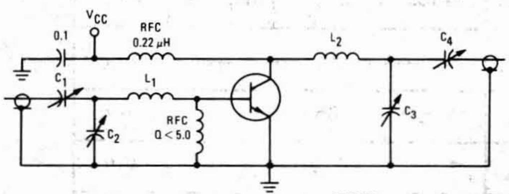
MM1557, MM1558, MM1559 (continued)

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Sustaining Voltage* ($I_C = 200$ mAdc, $I_B = 0$)		$BV_{CEO(sus)}$*	35	-	-	Vdc
Collector-Emitter Sustaining Voltage ($I_C = 200$ mAdc, $R_{BE} = 0$)		$BV_{CES(sus)}$	65	-	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 5.0$ mAdc, $I_C = 0$)	MM1557	BV_{EBO}	4.0	-	-	Vdc
($I_E = 10$ mAdc, $I_C = 0$)	MM1558, MM1559		4.0	-	-	
Collector Cutoff Current ($V_{CB} = 30$ Vdc, $I_E = 0$)		I_{CBO}	-	-	1.0	mAdc
ON CHARACTERISTICS						
DC Current Gain ($I_C = 100$ mAdc, $V_{CE} = 5.0$ Vdc)	MM1557	h_{FE}	5.0	-	-	-
($I_C = 200$ mAdc, $V_{CE} = 5.0$ Vdc)	MM1558		5.0	-	-	
($I_C = 500$ mAdc, $V_{CE} = 5.0$ Vdc)	MM1559		5.0	-	-	
DYNAMIC CHARACTERISTICS						
Output Capacitance ($V_{CB} = 30$ Vdc, $I_E = 0$, f = 0.1 to 1.0 MHz)	MM1557	C_{ob}	-	-	20	pF
	MM1558		-	-	50	
	MM1559		-	-	100	
FUNCTIONAL TEST						
Power Input ($P_{out} = 7.0$ Watts, $V_{CE} = 28$ Vdc, f = 175 MHz) (Figure 1)	MM1557	P_{in}	-	0.4	1.0	Watts
($P_{out} = 20$ Watts, $V_{CE} = 28$ Vdc, f = 175 MHz) (Figure 1)	MM1558		-	1.9	3.0	
($P_{out} = 40$ Watts, $V_{CE} = 28$ Vdc, f = 175 MHz) (Figure 2)	MM1559		-	5.0	7.0	
Common-Emitter Amplifier Power Gain ($P_{out} = 7.0$ Watts, $V_{CE} = 28$ Vdc, f = 175 MHz) (Figure 1)	MM1557	G_{PE}	8.4	12.5	-	dB
($P_{out} = 20$ Watts, $V_{CE} = 28$ Vdc, f = 175 MHz) (Figure 1)	MM1558		8.2	10.2	-	
($P_{out} = 40$ Watts, $V_{CE} = 28$ Vdc, f = 175 MHz) (Figure 2)	MM1559		7.6	9.1	-	
Collector Efficiency ($P_{out} = 7.0$ Watts, $V_{CE} = 28$ Vdc, f = 175 MHz) (Figure 1)	MM1557	η	60	-	-	%
($P_{out} = 20$ Watts, $V_{CE} = 28$ Vdc, f = 175 MHz) (Figure 1)	MM1558		60	-	-	
($P_{out} = 40$ Watts, $V_{CE} = 28$ Vdc, f = 175 MHz) (Figure 2)	MM1559		60	-	-	

* Pulsed through 25 mH inductor

FIGURE 1 — 175 MHz TEST CIRCUIT (MM1557, MM1558)



MM1557

C_1, C_3, C_4 – 5.0 – 80 pF

C_2 – 9.0 – 180 pF

L_1 – 1¼" Straight #14 AWG

L_2 – 3 Turns #16 AWG, 14" I.D.

MM1558

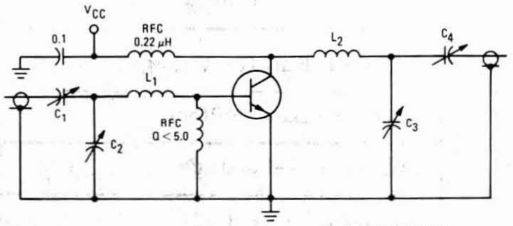
C_1 – 3.0 – 30 pF

$C_2, C_3, C_4,$ – 9.0 – 180 pF

L_1 – 1" Straight #14 AWG

L_2 – 1 Turn #16 AWG, ¼" I.D.

FIGURE 2 — 175 MHz TEST CIRCUIT (MM1559)



L_1 – 1" Straight #14 AWG

L_2 – 1 Turn #16 AWG, ¼" I.D.

$C_1, C_2, C_3, C_4,$ - ARCO 464 25-280 pF

CIRCUIT DESIGN DATA

REAL INPUT IMPEDANCE versus FREQUENCY

FIGURE 3

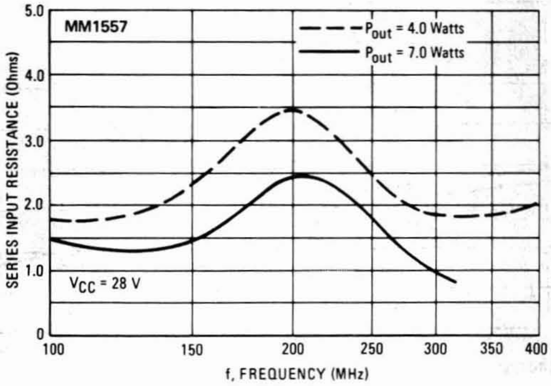


FIGURE 5

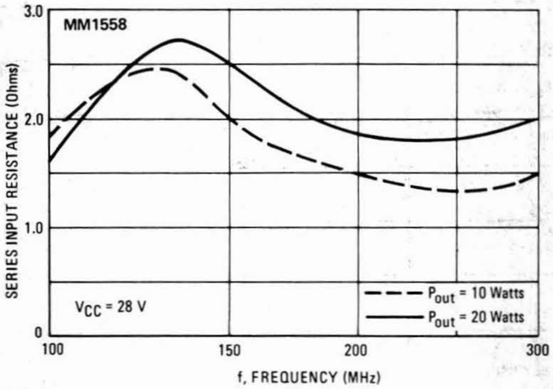
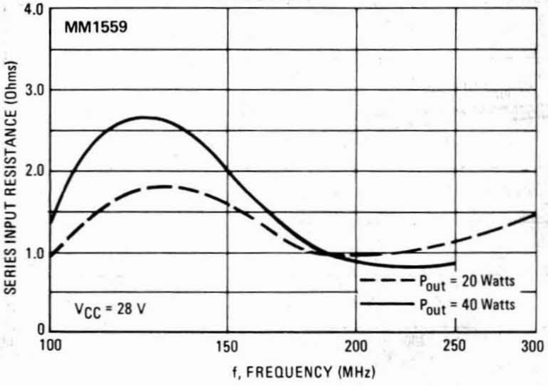


FIGURE 7



IMAGINARY INPUT IMPEDANCE versus FREQUENCY

FIGURE 4

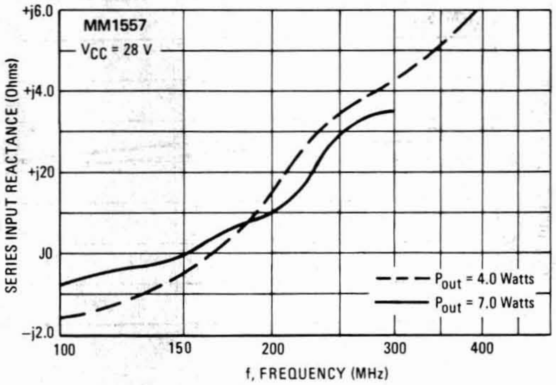


FIGURE 6

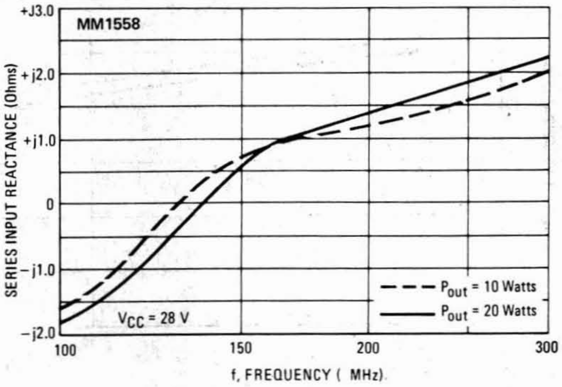
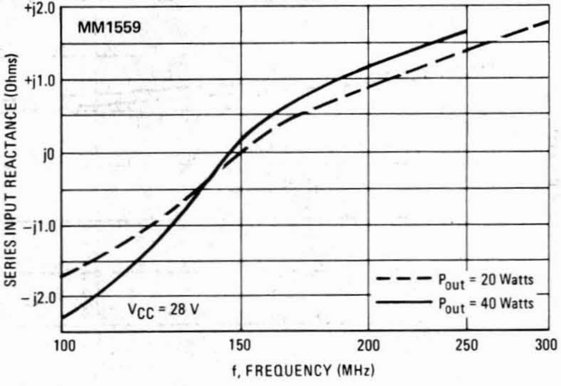


FIGURE 8



CIRCUIT DESIGN DATA

LARGE SIGNAL OUTPUT CAPACITANCE versus FREQUENCY

FIGURE 9

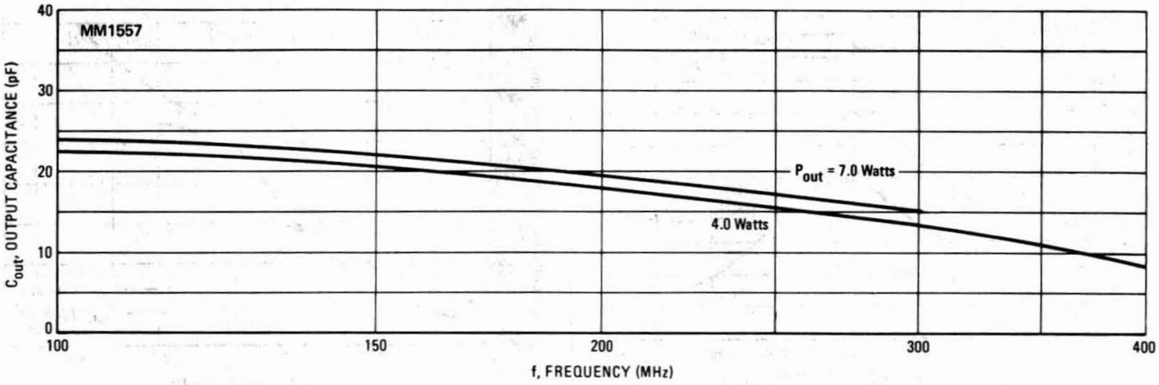


FIGURE 10

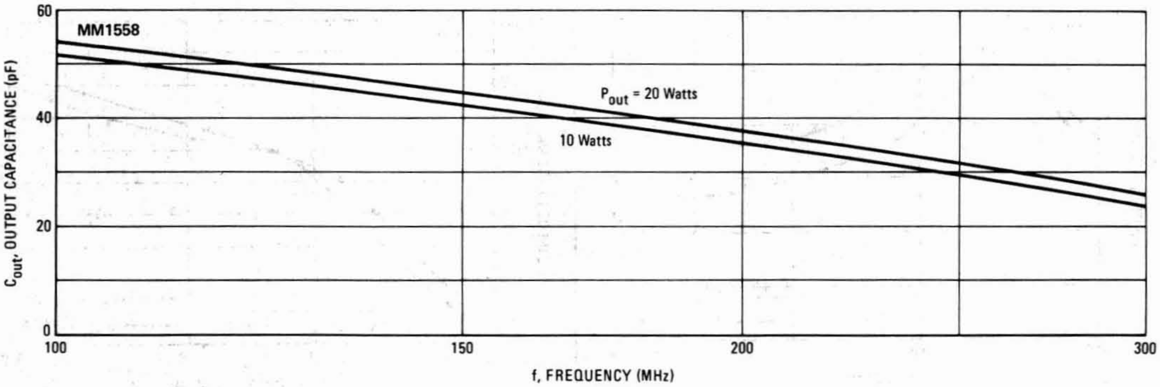
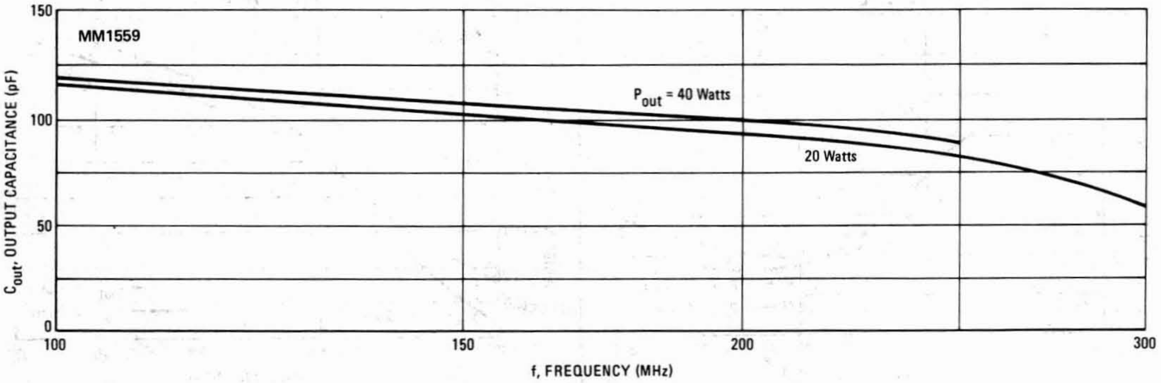


FIGURE 11



PERFORMANCE DATA

POWER OUTPUT versus FREQUENCY

FIGURE 12

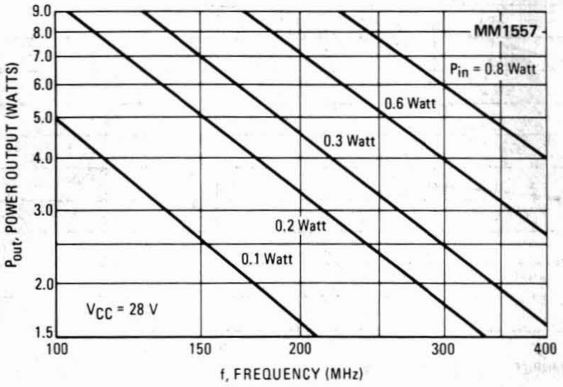


FIGURE 13

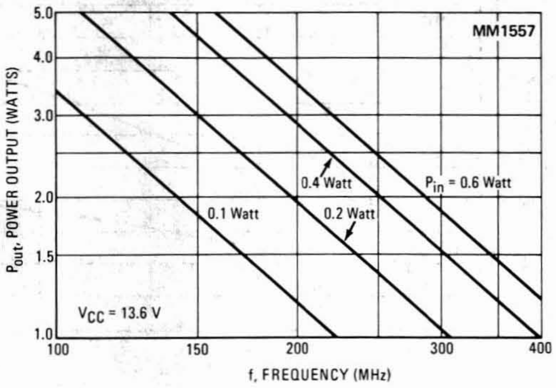


FIGURE 14

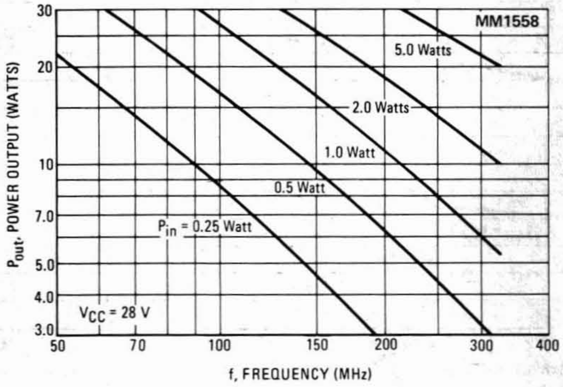


FIGURE 15

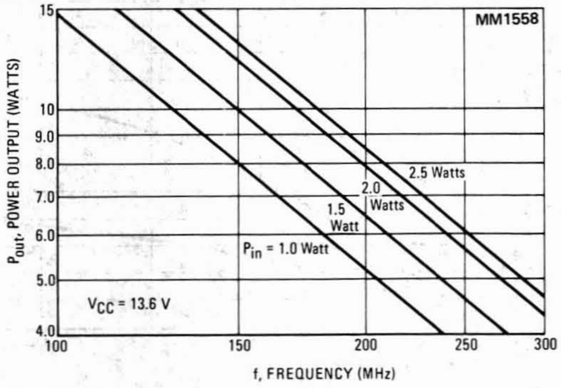


FIGURE 16

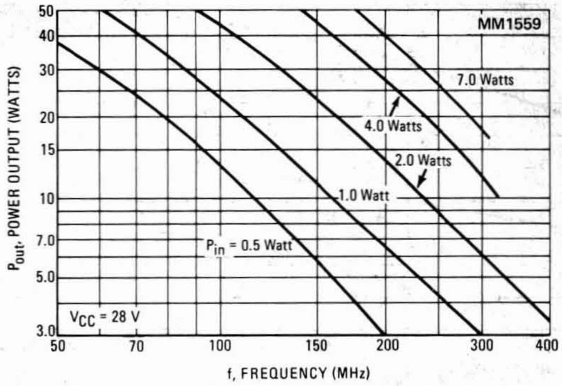
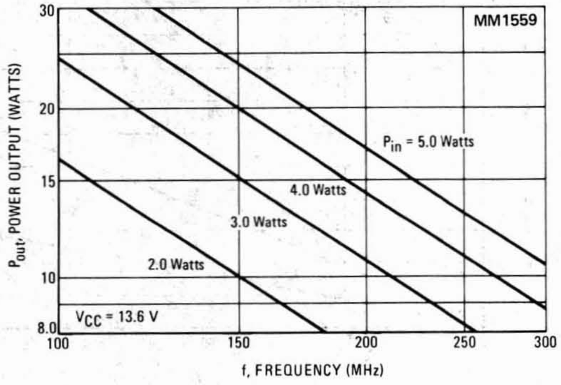


FIGURE 17



PERFORMANCE DATA

POWER OUTPUT versus POWER INPUT

FIGURE 18

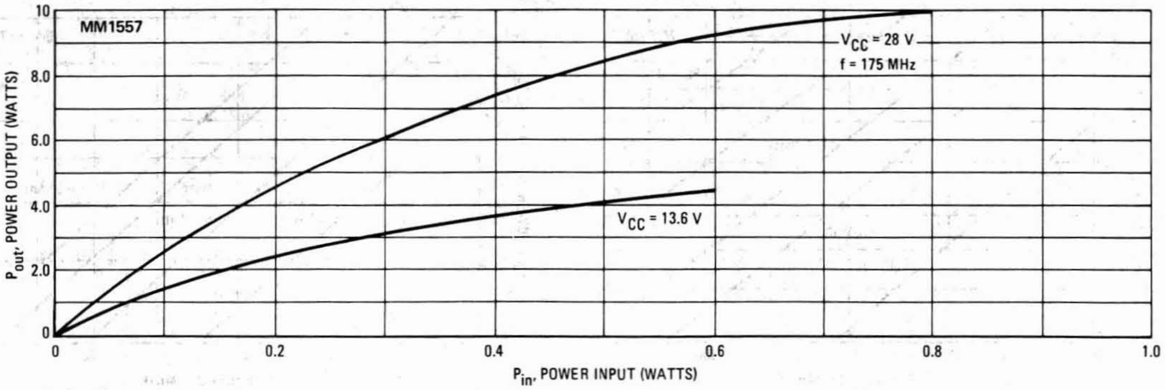


FIGURE 19

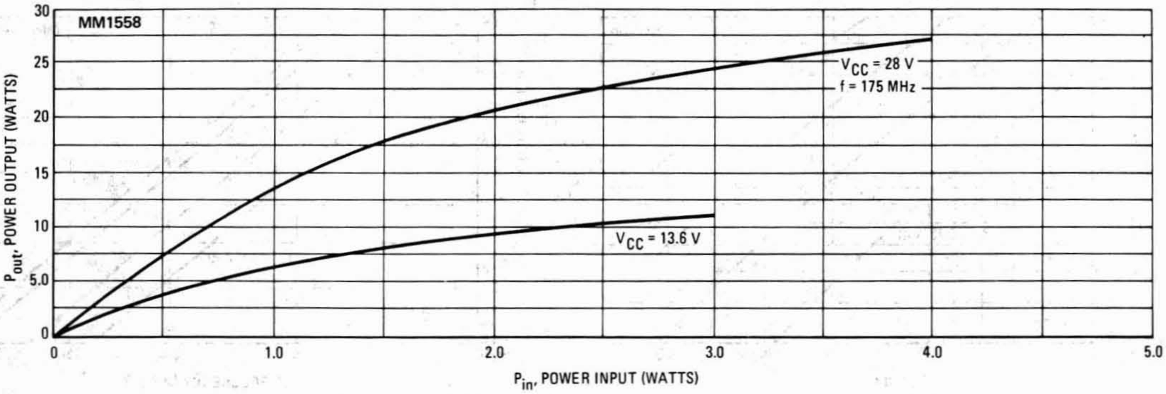
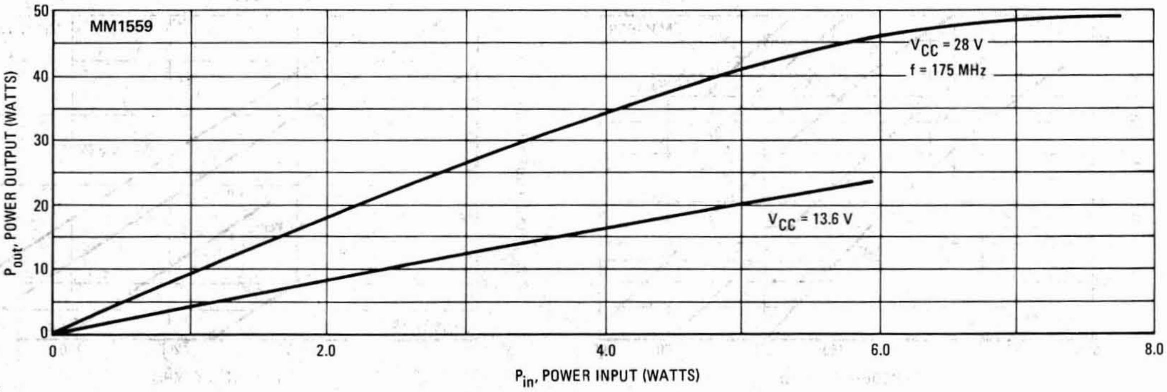


FIGURE 20



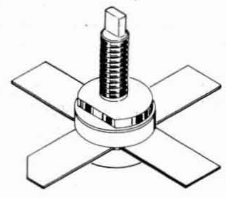
MM1603 (SILICON)

NPN SILICON RF POWER TRANSISTORS

. . . designed for power amplifier or oscillator applications in military and industrial equipment. Suitable for Class AB, B or C operation in 13.6 V applications to 240 MHz.

- Balanced Emitter Construction for Excellent Safe Operating Area. Designed to Withstand an Open or Shorted Load at Rated Power Output
- Low Profile Stripline Package for Low Lead Inductance and Better Broadband Capability
- 25 Watts Power Output @ 13.6 Volts, 4.4 dB Gain (Min) @ 175 MHz

NPN SILICON
RF POWER TRANSISTOR



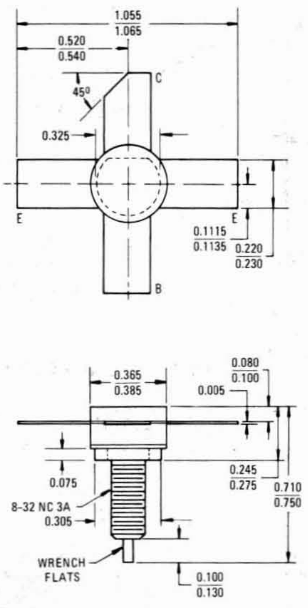
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	18	Vdc
Collector-Base Voltage	V_{CB}	36	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	5.0	Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	70 400	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

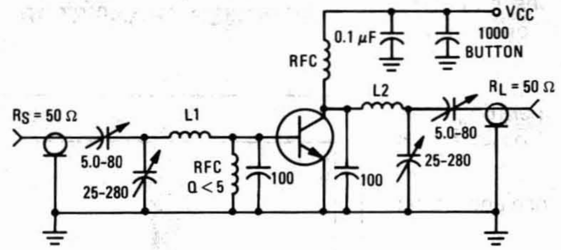
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* ($I_C = 200$ mAdc, $I_B = 0$)	BV_{CEO}*	18	-	-	Vdc
Collector-Emitter Breakdown Voltage* ($I_C = 200$ mAdc, $I_E = 0$)	BV_{CES}*	36	-	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 5.0$ mAdc, $I_C = 0$)	BV_{EBO}	4.0	-	-	Vdc
Collector Cutoff Current ($V_{CB} = 15$ Vdc, $I_E = 0$)	I_{CBO}	-	-	1.0	mAdc
ON CHARACTERISTICS					
DC Current Gain ($I_C = 500$ mAdc, $V_{CE} = 5.0$ Vdc)	h_{FE}	5.0	-	-	-
DYNAMIC CHARACTERISTICS					
Output Capacitance ($V_{CB} = 15$ Vdc, $I_E = 0$, f = 0.1 to 1.0 MHz)	C_{ob}	-	80	120	pF
FUNCTIONAL TESTS					
Power Input ($P_{out} = 25$ Watts, $V_{CE} = 13.6$ Vdc, f = 175 MHz) (Figure 1)	P_{in}	-	-	9.0	Watts
Common-Emitter Amplifier Power Gain ($P_{out} = 25$ Watts, $V_{CE} = 13.6$ Vdc, f = 175 MHz) (Figure 1)	G_{PE}	4.4	-	-	dB
Collector Efficiency ($P_{out} = 25$ Watts, $V_{CE} = 13.6$ Vdc, f = 175 MHz) (Figure 1)	η	50	-	-	%

*Pulsed through 25 mH inductor.



CASE 145A

FIGURE 1 — 175 MHZ TEST CIRCUIT



VCC
0.1 μF
1000 BUTTON
RFC
L2
RL = 50 Ω
RS = 50 Ω
L1
5.0-80
25-280
RFC Q < 5
100
100
5.0-80
25-280

ALL CAPACITORS IN pF UNLESS OTHERWISE INDICATED
L1 — #14 AWG STRAIGHT WIRE, 1-3/8" LONG
L2 — 1 TURN #14 AWG WIRE, 3/8" DIA. 1-1/2" LONG

FIGURE 2 — PARALLEL EQUIVALENT OUTPUT CAPACITANCE versus FREQUENCY

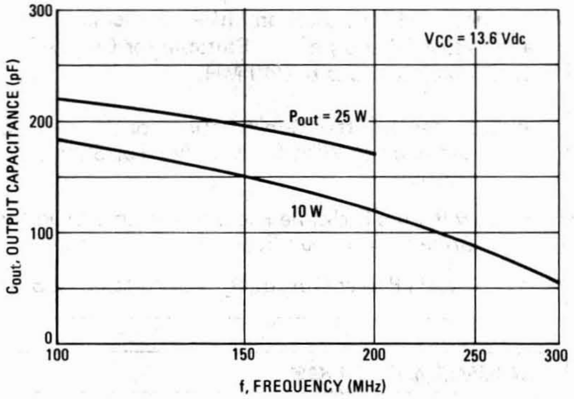


FIGURE 3 — PARALLEL EQUIVALENT INPUT CAPACITANCE versus FREQUENCY

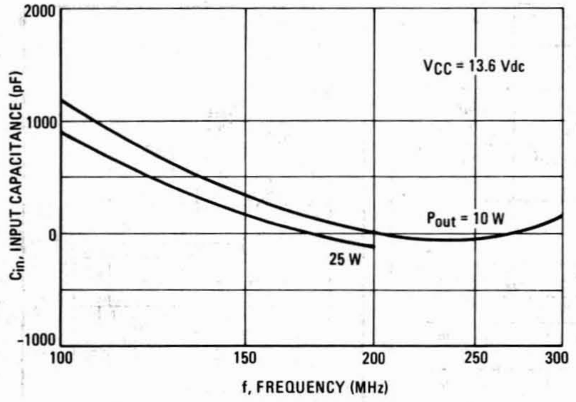


FIGURE 4 — PARALLEL EQUIVALENT INPUT RESISTANCE versus FREQUENCY

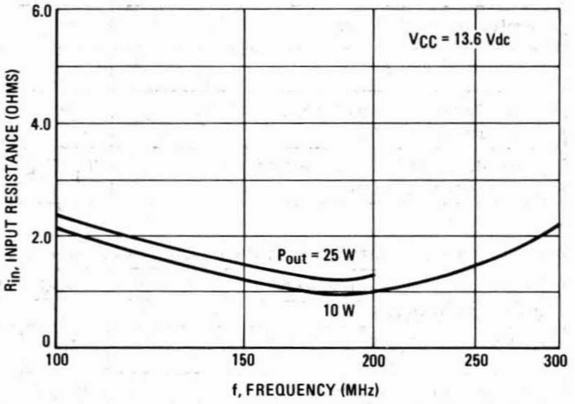


FIGURE 5 — POWER OUTPUT versus FREQUENCY

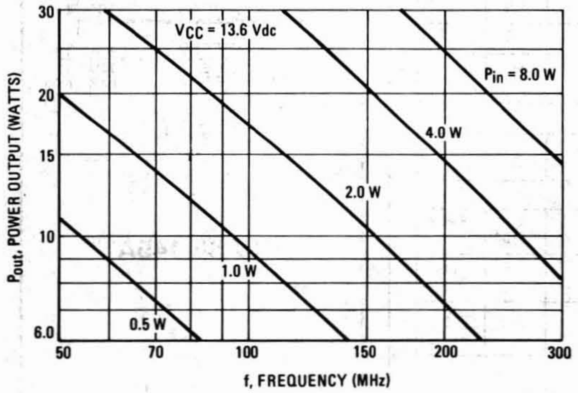
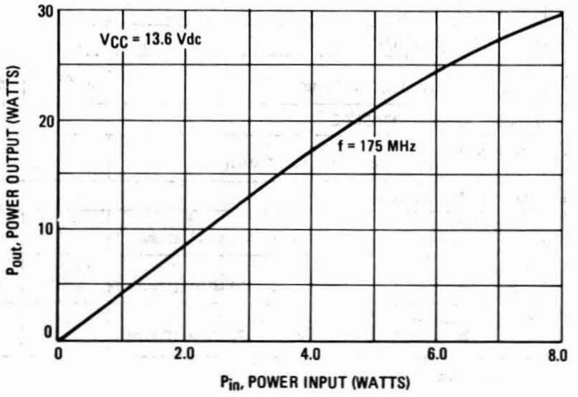


FIGURE 6 — POWER OUTPUT versus POWER INPUT



MM1748 (SILICON)

CASE 27
(TO-52)

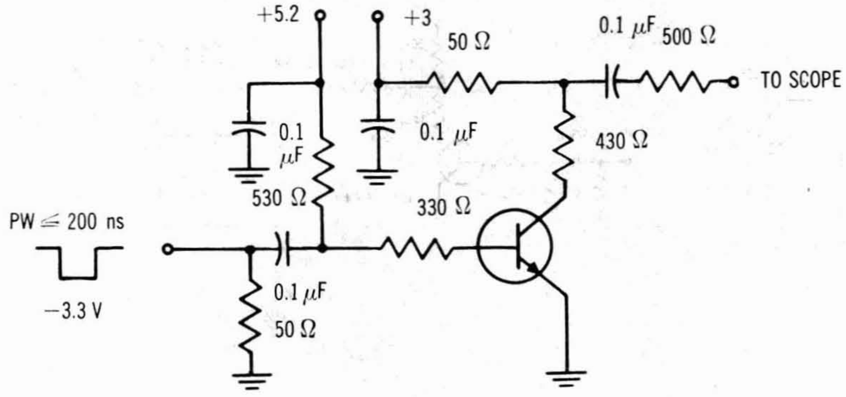
Collector connected to case

NPN silicon annular transistor designed for ultra-high speed switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	6	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector Current	I_C	100	mAdc
Total Device Dissipation $T_A = 25^oC$ Derate above 25°C	P_D	300 1.71	mWatts mW/°C
Total Device Dissipation $T_C = 100^oC$ Derate above 100°C	P_D	500 2.0	mWatts mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

FIGURE 1 — STORAGE TIME CONSTANT TEST CIRCUIT

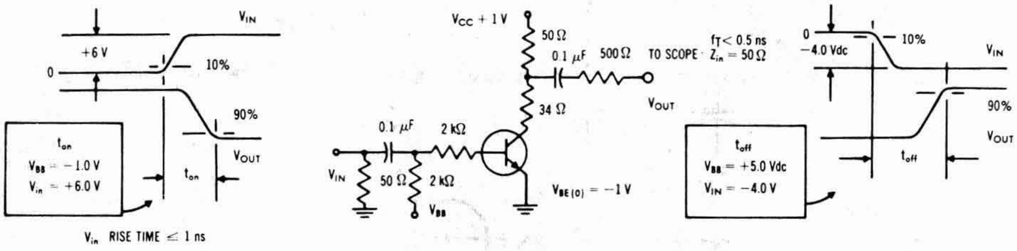

+5.2
+3
50 Ω
0.1 μF
500 Ω
TO SCOPE
0.1 μF
0.1 μF
430 Ω
530 Ω
330 Ω
PW ≤ 200 ns
−3.3 V
0.1 μF
50 Ω

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	6	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	15	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4	-	-	Vdc
Collector Cutoff Current (V_{CB} = 5 Vdc, I_E = 0) (V_{CB} = 5 Vdc, I_E = 0, T_A = 125°C)	I_{CBO}	- -	0.002 0.5	0.05 5.0	μAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 0.5 Vdc) (I_C = 10 mAdc, V_{CE} = 0.5 Vdc, T_A = -55°C) (I_C = 30 mAdc, V_{CE} = 1 Vdc)	h_{FE}*	20 10 15	- - -	120 - -	-
Collector-Emitter Saturation Voltage (I_C = 3 mAdc, I_B = 0.15 mAdc)	$V_{CE(sat)}$	-	0.2	0.3	Vdc
Base-Emitter Saturation Voltage (I_C = 3 mAdc, I_B = 0.15 mAdc)	$V_{BE(sat)}$	0.70	-	0.85	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 5 mAdc, V_{CE} = 4 Vdc, f = 100 MHz)	f_T	600	-	-	MHz
Output Capacitance (V_{CB} = 5 Vdc, I_E = 0)	C_{ob}	-	-	3	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0)	C_{ib}	-	-	2	pF
Turn-On Time, Figure 2 (V_{CC} = 1 Vdc, V_{EB} (off) = 1 Vdc, I_C = 10 mAdc, I_{B1} = 2 mAdc, I_{B2} = 1.0 mA)	t_{on}	-	8	15	ns
Turn-Off Time, Figure 2 (V_{CC} = 1 Vdc, I_C = 10 mAdc, I_{B1} = I_{B2} = 1 mAdc)	t_{off}	-	6	15	ns
Storage Time, Figure 1 (I_C = 5 mAdc, I_{B1} = I_{B2} = 5 mAdc)	t_s	-	-	6	ns

*Pulse Test: Pulse Width = 300 μs; Duty Cycle = 2%

FIGURE 2 — TURN-ON & TURN-OFF TIME TEST CIRCUIT


V_{IN}
+6 V
0
10%
90%
V_{OUT}
t_{on}
V_{BB} = −1.0 V
V_{in} = +6.0 V
t_{on}
V_{in} RISE TIME ≤ 1 ns
V_{CC} + 1 V
50 Ω
0.1 μF
500 Ω
TO SCOPE
f_T < 0.5 ns
Z_{in} = 50 Ω
34 Ω
V_{OUT}
0.1 μF
2 kΩ
V_{IN}
50 Ω
2 kΩ
V_{BB}
$V_{BE(0)}$ = −1 V
0
−4.0 Vdc
10%
V_{IN}
90%
V_{OUT}
t_{off}
V_{BB} = +5.0 Vdc
V_{IN} = −4.0 V
t_{off}

MM1803

For Specifications, See **2N3137** Data.

MM1812 SILICON

CASE 31
(TO-5)

NPN silicon transistor designed for audio power amplifier applications up to 1 watt output.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	175	Vdc
Collector-Emitter Voltage	V_{CEO}	175	Vdc
Emitter-Base Voltage	V_{EB}	4	Vdc
Collector-Current	I_C	100	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	1.0 5.71	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	5 28.6	Watts mW/°C
Operating Junction Temperature	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	— —	0.1 100	µAdc
Emitter Cutoff Current (V_{EB} = 3 Vdc, I_C = 0)	I_{EBO}	—	0.025	µAdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	BV_{CBO}	175	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	175	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)	BV_{EBO}	4	—	Vdc
Collector Saturation Voltage* (I_C = 10 mAdc, I_B = 1 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{CE(sat)}$*	— —	0.3 0.6	Vdc
DC Current Gain * (I_C = 1.0 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 100 mAdc, V_{CE} = 10 Vdc)	h_{FE}*	25 35 40	— 200 300	—
Small Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{fe}	50	200	—
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{re}	—	4	$X10^{-4}$
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{ie}	0.2	1.25	k ohms
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{oe}	10	200	µmhos
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	10	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	100	pF

		Min	Typ	Max	
Power Gain (P_{out} = 1 W, V_{CE} = 85 Vdc, I_C = 30 mAdc, f = 1 kHz R_S = 400 ohms, R_L = 2.9 k ohms)	G_{pe}	36	44	—	dB

*Pulse Test: PW ≦ 300 µs, duty cycle ≦ 2%

FIGURE 1 — CURRENT GAIN CHARACTERISTICS versus JUNCTION TEMPERATURE

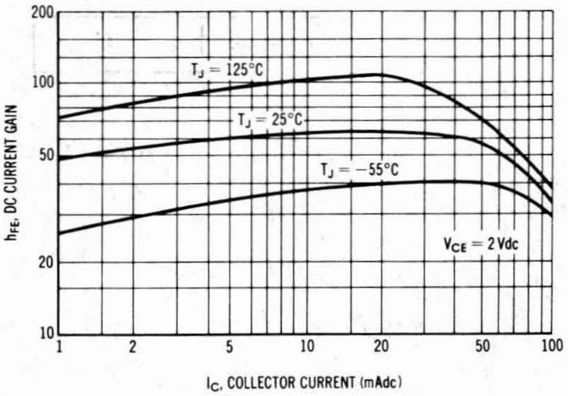
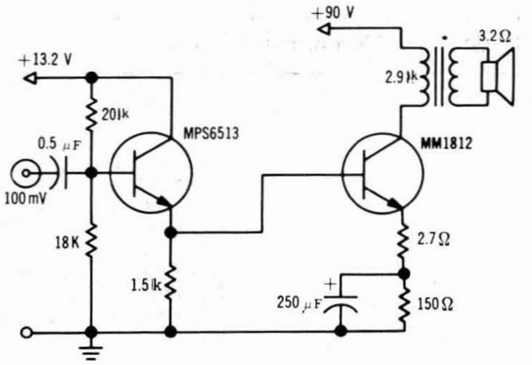


FIGURE 2 — 750 mW CLASS A AUDIO AMPLIFIER



*TRANSFORMER EFFICIENCY ≈ 75%

MM1941 (SILICON)

Collector connected to case

CASE 22
(TO-18)

NPN silicon annular transistor for high-frequency power oscillator, multiplier and driver applications.

MAXIMUM RATINGS (Tc = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	30	Volts
Collector-Emitter Voltage	V_{CES}	30	Volts
Emitter-Base Voltage	V_{EB}	3.0	Volts
Base Current	I_B	30	mAdc
Collector Current	I_C	200	mAdc
Input Power	P_{in}	100	mW
Output Power	P_{out}	250	mW
Power Dissipation @ T_C = 25°C Derate above 25°C	P_D*	600 4.0	mW mW/°C
Power Dissipation @ T_A = 25°C Derate above 25°C	P_D*	300 2.0	mW mW/°C
Junction Temperature	T_J	175	°C
Storage Temperature Range	T_{stg}	-65 to +175	°C

*See Safe Area Curve

ELECTRICAL CHARACTERISTICS (TA = 25°C unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Collector-Emitter Sustain Voltage	$V_{CES(sus)}$*	I_C = 15 mA, R_{BE} = 0	30	40	-	Volts
Collector-Base Breakdown Voltage	BV_{CBO}	I_C = 100 µAdc, I_E = 0	30	40	-	Volts
Collector Emitter-Open Base Sustain Voltage	$BV_{CEO(sus)}$*	I_C = 15 mA, I_B = 0	20	-	-	Volts
Collector Cutoff Current	I_{CBO}	V_{CB} = 15 Vdc, I_E = 0 V_{CB} = 15 Vdc, I_E = 0, T_C = 100°C	- -	0.01 -	0.1 25	µAdc
Emitter Cutoff Current	I_{EBO}	V_{EB} = 3 Vdc, I_C = 0	-	0.1	10	µAdc
DC Current Gain	h_{FE}	I_C = 10 mAdc, V_{CE} = 10 Vdc	25	50	-	-
AC Current Gain	$\lvert h_{fe} \rvert$	V_{CE} = 10 Vdc, I_C = 10 mAdc f = 100 mc	6	8	-	-
Collector Output Capacitance	C_{ob}	V_{CB} = 15 Vdc, I_E = 0, f = 100 kHz	-	-	2.5	pF
Power Output	P_{out}	P_{in} = 20 mW max, f = 175 MHz	100	-	-	mW
Power Gain	G_e	V_{CC} = 13.6 Vdc, $I_{C(max)}$ = 25 mA	7	9	-	dB

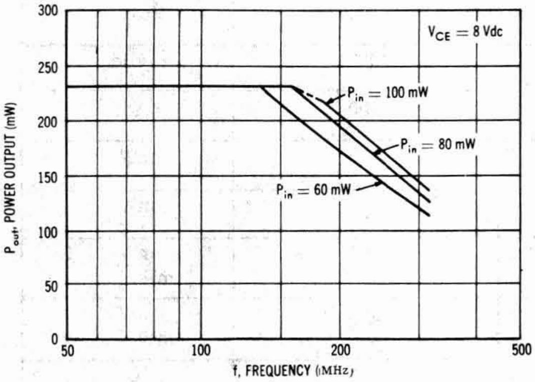
*Pulse Test: PW = 100 µs; DC = 2%

MM1941 (continued)

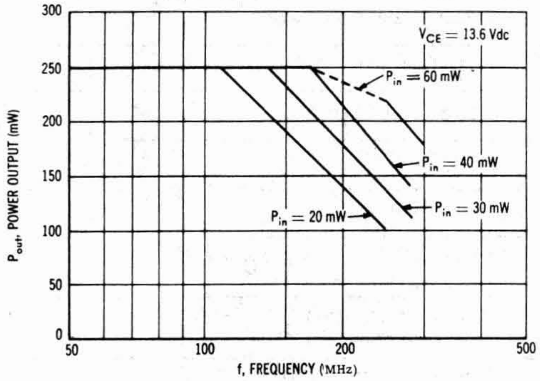
ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Power Output (Oscillator)	P_{out}	f = 80 MHz, V_{CC} = 13.6 Vdc, $I_{C(typ)}$ = 20 mAdc	-	50	-	mW
Power Gain (Multiplier)	G_e	f_{in} = 80 MHz, f_{out} = 240 MHz V_{CC} = 13.6 Vdc, $P_{out} \approx$ 30 mW $I_{C(typ)}$ = 25 mAdc	-	3	-	dB

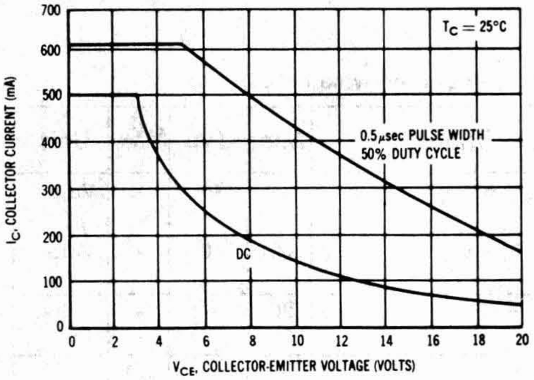
POWER OUTPUT versus FREQUENCY



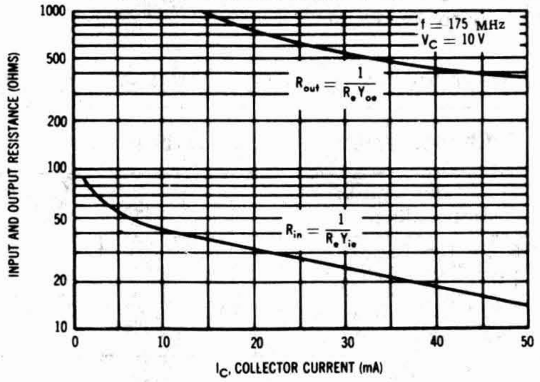
POWER OUTPUT versus FREQUENCY



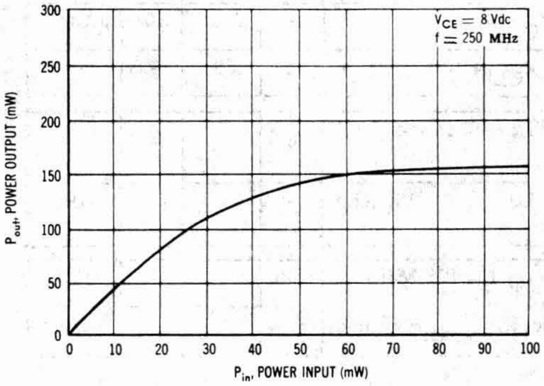
SAFE OPERATING AREA



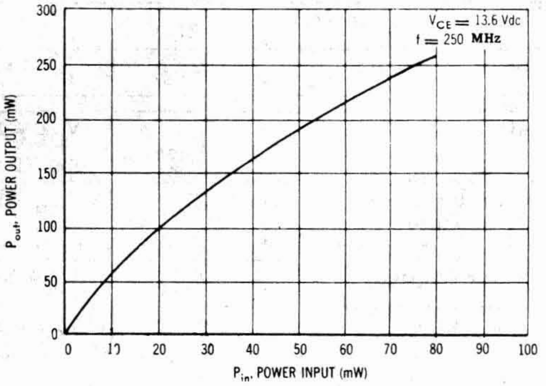
INPUT AND OUTPUT IMPEDANCE versus COLLECTOR CURRENT PARALLEL EQUIVALENT



POWER OUTPUT CHARACTERISTICS



POWER OUTPUT CHARACTERISTICS



MM2258 SILICON
MM2259
MM2260

CASE 31
(TO-5)

NPN silicon transistors designed for video output circuitry in transistorized television receivers.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value		Unit
		MM2258	MM2259 MM2260	
Collector-Base Voltage	V_{CB}	120	175	Vdc
Collector-Emitter Voltage	V_{CEO}	120	175	Vdc
Emitter-Base Voltage	V_{EB}	5		Vdc
Collector Current	I_C	500	300	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derating Factor Above 25°C	P_D	1.0 5.71		Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derating Factor Above 25°C	P_D	5 28.6		Watt mW/°C
Junction Temperature, Operating	T_J	+200		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

THERMAL RESISTANCE

$\theta_{JA(air)} = 175°C/W$

$\theta_{JC(case)} = 35°C/W$

MM2258, MM2259, MM2260 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristics		Symbol	Min	Typ	Max	Unit
Collector Cutoff Current (V_{CB} = 75 Vdc, I_E = 0) (V_{CB} = 75 Vdc, I_E = 0, T_A = 150°C)		I_{CBO}	— —	— —	0.050 50	µAdc
Emitter Cutoff Current (V_{EB} = 4 Vdc, I_C = 0)		I_{EBO}	—	—	25	nAdc
Collector-Base Breakdown Voltage (I_C = 10 µAdc, I_E = 0)	MM2258 MM2259, MM2260	BV_{CBO}	120 175	— —	— —	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	MM2258 MM2259, MM2260	BV_{CEO}*	120 175	— —	— —	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)		BV_{EBO}	5	—	—	Vdc
Collector-Emitter Saturation Voltage (I_C = 25 mAdc, I_B = 2.5 mAdc)		$V_{CE(sat)}$	—	—	0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 25 mAdc, I_B = 2.5 mAdc)		$V_{BE(sat)}$	—	—	1.0	Vdc
DC Current Gain* (I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	MM2259 MM2258, MM2260	h_{FE}	25 50	— —	— —	—
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	MM2259 MM2258, MM2260		35 50	— —	— —	
(I_C = 50 mAdc, V_{CE} = 10 Vdc)	MM2259 MM2258, MM2260		35 50	— —	— —	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	MM2258 MM2259, MM2260	C_{ob}	— —	— —	9 8	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	—	—	80	pF
Feedback (Miller) Capacitance (V_{CB} = 25 Vdc, I_C = 10 mAdc)	MM2258 MM2259, MM2260	C_{cb}	— —	4.2 3.0	5.0 4.5	pF
Small Signal Current Gain (V_{CE} = 25 Vdc, I_C = 20 mAdc, f = 100 MHz)		$\|h_{fe}\|$	1.5	—	—	—

*Pulse Test: PW ≤ 300 µs, duty cycle ≤ 2%

FIGURE 1 — DC CURRENT GAIN CHARACTERISTICS versus JUNCTION TEMPERATURE

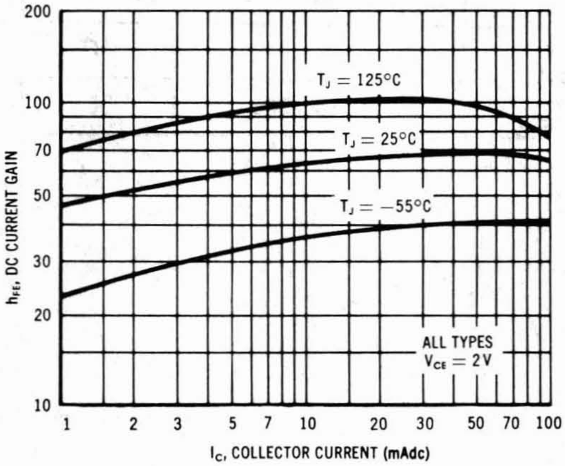
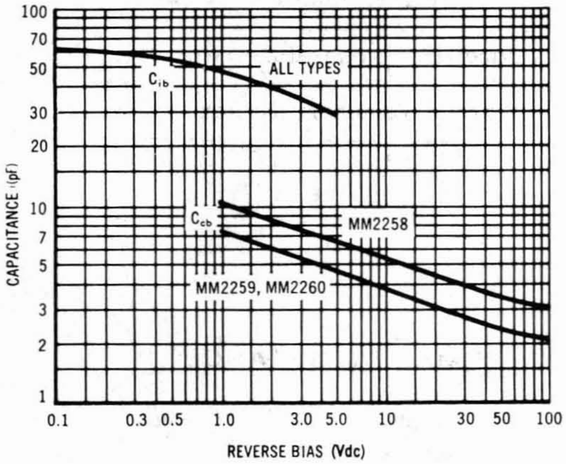


FIGURE 2 — JUNCTION CAPACITANCE VARIATIONS



SMALL SIGNAL h PARAMETER CHARACTERISTICS

(V_{CE} = 10 V, T_A = 25°C, f = 1 kHz)

FIGURE 3 — CURRENT GAIN

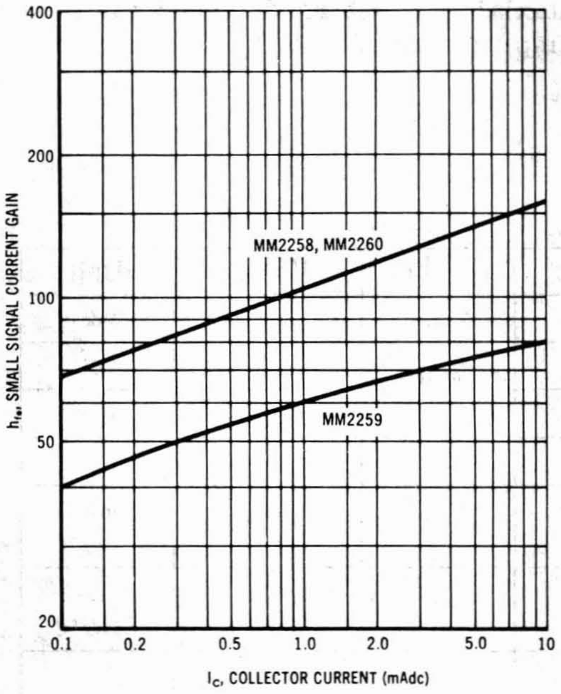


FIGURE 4 — OUTPUT ADMITTANCE

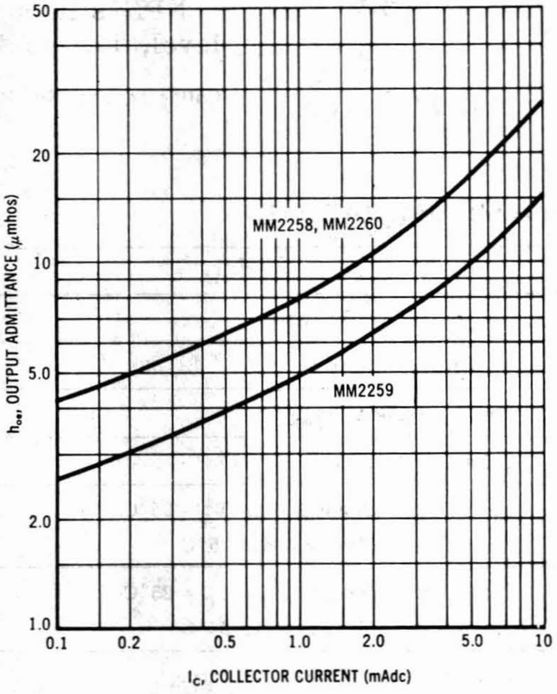


FIGURE 5 — INPUT IMPEDANCE

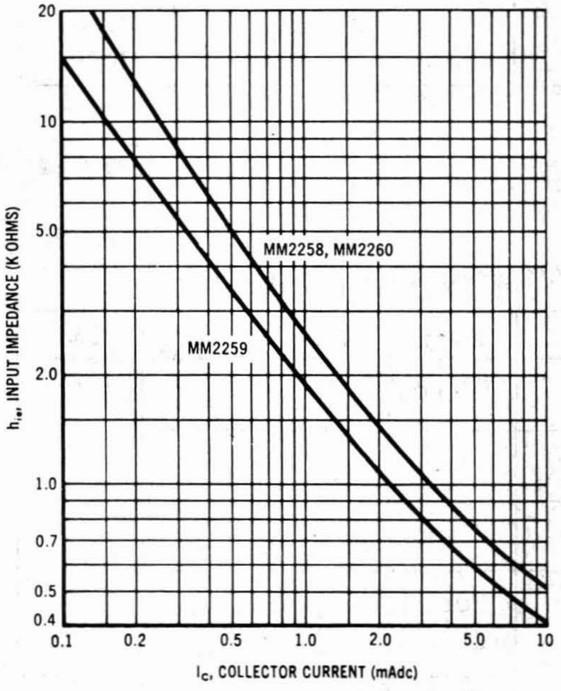
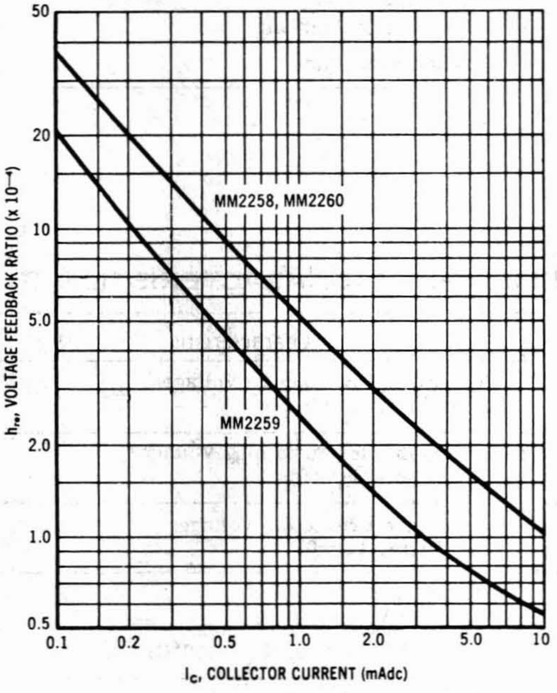
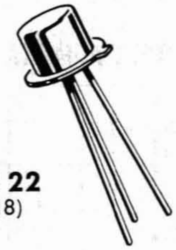


FIGURE 6 — VOLTAGE FEEDBACK RATIO



MM2483 SILICON
MM2484



CASE 22
(TO-18)

NPN silicon epitaxial transistors designed for low-level, low-noise amplifier applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	60	Vdc
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Emitter-Base Voltage	V_{EB}	6	Vdc
Collector Current	I_C	50	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derating Factor above 25°C	P_D	360 2.1	mW mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derating Factor above 25°C	P_D	1.2 6.9	Watts mW/°C
Junction Temperature, Operating	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C
Thermal Resistance: Junction-to Ambient Junction-to-Case	 θ_{JA} θ_{JC}	 486 146	 °C/W °C/W

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage ($I_C = 10\ \mu A$, $I_E = 0$)	BV_{CBO}	60	—	V
Collector-Emitter Sustaining Voltage* ($I_C = 10$ mA, $I_B = 0$)	$V_{CEO(sus)}$	60	—	V
Emitter-Base Breakdown Voltage ($I_E = 10\ \mu A$, $I_C = 0$)	BV_{EBO}	6	—	V
Collector Cutoff Current ($V_{CB} = 45$ V, $I_E = 0$) ($V_{CB} = 45$ V, $I_E = 0$, $T_A = 150°C$)	I_{CBO}	 — —	 0.010 10	μA
Emitter Cutoff Current ($V_{EB} = 5.0$ V, $I_C = 0$)	I_{EBO}	—	0.010	μA
Collector-Emitter Saturation Voltage ($I_C = 1.0$ mA, $I_B = 0.1$ mA)	$V_{CE(sat)}$	—	0.35	V

***Pulse Conditions: Length = 300 μs, Duty Cycle ≤ 2%**

MM2483, MM2484 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
DC Current Gain	h_{FE}			—
(I_C = 1.0 μA, V_{CE} = 5.0 V) MM2484		30	—	
(I_C = 10 μA, V_{CE} = 5.0 V) MM2483		40	120	
MM2484		100	500	
(I_C = 10 μA, V_{CE} = 5.0 V, -55°C) MM2483		10	—	
MM2484		20	—	
(I_C = 100 μA, V_{CE} = 5.0 V) MM2483		75	—	
MM2484		175	—	
(I_C = 500 μA, V_{CE} = 5.0 V) MM2483		100	—	
MM2484		200	—	
(I_C = 1.0 mA, V_{CE} = 5.0 V) MM2483		175	—	
MM2484		250	—	
(I_C = 10 mA, V_{CE} = 5.0 V)* MM2483		—	500	
MM2484		—	800	
Emitter-Base On Voltage (I_C = 100 μA, V_{CE} = 5.0 V)	$V_{BE(on)}$	0.5	0.7	V
High-Frequency Current Gain (I_C = 50 μA, V_{CE} = 5.0 V, f = 5.0 MHz) MM2483	h_{fe}	2.4	—	—
MM2484		3.0		
(I_C = 500 μA, V_{CE} = 5.0 V, f = 30 MHz)		2.0	—	
Output Capacitance (V_{CB} = 5.0 V, I_E = 0)	C_{ob}	—	6.0	pF
Emitter Transition Capacitance (V_{EB} = 0.5 V, I_C = 0)	C_{TE}	—	6.0	pF
Small Signal Current Gain (I_C = 1.0 mA, V_{CE} = 5.0 V, f = 1 kHz) MM2483	h_{fe}	80	450	—
MM2484		150	900	
Input Impedance (I_C = 1.0 mA, V_{CE} = 5.0 V, f = 1 kHz)	h_{ie}	3.5	24	kohms
Output Conductance (I_C = 1.0 mA, V_{CE} = 5.0 V, f = 1 kHz)	h_{oe}	—	50	μmhos
Voltage Feedback Ratio (I_C = 1.0 mA, V_{CE} = 5.0 V, f = 1 kHz)	h_{re}	—	2500	X10^{-6}
Common Base Input Impedance (I_C = 1.0 mA, V_{CE} = 5.0 V, f = 1 kHz)	h_{ib}	25	32	ohms
Wide Band Noise Figure (I_C = 10 μA, V_{CE} = 5.0 V, R_S = 10 kohms MM2483	NF	—	4	dB
MM2484		—	3	
Power Bandwidth of 15.7 kHz (3 dB points at 10 Hz and 10 kHz)				
Narrow Band Noise Figure (I_C = 10 μA, V_{CE} = 5.0 V, f = 1 kHz MM2483	NF	—	4	dB
R_S = 10 kohms (Power Bandwidth = 200 Hz) MM2484		—	3	
(I_C = 10 μA, V_{CE} = 5.0 V, f = 10 kHz, MM2483		—	3	
R_S = 10 kohms (Power Bandwidth = 2 kHz) MM2484		—	2	
(I_C = 10 μA, V_{CE} = 5 V, f = 10 kHz MM2483		—	15	
R_S = 10 kohms (Power Bandwidth = 20 Hz) MM2484		—	10	

*Pulse Conditions: **PW ≤ 300 μs, Duty Cycle ≤ 2%**

MM2894 (SILICON)

CASE 22
(TO-18)

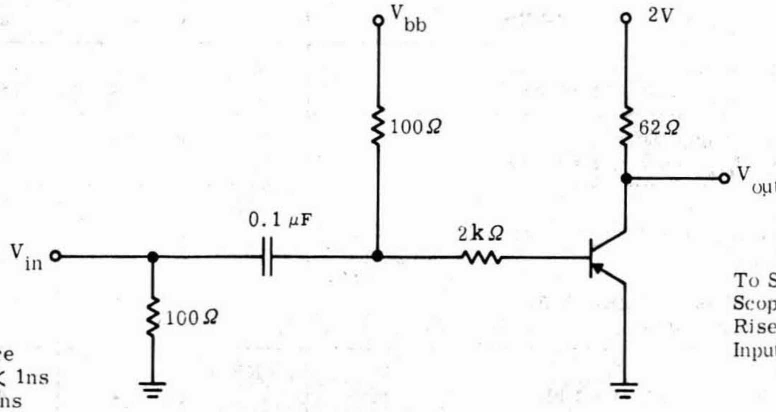
PNP silicon annular transistor for low-level, high-speed switching applications.

Collector connected to case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	15	Vdc
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Total Device Dissipation @ 25° C Ambient Temperature Derate above 25° C	P_D	0.36 2.06	Watt mW/° C
Total Device Dissipation @ 25° C Case Temperature Derate above 25° C	P_D	1.2 6.9	Watts mW/° C
Operating Junction Temperature	T_J	200	° C
Storage Temperature	T_{stg}	-65 to 200	° C

SWITCHING TIME TEST CIRCUIT



Pulse Source
Rise Time < 1ns
P.W. > 200ns
Z_{in} = 50 Ω

To Sampling
Scope
Rise Time < 1ns
Input Z = 100 k

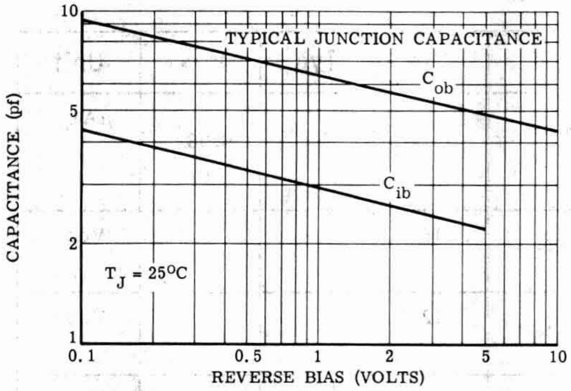
T_{on} V_{bb} = 3V V_{in} = 7V

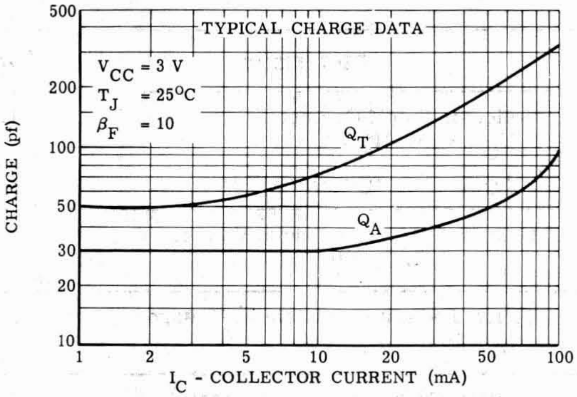
T_{off} V_{bb} = 4V V_{in} = 6V

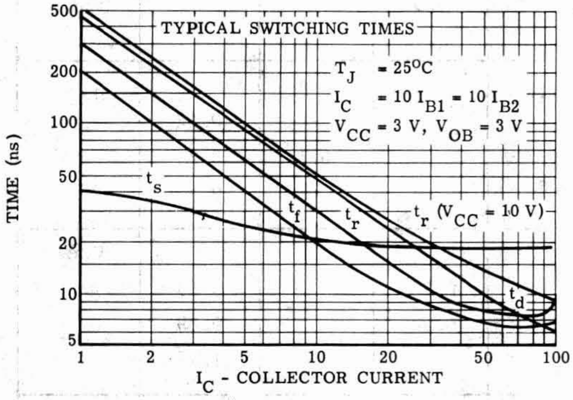
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

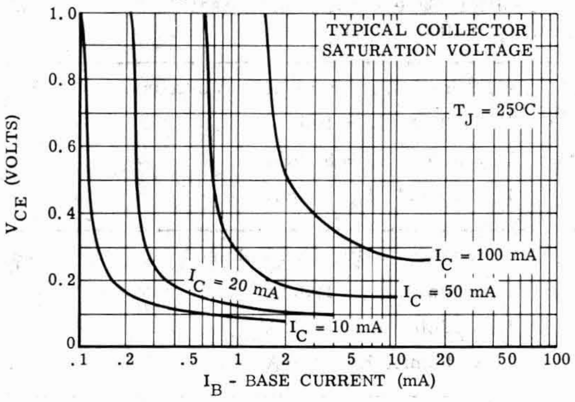
Characteristic	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current V_{CB} = 6V, I_E = 0 V_{CB} = 6V, I_E = 0, T_A = 125° C	I_{CBO}			 0.08 10	μA
Collector-Base Breakdown Voltage I_C = 10μA, I_E = 0	BV_{CBO}	15			Vdc
Collector-Emitter Sustaining Voltage* I_C = 10mA, I_B = 0	$V_{CEO(sust)}$	12			Vdc
Emitter-Base Breakdown Voltage I_E = 100μA, I_C = 0	BV_{EBO}	4.5			Vdc
Collector-Emitter Saturation Voltage I_C = 10mA, I_B = 1.0mA I_C = 30mA, I_B = 3.0mA I_C = 100mA, I_B = 10mA	$V_{CE(sat)}$		 0.1 	 0.15 0.2 0.5	Vdc
Base-Emitter Saturation Voltage I_C = 10mA, I_B = 1.0mA I_C = 30mA, I_B = 3.0mA I_C = 100mA, I_B = 10mA	$V_{BE(sat)}$	 0.68 0.74 		 0.83 0.89 1.7	Vdc
DC Pulse Current Gain* I_C = 1mA V_{CE} = 0.3v I_C = 10mA V_{CE} = 0.3v I_C = 30mA, V_{CE} = 0.5v I_C = 30mA, V_{CE} = 0.5v (-55° C) I_C = 100mA, V_{CE} = 1.0V	h_{FE*}	 25 30 40 17 25	 70 	 150 	—
High Frequency Current Gain (f = 100 MHz) VCE = 100 IC = 30mA	h_{fe}	4.0			—
Output Capacitance V_{CB} = 5.0V, I_E = 0, f = 140 kHz)	C_{ob}			6.0	pF
Emitter Transition Capacitance V_{EB} = 0.5V, I_C = 0, f = 140 kHz)	C_{TE}			6.0	pF
Turn On Time I_C = 30mA, I_{B1} = 1.5mA	t_{on}		23	60	ns
Turn Off Time I_C = 30mA, I_{B1} = I_{B2} = 1.5mA	t_{off}		34	60	ns

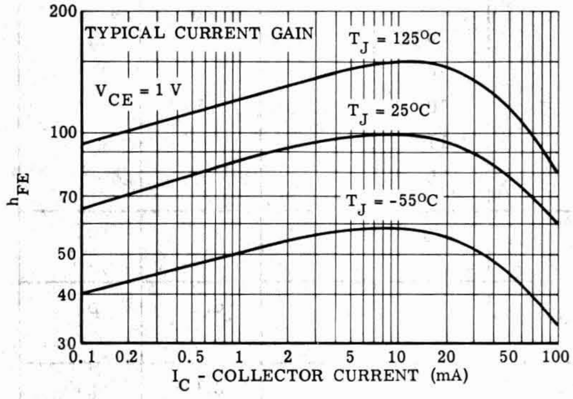
* Pulse Conditions; Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

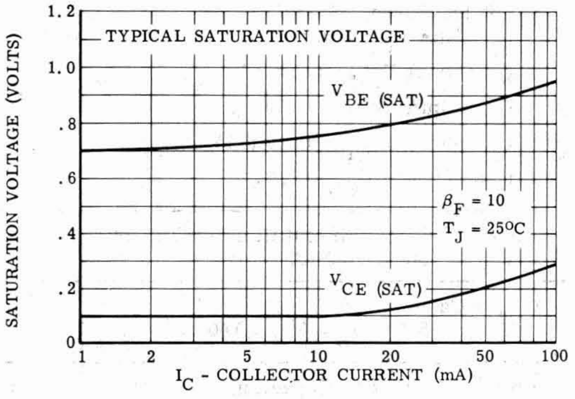

TYPICAL JUNCTION CAPACITANCE
CAPACITANCE (pf)
C_{ob}
C_{ib}
$T_J = 25^oC$
10
5
2
1
0.1
0.5
1
2
5
10
REVERSE BIAS (VOLTS)

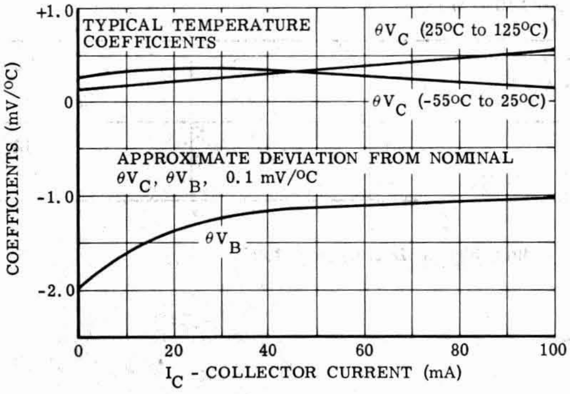

TYPICAL CHARGE DATA
$V_{CC} = 3$ V
$T_J = 25^oC$
$\beta_F = 10$
CHARGE (pf)
Q_T
Q_A
500
200
100
50
30
20
10
1
2
5
10
20
50
100
I_C - COLLECTOR CURRENT (mA)


TYPICAL SWITCHING TIMES
$T_J = 25^oC$
$I_C = 10\ I_{B1} = 10\ I_{B2}$
$V_{CC} = 3$ V, $V_{OB} = 3$ V
TIME (ns)
t_s
t_f
t_r
t_r ($V_{CC} = 10$ V)
t_d
500
200
100
50
20
10
5
1
2
5
10
20
50
100
I_C - COLLECTOR CURRENT


TYPICAL COLLECTOR SATURATION VOLTAGE
$T_J = 25^oC$
V_{CE} (VOLTS)
$I_C = 100$ mA
$I_C = 20$ mA
$I_C = 50$ mA
$I_C = 10$ mA
1.0
0.8
0.6
0.4
0.2
0
.1
.2
.5
1
2
5
10
20
50
100
I_B - BASE CURRENT (mA)


TYPICAL CURRENT GAIN
$V_{CE} = 1$ V
$T_J = 125^oC$
$T_J = 25^oC$
$T_J = -55^oC$
h_{FE}
200
100
70
50
40
30
0.1
0.2
0.5
1
2
5
10
20
50
100
I_C - COLLECTOR CURRENT (mA)


TYPICAL SATURATION VOLTAGE
V_{BE} (SAT)
V_{CE} (SAT)
$\beta_F = 10$
$T_J = 25^oC$
SATURATION VOLTAGE (VOLTS)
1.2
1.0
.8
.6
.4
.2
0
1
2
5
10
20
50
100
I_C - COLLECTOR CURRENT (mA)


TYPICAL TEMPERATURE COEFFICIENTS
θV_C (25^oC to 125^oC)
θV_C (-55^oC to 25^oC)
APPROXIMATE DEVIATION FROM NOMINAL
θV_C, θV_B, 0.1 mV/^oC
θV_B
COEFFICIENTS (mV/^oC)
+1.0
0
-1.0
-2.0
0
20
40
60
80
100
I_C - COLLECTOR CURRENT (mA)

MM3000 thru MM3003 (SILICON)

CASE 79
(TO-39)

NPN silicon epitaxial transistors designed for general-purpose, high-voltage applications.

MAXIMUM RATINGS

<table>
<tr><th>Rating</th><th>Symbol</th><th>MM3000</th><th>MM3001</th><th>MM3002</th><th>MM3003</th><th>Unit</th></tr>
<tr><td>Collector-Emitter Voltage</td><td>V_{CEO}</td><td>100</td><td>150</td><td>200</td><td>250</td><td>Vdc</td></tr>
<tr><td>Emitter-Base Voltage</td><td>V_{EB}</td><td colspan="4">← 5.0 →</td><td>Vdc</td></tr>
<tr><td>Collector Current</td><td>I_C</td><td>200</td><td>200</td><td>50</td><td>50</td><td>mAdc</td></tr>
<tr><td>Total Device Dissipation @ $T_A = 25°C$
Derate above 25°C</td><td>P_D</td><td colspan="4">← 1.0 →
← 5.71 →</td><td>Watt
mW/°C</td></tr>
<tr><td>Total Device Dissipation @ $T_C = 25°C$
Derate above 25°C</td><td>P_D</td><td colspan="4">← 5.0 →
← 28.6 →</td><td>Watts
mW/°C</td></tr>
<tr><td>Operating and Storage Junction Temperature Range</td><td>T_J, T_{stg}</td><td colspan="4">← -65 to +200 →</td><td>°C</td></tr>
</table>

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	100		Vdc
	MM3000		100	-	
	MM3001		150	-	
	MM3002		200	-	
	MM3003		250	-	
Emitter-Base Breakdown Voltage (I_E = 10 µAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current		I_{CBO}			µAdc
(V_{CB} = 50 Vdc, I_E = 0)	MM3000		-	1.0	
(V_{CB} = 75 Vdc, I_E = 0)	MM3001		-	1.0	
(V_{CB} = 100 Vdc, I_E = 0)	MM3002, MM3003		-	5.0	
ON CHARACTERISTICS					
DC Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc)		h_{FE}	20	-	-
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		f_T	150	-	MHz
Output Capacitance (V_{CB} = 20 Vdc, I_E = 0, f = 100 kHz)	MM3000, MM3001 MM3002, MM3003	C_{ob}	- -	7.0 15	pF

MM3008 (SILICON)
MM3009

CASE 79
(TO-39)

High-voltage NPN silicon transistors designed for video output circuitry in transistorized television receivers.

MAXIMUM RATINGS

Rating	Symbol	MM3008	MM3009	Unit
Collector-Emitter Voltage	V_{CEO}	120	180	Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current	I_C	400		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	1.0 5.71		Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	4.0 22.8		Watts mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* ($I_C = 10$ mAdc, $I_B = 0$)	MM3008 MM3009	BV_{CEO}*	120 180	- -	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10\ \mu$Adc $I_C = 0$)		BV_{EBO}	6.0	-	Vdc
Collector Cutoff Current ($V_{CB} = 120$ Vdc, $I_E = 0$) ($V_{CB} = 180$ Vdc, $I_E = 0$)	MM3008 MM3009	I_{CBO}	- -	0.1 0.1	μAdc
Emitter Cutoff Current ($V_{BE} = 4.0$ Vdc, $I_C = 0$)		I_{EBO}		0.1	μAdc
ON CHARACTERISTICS					
DC Current Gain ($I_C = 1.0$ mAdc, $V_{CE} = 10$ Vdc) ($I_C = 10$ mAdc, $V_{CE} = 10$ Vdc) ($I_C = 30$ mAdc, $V_{CE} = 10$ Vdc)		h_{FE}	30 40 30	- - -	-
DYNAMIC CHARACTERISTICS					
Current-Gain-Bandwidth Product ($I_C = 20$ mAdc, $V_{CE} = 20$ Vdc, f = 20 MHz)		f_T	50	-	MHz
Collector-Base Capacitance ($V_{CB} = 20$ Vdc, $I_E = 0$, f = 100 kHz)		C_{cb}	-	3.0	pF
Input Capacitance ($V_{BE} = 0.5$ Vdc, $I_C = 0$, f = 100 kHz)		C_{ib}	-	20	pF

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 1 — CURRENT GAIN

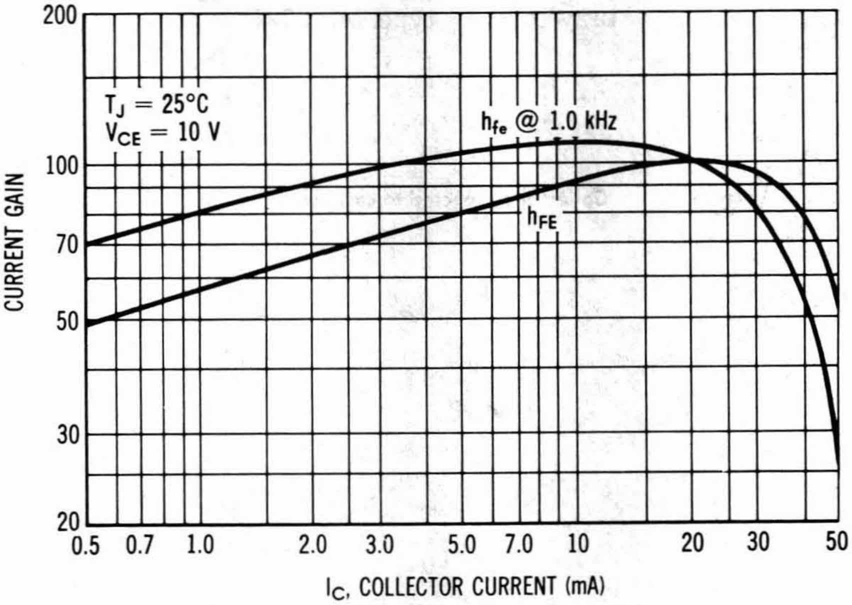
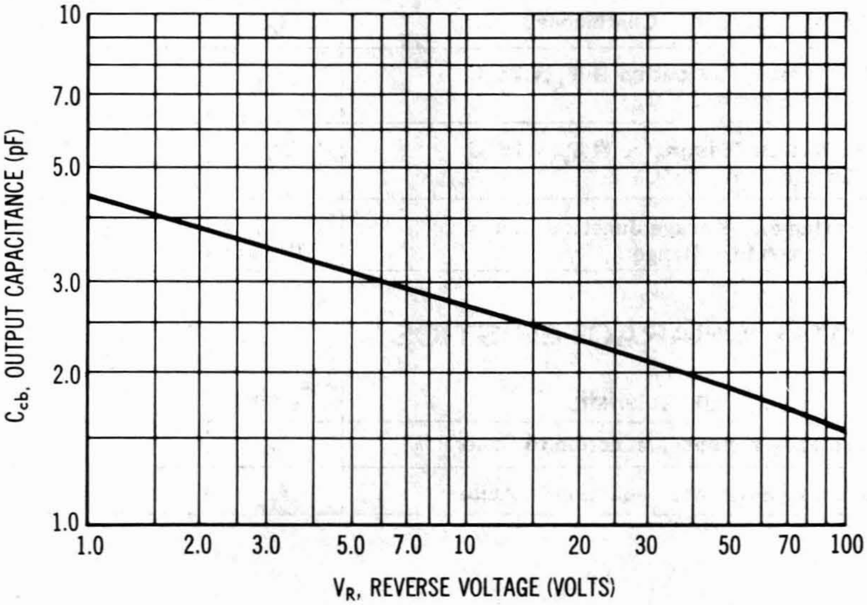


FIGURE 2 — CAPACITANCE



MM3724 (SILICON)
MM3725

NPN silicon annular transistors designed for medium-current, high-speed saturated switching and core driver applications. Type MM3725 is complementary to PNP type MM3726.

Collector connected to case

CASE 31
(TO-5)

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	MM3724	MM3725	Unit
Collector-Emitter Voltage	V_{CEO}	30	50	Vdc
Emitter-Base Voltage	V_{EB}	6		Vdc
Collector Current — Continuous	I_C	1.5		Adc
Total Device Dissipation @ $T_A = 25°C$ **Derate above 25°C**	P_D	1.0 5.71		Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ **Derate above 25°C**	P_D	5.0 28.6		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	35	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	175	°C/W

ELECTRICAL CHARACTERISTICS (TA = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0) MM3724 MM3725	—	BV_{CEO}	30 50	— —	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	—	BV_{EBO}	6	—	Vdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0)	—	I_{CBO}	—	0.5	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 500 mAdc, V_{CE} = 2 Vdc) (I_C = 1 Adc, V_{CE} = 5 Vdc)	9	h_{FE}	25 15	150 —	—
Collector-Emitter Saturation Voltage (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1 Adc, I_B = 100 mAdc)	10, 11	$V_{CE(sat)}$	— —	0.6 0.9	Vdc
Base-Emitter Saturation Voltage (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1 Adc, I_B = 100 mAdc)	11	$V_{BE(sat)}$	0.8 —	1.0 1.3	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	—	f_T	200	—	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz, emitter guarded)	3	C_{cb}	—	9	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz, collector guarded)	3	C_{eb}	—	80	pF
Turn-On Time (V_{CC} = 30 Vdc, $V_{EB(off)}$ = 2 Vdc, I_C = 500 mAdc, I_{B1} = 50 mAdc, R_B = 200 ohms, R_L = 60 ohms)	1, 5, 6	t_{on}	—	30	ns
Turn-Off Time (V_{CC} = 30 Vdc, I_C = 500 mAdc, I_{B1} = I_{B2} = 50 mAdc, R_B = 200 ohms, R_L = 60 ohms)	2, 6, 7, 8	t_{off}	—	50	ns
Turn-On Time (V_{CC} = 30 Vdc, $V_{EB(off)}$ = 2 Vdc, I_C = 1 Adc, I_{B1} = 100 mAdc, R_B = 100 ohms, R_L = 30 ohms)	1, 5, 6	t_{on}	—	40	ns
Turn-Off Time (V_{CC} = 30 Vdc, I_C = 1 Adc, I_{B1} = I_{B2} = 100 mAdc, R_B = 100 ohms, R_L = 30 ohms)	2, 6, 7, 8	t_{off}	—	50	ns

SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 — TURN-ON TIME

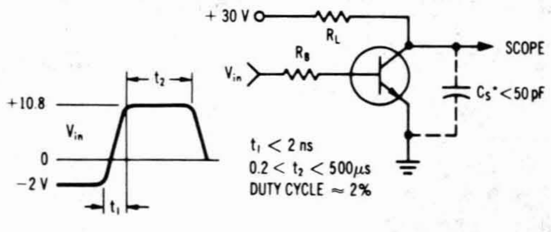
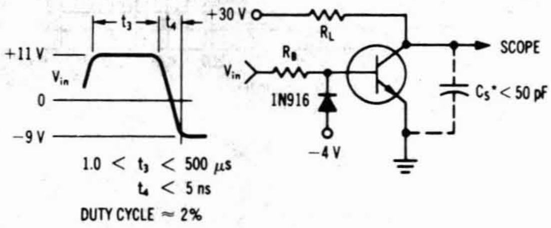


FIGURE 2 — TURN-OFF TIME



*TOTAL SHUNT CAPACITANCE OF TEST JIG, CONNECTORS, AND OSCILLOSCOPE.

TRANSIENT CHARACTERISTICS

—— 25°C ‒ ‒ ‒ 150°C

FIGURE 3 — CAPACITANCES

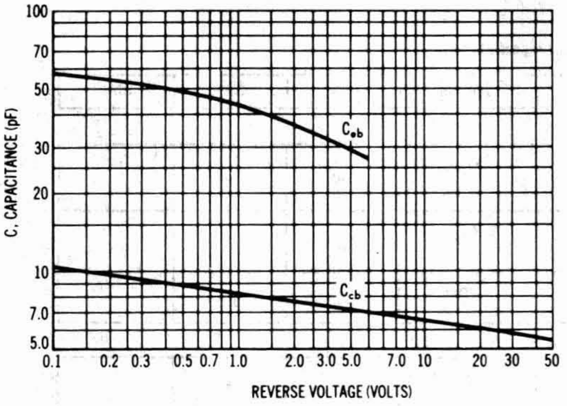


FIGURE 4 — CHARGE DATA

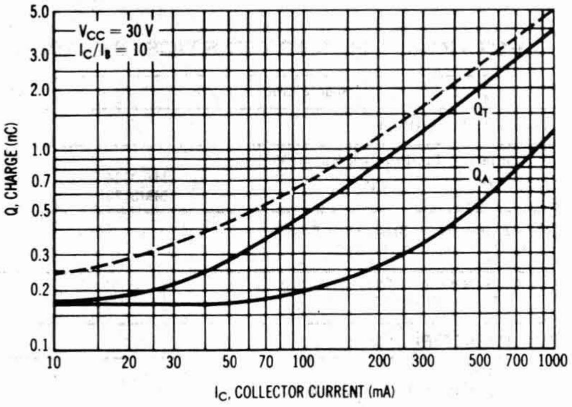


FIGURE 5 — TURN-ON TIME

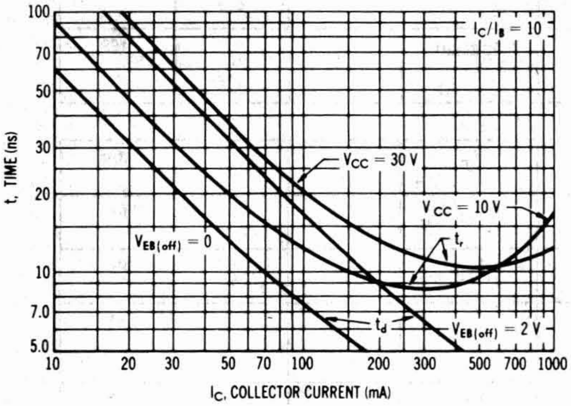


FIGURE 6 — RISE AND FALL TIMES

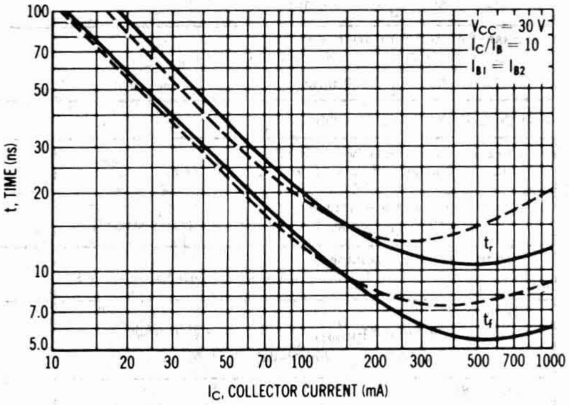


FIGURE 7 — STORAGE TIME

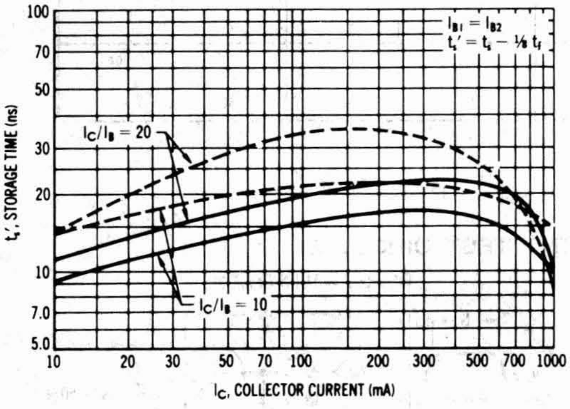
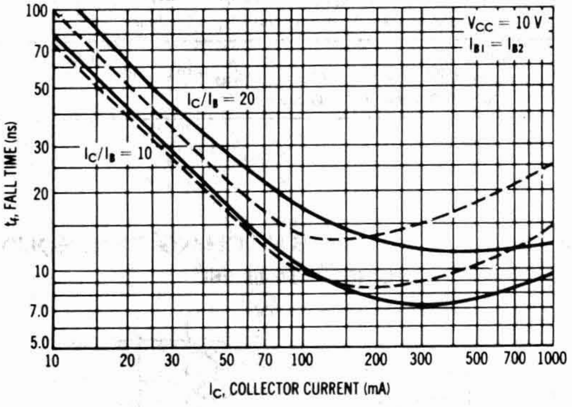


FIGURE 8 — FALL TIME

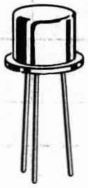


MM5000, MM5001, MM5002 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristics	Symbol	Min	Typ	Max	Units
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 2.0 mAdc, I_B = 0)	BV_{CEO}	15	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 µAdc, I_E = 0)	BV_{CBO}	30	-	-	Vdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 3.0 mAdc, V_{CE} = 12 Vdc)	h_{FE}	30	-	-	-
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain-Bandwidth Product (I_C = 3.0 mAdc, V_{CE} = 12 Vdc, f = 100 MHz)	f_T	800	-	-	MHz
Collector-Base Capacitance (V_{CB} = 12 Vdc, I_E = 0, f = 100 kHz)	C_{cb}	-	0.4	0.6	pF
Collector-Base Time Constant (I_E = 3.0 mAdc, V_{CB} = 12 Vdc, f = 31.8 MHz) MM5000 MM5001 MM5002	$r_b'C_c$	 - - -	 - - -	 3.5 5.0 7.5	ps
Noise Figure (Figure 1) (I_C = 3.0 mAdc, V_{CE} = 12 Vdc, R_S = 50 ohms, f = 200 MHz) MM5000 MM5001 MM5002	NF	 - - -	 - - -	 1.6 2.0 2.2	dB
Noise Figure (I_C = 3.0 mAdc, V_{CE} = 12 Vdc, R_S = 50 ohms, f = 450 MHz)	NF	-	3.5	-	dB
FUNCTIONAL TEST					
Common-Emitter Amplifier Power Gain (I_C = 3.0 mAdc, V_{CE} = 12 Vdc, f = 200 MHz) (Figure 1) MM5000 MM5001 MM5002	G_{pe}	 24 22 20	 - - -	 - - -	dB
Common-Emitter Amplifier Power Gain (I_C = 3.0 mAdc, V_{CE} = 12 Vdc, f = 450 MHz)	G_{pe}	-	16	-	dB

MM8000 (SILICON)
MM8001



CASE 79
(TO-39)

NPN silicon high-frequency transistor designed for high-frequency CATV amplifier applications. Suitable for use as output driver or pre-driver stages in VHF and UHF equipment.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector Current	I_C	0.4	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	3.5 20	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

MM5000, MM5001, MM5002 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristics	Symbol	Min	Typ	Max	Units
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage ($I_C = 2.0$ mAdc, $I_B = 0$)	BV_{CEO}	15	-	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 100$ µAdc, $I_E = 0$)	BV_{CBO}	30	-	-	Vdc
ON CHARACTERISTICS					
DC Current Gain ($I_C = 3.0$ mAdc, $V_{CE} = 12$ Vdc)	h_{FE}	30	-	-	-
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain-Bandwidth Product ($I_C = 3.0$ mAdc, $V_{CE} = 12$ Vdc, f = 100 MHz)	f_T	800	-	-	MHz
Collector-Base Capacitance ($V_{CB} = 12$ Vdc, $I_E = 0$, f = 100 kHz)	C_{cb}	-	0.4	0.6	pF
Collector-Base Time Constant ($I_E = 3.0$ mAdc, $V_{CB} = 12$ Vdc, f = 31.8 MHz) MM5000 MM5001 MM5002	$r_b'C_c$	 - - -	 - - -	 3.5 5.0 7.5	ps
Noise Figure (Figure 1) ($I_C = 3.0$ mAdc, $V_{CE} = 12$ Vdc, $R_S = 50$ ohms, f = 200 MHz) MM5000 MM5001 MM5002	NF	 - - -	 - - -	 1.6 2.0 2.2	dB
Noise Figure ($I_C = 3.0$ mAdc, $V_{CE} = 12$ Vdc, $R_S = 50$ ohms, f = 450 MHz)	NF	-	3.5	-	dB
FUNCTIONAL TEST					
Common-Emitter Amplifier Power Gain ($I_C = 3.0$ mAdc, $V_{CE} = 12$ Vdc, f = 200 MHz) (Figure 1) MM5000 MM5001 MM5002	G_{pe}	 24 22 20	 - - -	 - - -	dB
Common-Emitter Amplifier Power Gain ($I_C = 3.0$ mAdc, $V_{CE} = 12$ Vdc, f = 450 MHz)	G_{pe}	-	16	-	dB

MM8000 (SILICON)
MM8001

CASE 79
(TO-39)

NPN silicon high-frequency transistor designed for high-frequency CATV amplifier applications. Suitable for use as output driver or pre-driver stages in VHF and UHF equipment.

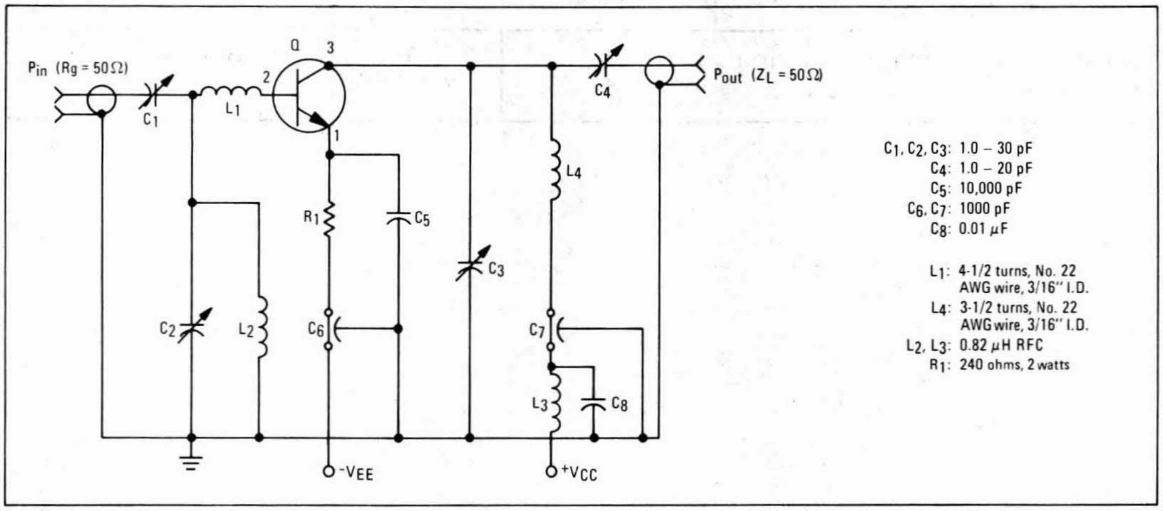
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector Current	I_C	0.4	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	3.5 20	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (I_C = 5.0 mAdc, I_B = 0)	$BV_{CEO(sus)}$	30	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	40	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	3.5	-	-	Vdc
Collector Cutoff Current (V_{CE} = 28 Vdc, I_B = 0)	I_{CEO}	-	-	20	µAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 50 mAdc, V_{CE} = 15 Vdc)	h_{FE}	30	-	-	-
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product (I_C = 25 mAdc, V_{CE} = 15 Vdc, f = 200 MHz) (I_C = 50 mAdc, V_{CE} = 15 Vdc, f = 200 MHz) (I_C = 100 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)	f_T	1000 1200 1000	- - -	- - -	MHz
Output Capacitance (V_{CB} = 30 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	-	3.5	pF
Noise Figure Figure 1 Test Circuit (I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)	NF	-	2.7	-	dB
FUNCTIONAL TEST					
Common-Emitter Amplifier Power Gain Figure 1 Test Circuit (I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)	G_{pe}	-	11.4	-	dB

FIGURE 1 – 200 MHz TEST CIRCUIT

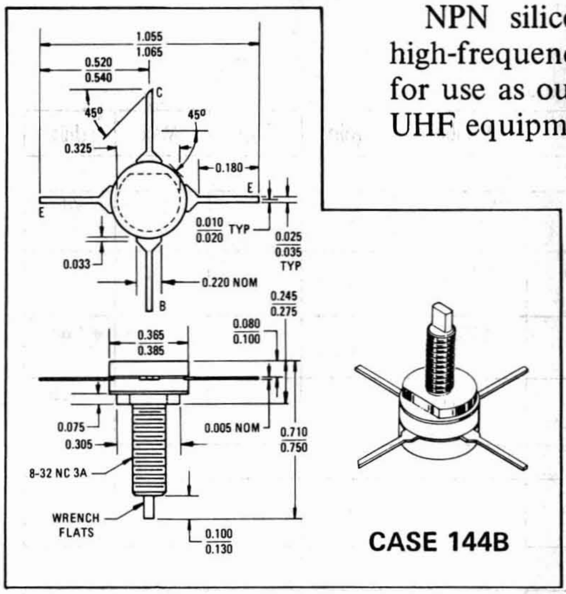


C1, C2, C3: 1.0 – 30 pF
C4: 1.0 – 20 pF
C5: 10,000 pF
C6, C7: 1000 pF
C8: 0.01 µF

L1: 4-1/2 turns, No. 22 AWG wire, 3/16" I.D.
L4: 3-1/2 turns, No. 22 AWG wire, 3/16" I.D.
L2, L3: 0.82 µH RFC
R1: 240 ohms, 2 watts

MM8003 (SILICON)

NPN silicon high-frequency transistor designed for high-frequency CATV amplifier applications. Suitable for use as output driver or pre-driver stages in VHF and UHF equipment.


1.055
1.065
0.520
0.540
C
45°
45°
0.325
0.180
E
E
0.010
0.020
TYP
0.025
0.035
TYP
0.033
0.220 NOM
B
0.245
0.275
0.080
0.100
0.365
0.385
0.075
0.305
0.005 NOM
0.710
0.750
8-32 NC 3A
WRENCH
FLATS
0.100
0.130

CASE 144B

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector Current	I_C	0.4	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	5.0 28.6	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

STATIC CHARACTERISTICS

FIGURE 9 — CURRENT GAIN

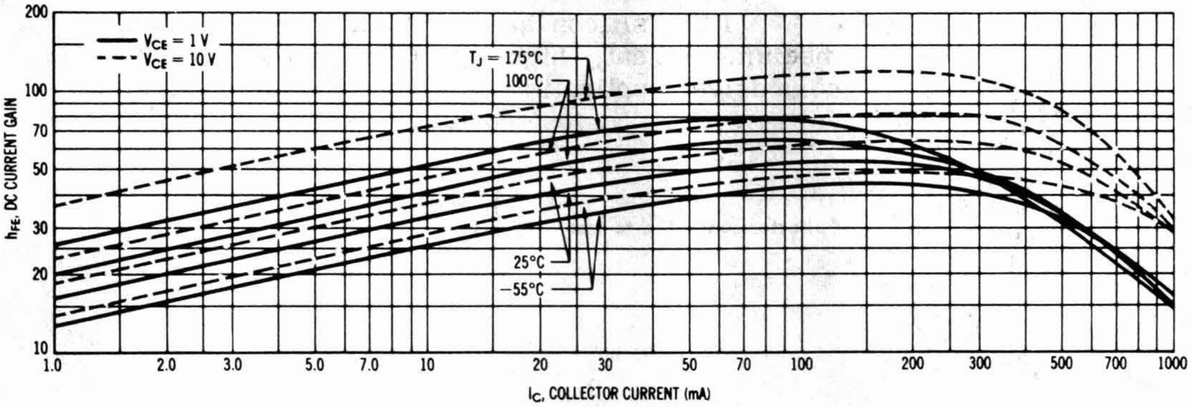


FIGURE 10 — SATURATION REGION

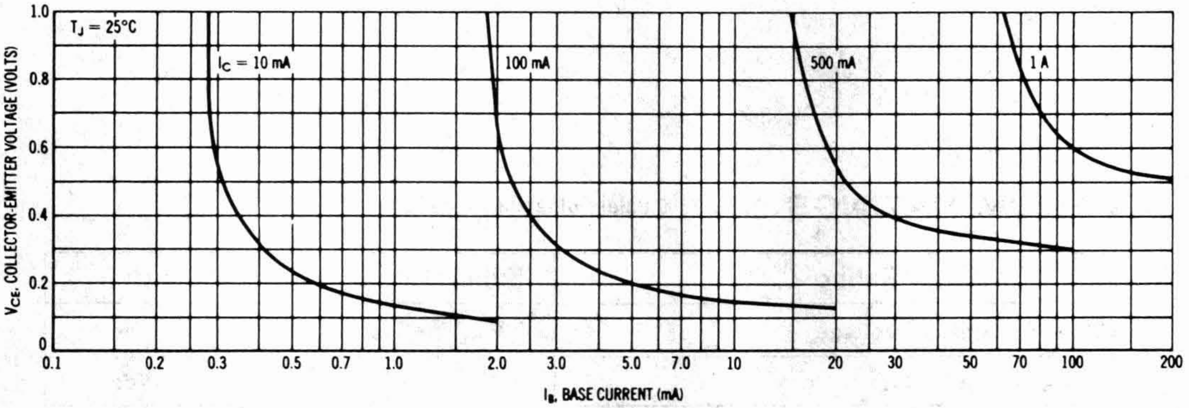


FIGURE 11 — "ON" VOLTAGES

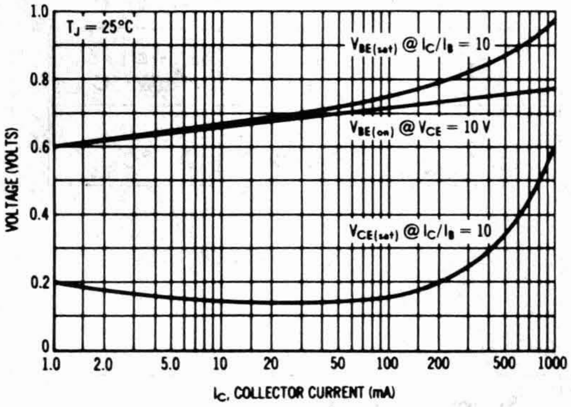
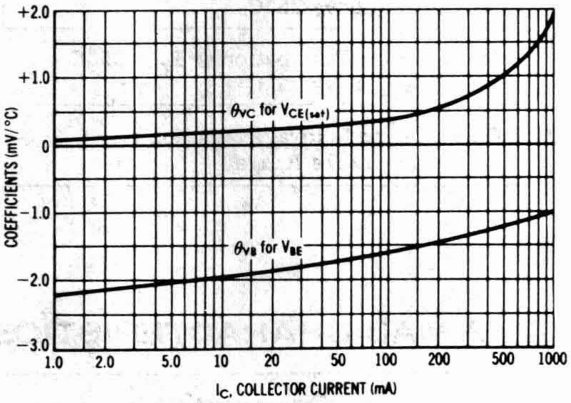
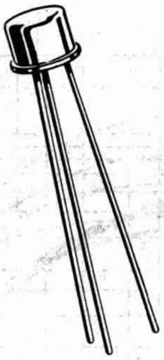


FIGURE 12 — TEMPERATURE COEFFICIENTS



MM3726 (SILICON)



CASE 31
(TO-5)

PNP silicon annular transistor designed for medium-current, high-speed saturated switching and core driver applications, and for complementary circuitry with NPN type MM3725.

Collector connected to case

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current — Continuous	I_C	1.5	Adc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 5.71	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	5.0 28.6	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

THERMAL CHARACTERISTICS

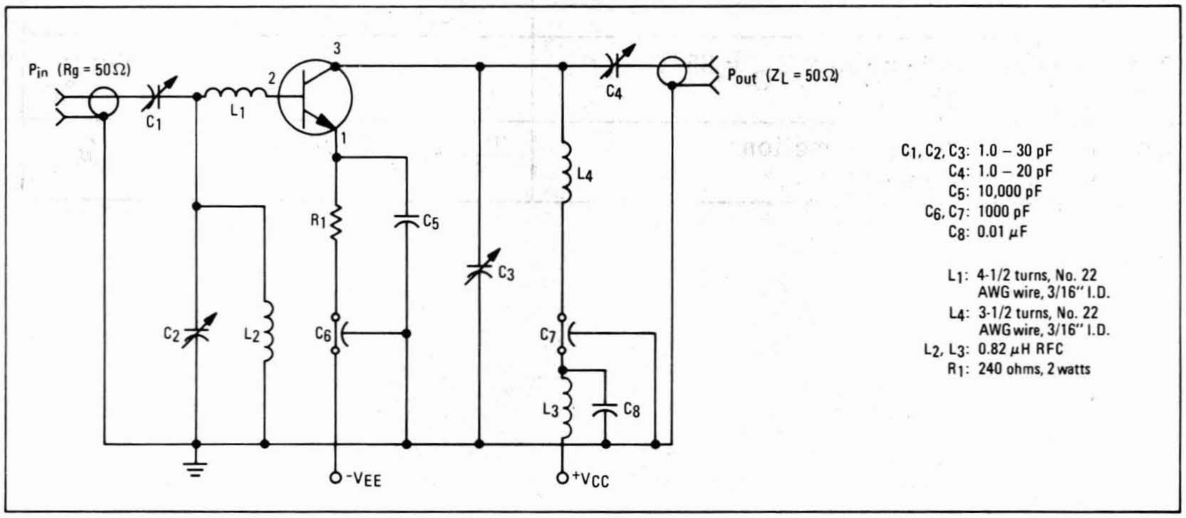
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	35	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	175	°C/W

MM8000, MM8001 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (I_C = 5.0 mAdc, I_B = 0)	$BV_{CEO(sus)}$	30	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 0.1 mAdc, I_E = 0)	BV_{CBO}	40	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	3.5	-	-	Vdc
Collector Cutoff Current (V_{CE} = 28 Vdc, I_B = 0)	I_{CEO}	-	-	20	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 50 mAdc, V_{CE} = 15 Vdc)	h_{FE}	30	-	-	-
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product (I_C = 25 mAdc, V_{CE} = 15 Vdc, f = 200 MHz) MM8000	f_T	550	-	-	MHz
MM8001		700	-	-	
(I_C = 50 mAdc, V_{CE} = 15 Vdc, f = 200 MHz) MM8000		700	-	-	
MM8001		900	-	-	
(I_C = 100 mAdc, V_{CE} = 15 Vdc, f = 200 MHz) MM8000		700	-	-	
MM8001		900	-	-	
Output Capacitance (V_{CB} = 30 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	-	3.5	pF
Noise Figure Figure 1 Test Circuit (I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)	NF	-	2.7	-	dB
FUNCTIONAL TESTS					
Common-Emitter Amplifier Power Gain Figure 1 Test Circuit (I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)	G_{pe}	-	11.4	-	dB

FIGURE 1 – 200 MHz TEST CIRCUIT



C_1, C_2, C_3: 1.0 – 30 pF
C_4: 1.0 – 20 pF
C_5: 10,000 pF
C_6, C_7: 1000 pF
C_8: 0.01 μF

L_1: 4-1/2 turns, No. 22 AWG wire, 3/16" I.D.
L_4: 3-1/2 turns, No. 22 AWG wire, 3/16" I.D.
L_2, L_3: 0.82 μH RFC
R_1: 240 ohms, 2 watts

MM8002 (SILICON)

CASE 79
(TO-39)

NPN silicon high-frequency transistor designed for high-frequency CATV amplifier applications. Suitable for use as output driver or pre-driver stages in VHF and UHF equipment.

MAXIMUM RATINGS

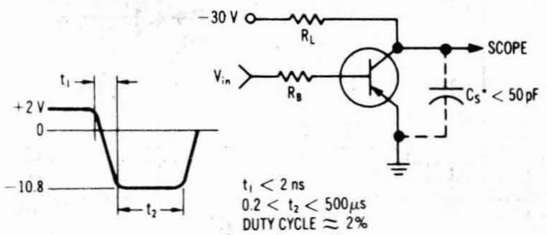
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	3.5	Vdc
Collector Current	I_C	0.4	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	3.5 20	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	—	BV_{CEO}	50	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	—	BV_{EBO}	5	—	Vdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0)	—	I_{CBO}	—	0.1	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 500 mAdc, V_{CE} = 2 Vdc) (I_C = 1 Adc, V_{CE} = 5 Vdc)	9	h_{FE}	 30 15	 120 —	—
Collector-Emitter Saturation Voltage (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1 Adc, I_B = 100 mAdc)	10, 11	$V_{CE(sat)}$	 — —	 0.6 1.2	Vdc
Base-Emitter Saturation Voltage (I_C = 500 mAdc, I_B = 50 mAdc) (I_C = 1 Adc, I_B = 100 mAdc)	11	$V_{BE(sat)}$	 0.8 —	 1.1 1.3	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	—	f_T	200	—	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz, emitter guarded)	3	C_{cb}	—	10	pF
Emitter-Base Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz, collector guarded)	3	C_{eb}	—	80	pF
Turn-On Time (V_{CC} = 30 Vdc, $V_{BE(off)}$ = 2 Vdc, I_C = 500 mAdc, I_{B1} = 50 mAdc, R_B = 200 ohms, R_L = 60 ohms)	1, 5, 6	t_{on}	—	30	ns
Turn-Off Time (V_{CC} = 30 Vdc, I_C = 500 mAdc, $I_{B1} = I_{B2}$ = 50 mAdc, R_B = 200 ohms, R_L = 60 ohms)	2, 7, 8	t_{off}	—	90	ns
Turn-On Time (V_{CC} = 30 Vdc, $V_{BE(off)}$ = 2 Vdc, I_C = 1 Adc, I_{B1} = 100 mAdc, R_B = 100 ohms, R_L = 30 ohms)	1, 5, 6	t_{on}	—	35	ns
Turn-Off Time (V_{CC} = 30 Vdc, I_C = 1 Adc, $I_{B1} = I_{B2}$ = 100 mAdc, R_B = 100 ohms, R_L = 30 ohms)	2, 7, 8	t_{off}	—	60	ns

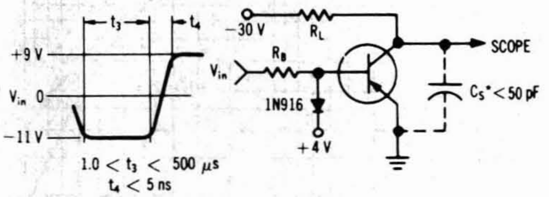
SWITCHING TIME EQUIVALENT TEST CIRCUITS

FIGURE 1 — TURN-ON TIME



$t_1 < 2$ ns
$0.2 < t_2 < 500 \mu s$
DUTY CYCLE ≈ 2%

FIGURE 2 — TURN-OFF TIME



$1.0 < t_3 < 500 \mu s$
$t_4 < 5$ ns
DUTY CYCLE ≈ 2%

*TOTAL SHUNT CAPACITANCE OF TEST JIG, CONNECTORS, AND OSCILLOSCOPE.

TRANSIENT CHARACTERISTICS

— 25°C --- 150°C

FIGURE 3 – CAPACITANCES

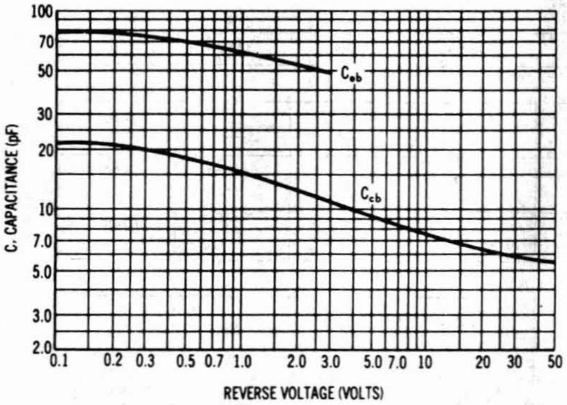


FIGURE 4 – CHARGE DATA

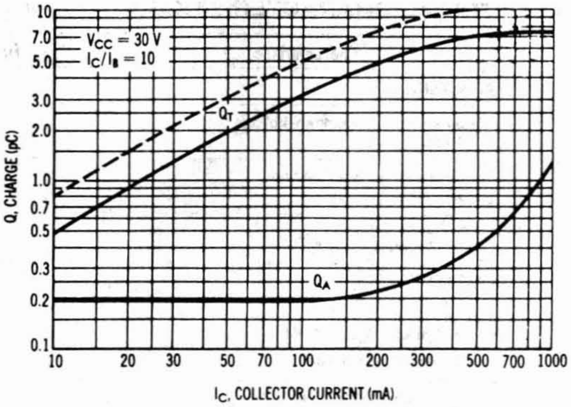


FIGURE 5 – TURN-ON TIME

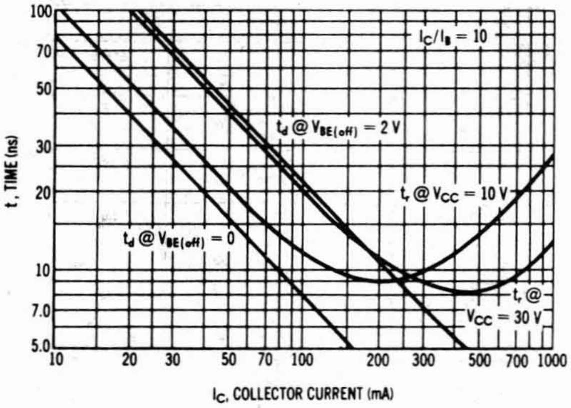


FIGURE 6 – RISE TIME

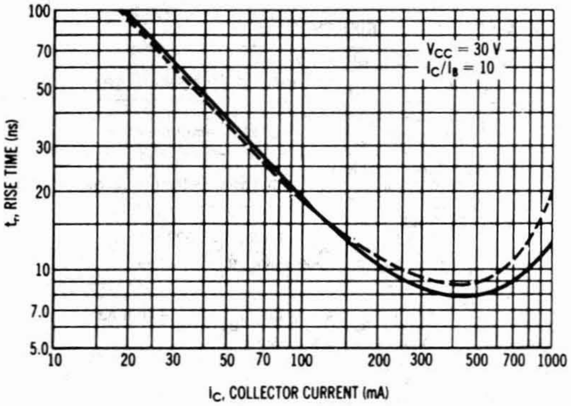


FIGURE 7 – STORAGE TIME

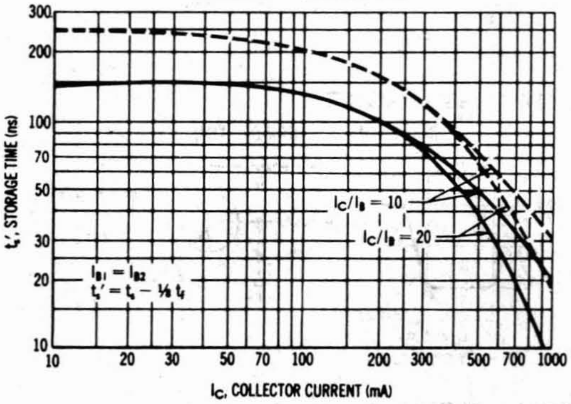
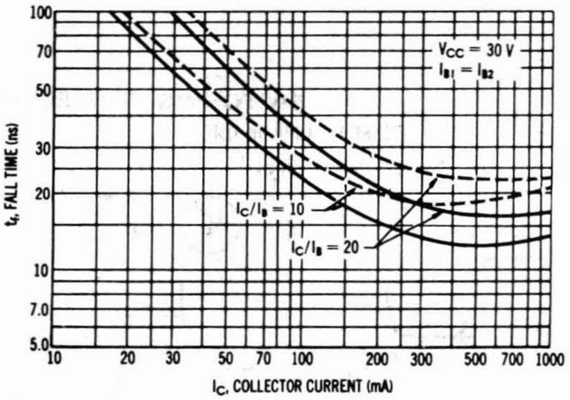


FIGURE 8 – FALL TIME



STATIC CHARACTERISTICS

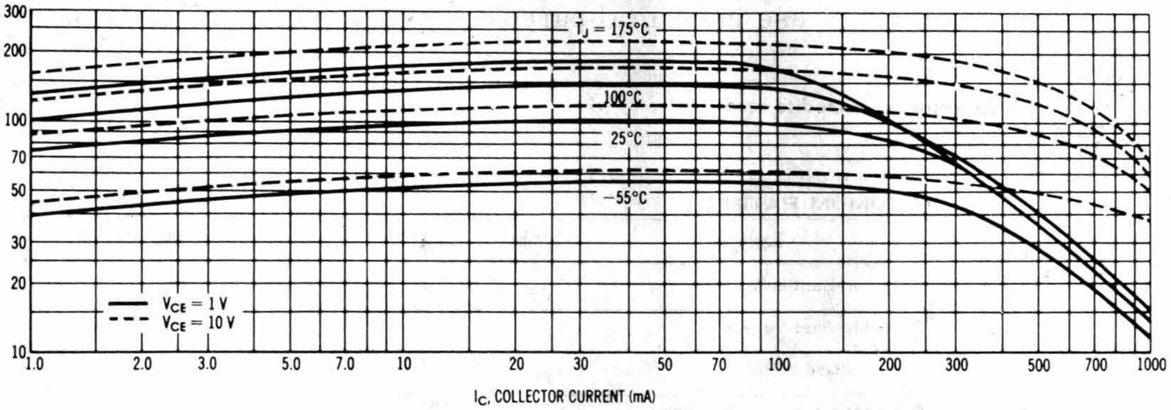


FIGURE 9 — CURRENT GAIN

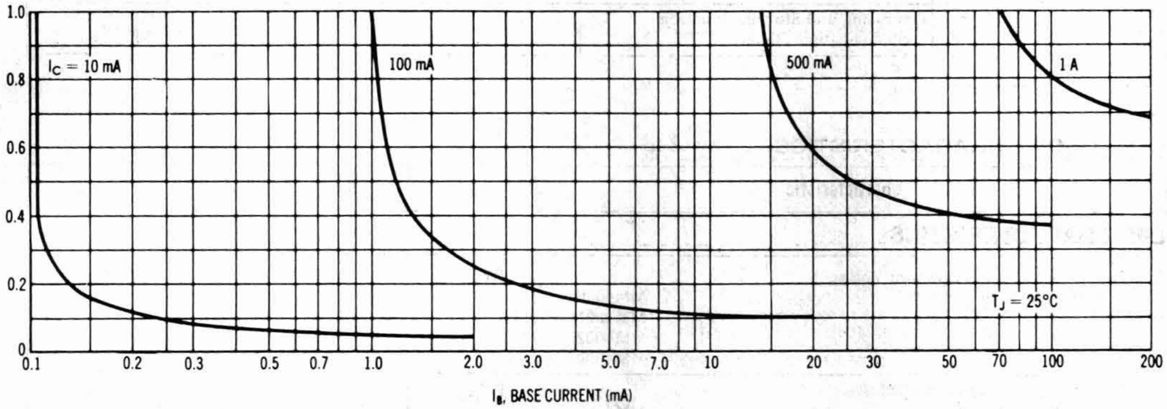


FIGURE 10 — SATURATION REGION

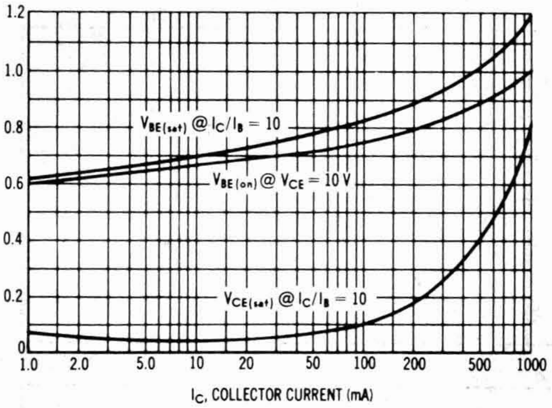


FIGURE 11 — "ON" VOLTAGES

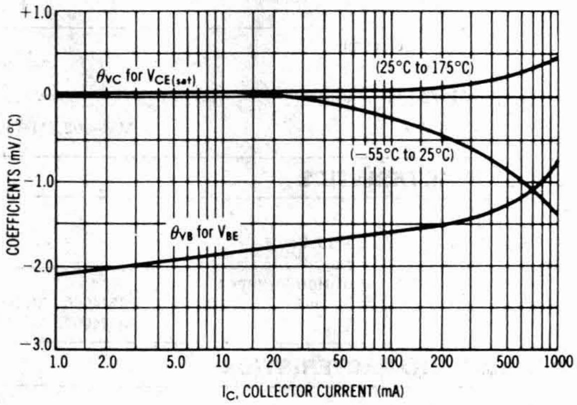


FIGURE 12 — TEMPERATURE COEFFICIENTS

MM4000 thru MM4003 (SILICON)

High-voltage PNP silicon annular transistors for use in general-purpose, high-voltage applications.

Collector connected to case

CASE 79
(TO-39)

MAXIMUM RATINGS

Rating	Symbol	MM4000	MM4001	MM4002	MM4003	Unit
Collector-Emitter Voltage	V_{CEO}	100	150	200	250	Vdc
Collector-Base Voltage	V_{CB}	100	150	200	250	Vdc
Emitter-Base Voltage	V_{EB}	4.0	4.0	4.0	4.0	Vdc
Collector Current — Continuous	I_C	100	500	500	500	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.6 3.4	1.0 5.71	1.0 5.71	1.0 5.71	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	3.0 17.2	5.0 28.6	5.0 28.6	5.0 28.6	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200				°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* ($I_C = 10$ mAdc, $I_B = 0$)	MM4000 MM4001 MM4002 MM4003	BV_{CEO}*	100 150 200 250	- - - -	Vdc
Collector-Base Breakdown Voltage ($I_E = 0$, $I_C = 10$ μAdc)	MM4000 MM4001 MM4002 MM4003	BV_{CBO}	100 150 200 250	- - - -	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100$ μAdc, $I_C = 0$)		BV_{EBO}	4.0	-	Vdc
Collector Cutoff Current ($V_{CB} = 50$ Vdc, $I_E = 0$) ($V_{CB} = 75$ Vdc, $I_E = 0$) ($V_{CB} = 150$ Vdc, $I_E = 0$)	 MM4000 MM4001 MM4002, MM4003	I_{CBO}	 - - -	 1.0 1.0 5.0	μAdc
ON CHARACTERISTICS					
DC Current Gain ($I_C = 10$ mAdc, $V_{CE} = 10$ Vdc)*		h_{FE}	20	-	-
Collector-Emitter Saturation Voltage* ($I_C = 10$ mAdc, $I_B = 1.0$ mAdc)	MM4000, MM4001 MM4002, MM4003	$V_{CE(sat)}$*	- -	0.6 5.0	Vdc
DYNAMIC CHARACTERISTICS					
Output Capacitance ($V_{CB} = 20$ Vdc, $I_E = 0$, f = 100 kHz)	MM4000 MM4001 MM4002, MM4003	C_{ob}	- - -	6.0 10 20	pF

* **Pulse Test: PW ≤ 300 μs, Duty Cycle ≤ 2%**

MM4048 (SILICON)

PNP silicon annular transistor designed for low frequency, low noise, low level amplifier applications.

CASE 22
(TO-18)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	45	Vdc
Collector-Base Voltage	V_{CB}	45	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current - Continuous	I_C	50	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	0.36 2.06	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	1.2 6.9	Watts mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 10$ mAdc, $I_B = 0$)	BV_{CEO}	45	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 10$ μAdc, $I_E = 0$)	BV_{CBO}	45	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10$ μAdc, $I_C = 0$)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current ($V_{CB} = 30$ Vdc, $I_E = 0$)	I_{CBO}	-	10	nAdc
Emitter Cutoff Current ($V_{BE} = 4.0$ Vdc, $I_C = 0$)	I_{EBO}	-	20	nAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 100$ μAdc, $V_{CE} = 5.0$ Vdc) ($I_C = 500$ μAdc, $V_{CE} = 5.0$ Vdc) ($I_C = 1.0$ mAdc, $V_{CE} = 5.0$ Vdc)	h_{FE}	 150 150 150	 - 450 -	-
Collector-Emitter Saturation Voltage ($I_C = 500$ μAdc, $I_B = 50$ μAdc)	$V_{CE(sat)}$	-	0.25	Vdc
Base-Emitter On Voltage ($I_C = 500$ μAdc, $V_{CE} = 5.0$ Vdc)	$V_{BE(on)}$	-	0.8	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product ($I_C = 1.0$ mAdc, $V_{CE} = 5.0$ Vdc, f = 100 MHz)	f_T	100	500	MHz
Output Capacitance ($V_{CB} = 5.0$ Vdc, $I_E = 0$, f = 100 kHz)	C_{ob}	-	4.0	pF
Input Capacitance ($V_{BE} = 0.5$ Vdc, $I_C = 0$, f = 100 kHz)	C_{ib}	-	8.0	pF
Noise Figure ($I_C = 100$ μAdc, $V_{CE} = 10$ Vdc, $R_S = 3.0$ k ohms, f = 10 Hz) ($I_C = 100$ μAdc, $V_{CE} = 10$ Vdc, $R_S = 3.0$ k ohms, f = 100 Hz) ($I_C = 100$ μAdc, $V_{CE} = 10$ Vdc, $R_S = 3.0$ k ohms, f = 1.0 kHz) ($I_C = 100$ μAdc, $V_{CE} = 10$ Vdc, $R_S = 3.0$ k ohms, f = 10 kHz) ($I_C = 100$ μAdc, $V_{CE} = 10$ Vdc, $R_S = 3.0$ k ohms, f = 10 Hz to 15.7 Hz)	NF	 - - - - -	 6.0 3.0 2.0 1.0 3.0	dB

MM5000 (GERMANIUM)
MM5001
MM5002

CASE 20
(TO-72)

PNP germanium high frequency transistors designed for use in low-noise, high-gain VHF/UHF amplifiers.

Active Elements Isolated From Case

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	0.3	Vdc
Collector Current	I_C	10	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	150 2.0	mW mW/°C
Operating & Storage Junction Temperature	T_J, T_{stg}	-65 to +100	°C

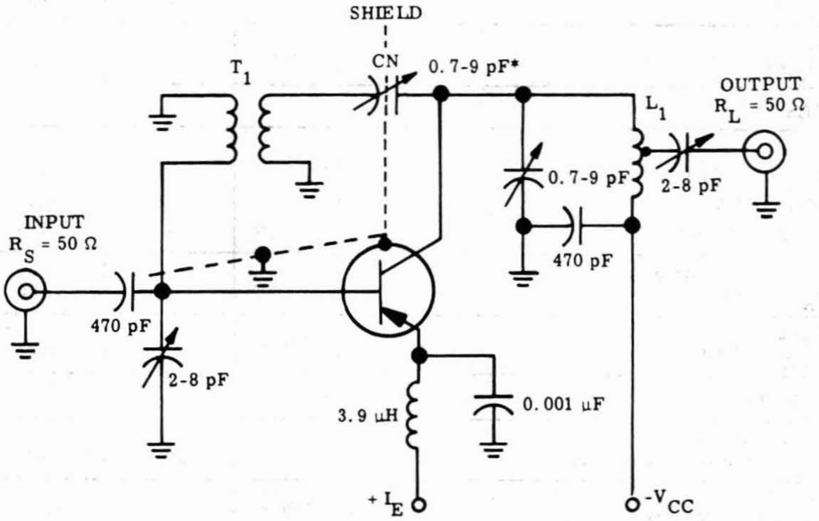

SHIELD
T_1
CN
0.7-9 pF*
L_1
OUTPUT
R_L = 50 Ω
0.7-9 pF
2-8 pF
470 pF
INPUT
R_S = 50 Ω
470 pF
2-8 pF
3.9 uH
0.001 uF
$+I_E$
$-V_{CC}$

FIGURE 1 — TEST CIRCUIT FOR POWER GAIN AND NOISE FIGURE

NOTES:

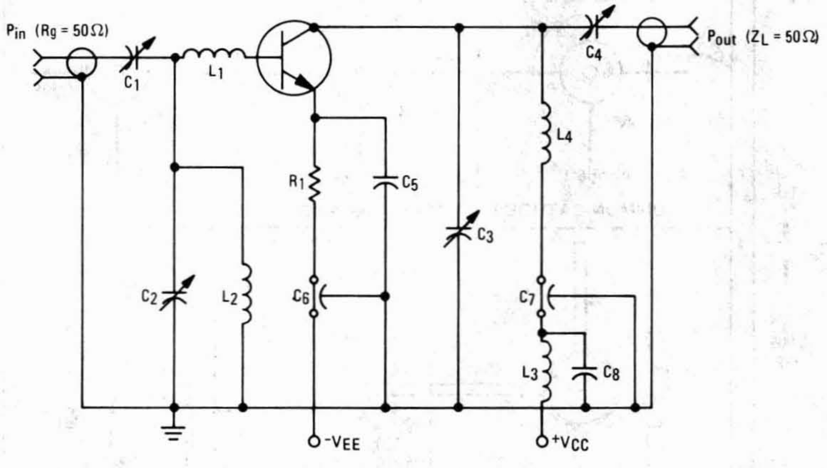
L_1	1/4 in. ID, 1/2 in. long, 4 turns #20 solid copper wire, center tapped.
T_1	1/4 in. ID, close wound, 3 turns #26 solid copper wire, 1:1 ratio bi-filler wound.
*	High Quality piston type capacitor.

Distance from emitter of transistor to ground side of bypass capacitor should be kept minimal.

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage (I_C = 30 mAdc, I_B = 0)	$BV_{CEO(sus)}$	30	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 1.0 mAdc, I_E = 0)	BV_{CBO}	40	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 0.1 mAdc, I_C = 0)	BV_{EBO}	3.5	-	-	Vdc
Collector Cutoff Current (V_{CE} = 28 Vdc, I_B = 0)	I_{CEO}	-	-	20	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 50 mAdc, V_{CE} = 15 Vdc)	h_{FE}	30	-	-	-
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product	f_T				MHz
(I_C = 25 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)		1000	-	-	
(I_C = 50 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)		1200	-	-	
(I_C = 100 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)		1000	-	-	
Output Capacitance (V_{CB} = 30 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	-	4.0	pF
Noise Figure Figure 1 Test Circuit (I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)	NF	-	2.7	-	dB
FUNCTIONAL TEST					
Common-Emitter Amplifier Power Gain Figure 1 Test Circuit (I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 200 MHz)	G_{pe}	-	11.4	-	dB

FIGURE 1 – 200 MHz TEST CIRCUIT

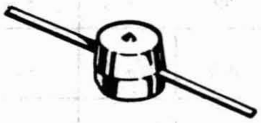


C_1, C_2, C_3: 1.0 – 30 pF
C_4: 1.0 – 20 pF
C_5: 10,000 pF
C_6, C_7: 1000 pF
C_8: 0.01 μF

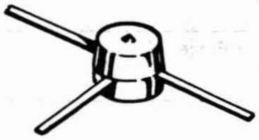
L_1: 4-1/2 turns, No. 22 AWG wire, 3/16" I.D.
L_4: 3-1/2 turns, No. 22 AWG wire, 3/16" I.D.
L_2, L_3: 0.82 μH RFC
R_1: 240 ohms, 2 watts

MMD6050 (SILICON)
MMD6100
MMD6150
MMD7000

Silicon epitaxial micro-miniature switching diodes – single, series and dual diodes designed for general-purpose, high-speed switching applications.



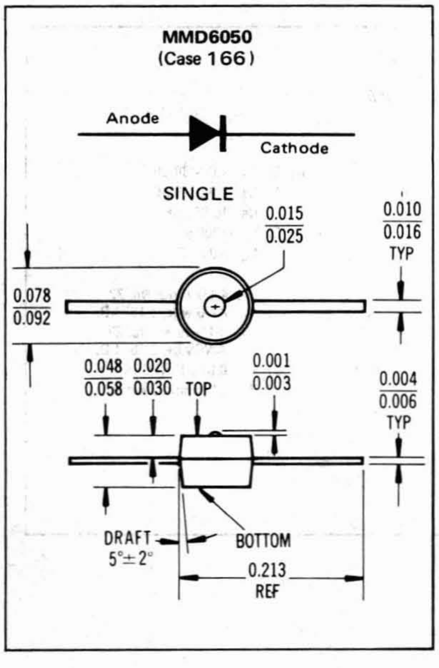
MMD6050 – Case 166

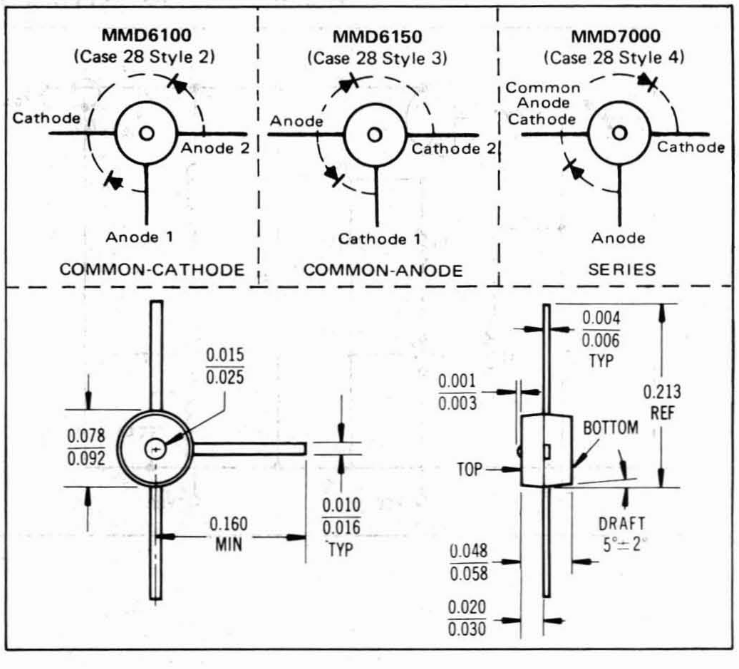


MMD6100 – Case 28 (2)
MMD6150 – Case 28 (3)
MMD7000 – Case 28 (4)

MAXIMUM RATINGS (each diode)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	70	Vdc
Peak Forward Recurrent Current	I_F	200	mA
Peak Forward Surge Current (Pulse Width = 10 μs)	$I_{FM(surge)}$	500	mA
Power Dissipation @ T_A = 25°C Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C


MMD6050
(Case 166)
Anode
Cathode
SINGLE
0.015
0.025
0.010
0.016
TYP
0.078
0.092
0.048
0.058
0.020
0.030
TOP
0.001
0.003
0.004
0.006
TYP
DRAFT
5°±2°
BOTTOM
0.213
REF


MMD6100
(Case 28 Style 2)
Cathode
Anode 2
Anode 1
COMMON-CATHODE
MMD6150
(Case 28 Style 3)
Anode
Cathode 2
Cathode 1
COMMON-ANODE
MMD7000
(Case 28 Style 4)
Common
Anode
Cathode
Cathode
Anode
SERIES
0.015
0.025
0.078
0.092
0.160
MIN
0.010
0.016
TYP
0.004
0.006
TYP
0.001
0.003
0.213
REF
BOTTOM
TOP
DRAFT
5°±2°
0.048
0.058
0.020
0.030

MMD6050, MMD6100, MMD6150, MMD7000 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Breakdown Voltage ($I_{(BR)}$ = 100 µAdc)	$V_{(BR)}$	70	-	-	Vdc
Reverse Current (V_R = 50 Vdc)	I_R	-	-	0.1	µAdc
Forward Voltage (I_F = 1.0 mAdc) (I_F = 100 mAdc)	V_F	0.55 0.85	- -	0.7 1.1	Vdc
Capacitance (V_R = 0)	C	-	1.2	2.0	pF
Reverse Recovery Time (I_F = I_R = 10 mAdc)	t_{rr}	-	1.5	5.0	ns

FIGURE 1 — FORWARD CHARACTERISTICS

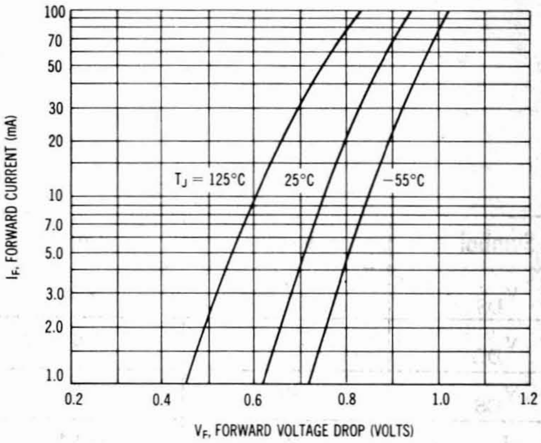


FIGURE 2 — REVERSE LEAKAGE CURRENT versus TEMPERATURE

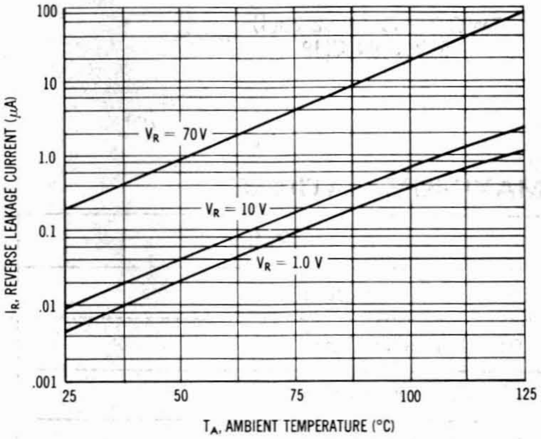


FIGURE 3 — CAPACITANCE

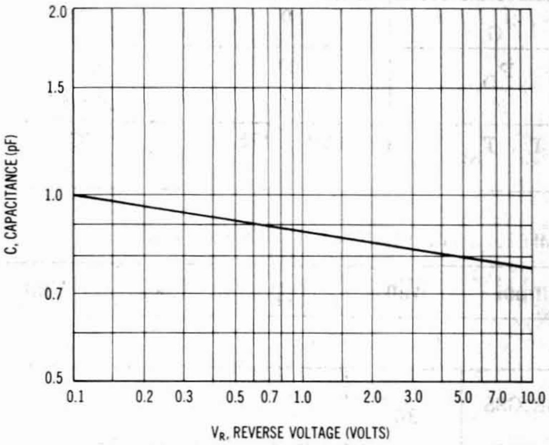


FIGURE 4 — REVERSE RECOVERY TIME

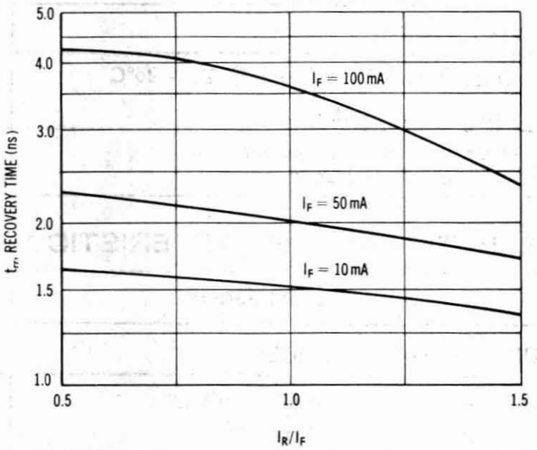
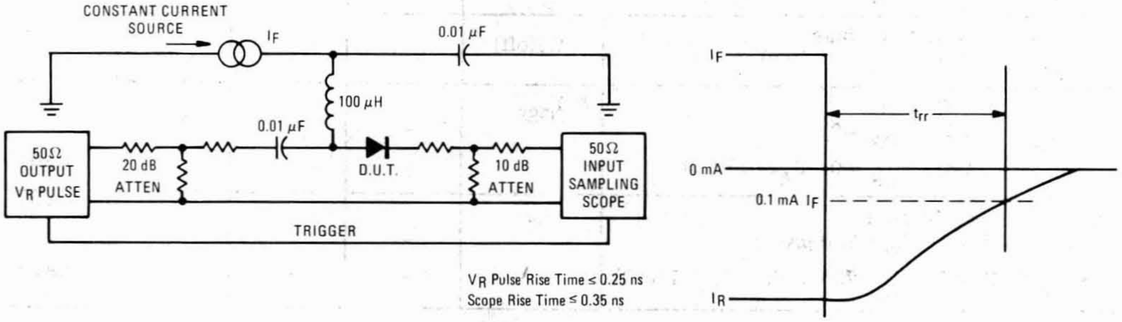


FIGURE 5 — RECOVERY TIME EQUIVALENT TEST CIRCUIT


CONSTANT CURRENT SOURCE
I_F
0.01 µF
100 µH
0.01 µF
50Ω OUTPUT V_R PULSE
20 dB ATTEN
D.U.T.
10 dB ATTEN
50Ω INPUT SAMPLING SCOPE
TRIGGER
I_F
t_{rr}
0 mA
0.1 mA I_F
I_R

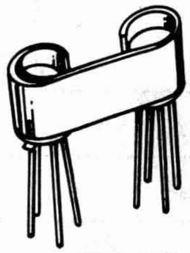
V_R Pulse Rise Time ≤ 0.25 ns
Scope Rise Time ≤ 0.35 ns

MMF 1, MMF 3, MMF 5 (SILICON)

(Matched @ I_D = 300 μAdc)

MMF 2, MMF 4, MMF 6

(Matched @ I_D = 750 μAdc)



TWO TO-72 CASE 20(1)
STYLE IN CLIP

Matched silicon N-channel junction field-effect transistors consisting of two individual MFE2003 device types which have been carefully matched for critical applications, such as differential amplifier service. Each matched pair is packaged in a metal clip for pair identity and each device is marked with the basic MFE2003 type number and a date code for further identification in the event of removal from the clip.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	30	Vdc
Drain Current	I_D	20	mAdc
Gate Current	I_G	10	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	300 2.0	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS (each MFE2003) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = 1.0 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	30	-	-	Vdc
Gate-Source Voltage (I_D = 0.3 mAdc, V_{DS} = 15 Vdc)	V_{GS}	0.5	-	5.0	Vdc
Gate-Source Cutoff Voltage (I_D = 0.5 nAdc, V_{DS} = 15 Vdc)	$V_{GS(off)}$	0.2	-	8.0	Vdc
Gate Reverse Current (V_{GS} = 15 Vdc, V_{DS} = 0) (V_{GS} = 15 Vdc, V_{DS} = 0, T_A = 150°C)	I_{GSS}	- -	- -	50 50	pAdc nAdc
Gate Reverse Current (V_{DG} = 15 Vdc, I_D = 750 μAdc) (V_{DG} = 15 Vdc, I_D = 750 μAdc, T_A = 100°C)	I_G	- -	- -	25 25	pAdc nAdc

ELECTRICAL CHARACTERISTICS (continued) (each MFE2003) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS					
Zero-Gate Voltage Drain Current (V_{DS} = 15 Vdc, V_{GS} = 0)	I_{DSS}	0.5	-	10	mAdc
Gate-Source Forward Voltage (I_G = 1.0 mAdc, V_{DS} = 0)	V_{GSF}	-	-	2.0	Vdc
DYNAMIC CHARACTERISTICS					
Forward Transfer Admittance (V_{DG} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz) (V_{DG} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	$\lvert y_{fs}\rvert$ $Re(y_{fs})$	1500 1500	- -	6500 -	µmhos
Input Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	$Re(y_{is})$	-	500	-	µmhos
Output Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	$\lvert y_{os}\rvert$	-	-	50	µmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	-	-	6.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	-	-	2.0	pF
Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_G = 1.0 Mohm, f = 100 Hz, BW = 1.0 Hz)	NF	-	-	2.5	dB
MATCHING CHARACTERISTICS (MMF1 thru MMF6, See Note)					
Zero-Gate Voltage Drain Current Ratio (I_{DSS_1} is the lower of the two values) (V_{DSS} = 15 Vdc, V_{GS} = 0) MMF1, MMF2 MMF3, MMF4, MMF5, MMF6	$\frac{I_{DSS_1}}{I_{DSS_2}}$	0.95 0.90	- -	1.0 1.0	-
Forward Transfer Admittance Ratio ($\lvert y_{fs}\rvert_1$ is the lower of the two values) (V_{DG} = 15 Vdc, I_D = 300 µAdc) MMF1 MMF3, MMF5 (V_{DG} = 15 Vdc, I_D = 750 µAdc) MMF2 MMF4, MMF6	$\frac{\lvert y_{fs}\rvert_1}{\lvert y_{fs}\rvert_2}$	0.98 0.95 0.98 0.95	- - - -	1.0 1.0 1.0 1.0	-
Differential Output Admittance (V_{DG} = 15 Vdc, I_D = 300 µAdc, f = 1.0 kHz) MMF1, MMF3, MMF5 (V_{DG} = 15 Vdc, I_D = 750 µAdc, f = 1.0 kHz) MMF2, MMF4, MMF6	$\lvert \lvert y_{os}\rvert_1 - \lvert y_{os}\rvert_2 \rvert$	- -	- -	1.0 1.0	µmho
Differential Gate-Source Voltage (V_{DG} = 15 Vdc, I_D = 300 µAdc) MMF1, MMF3, MMF5 (V_{DG} = 15 Vdc, I_D = 750 µAdc) MMF2, MMF4, MMF6	$\lvert V_{GS_1} - V_{GS_2}\rvert$	- -	- -	5.0 5.0	mVdc
Differential Gate Reverse Current (V_{DG} = 15 Vdc, I_D = 300 µAdc, T_A = 100°C) (V_{DG} = 15 Vdc, I_D = 750 µAdc, T_A = 100°C)	$\lvert I_{G_1} - I_{G_2}\rvert$	- -	1.0 1.0	10 10	nAdc
Differential Gate-Source Voltage Change with Temperature	See TABLE I				

TABLE I - Differential Gate-Source Voltage Change with Temperature

Conditions:

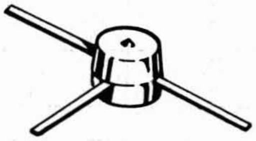
V_{DG} = 15 Vdc
MMF1, MMF3, MMF5 – I_D = 300 µAdc
MMF2, MMF4, MMF6 – I_D = 750 µAdc

Device Type	0°C to +25°C	+25°C to +100°C
MMF1, MMF2	0.250 mVdc	0.750 mVdc
MMF3, MMF4	0.625 mVdc	1.875 mVdc
MMF5, MMF6	1.250 mVdc	3.750 mVdc

NOTE: Matching Characteristics apply only to pairs of devices originally packaged as a matched pair.

MMT918 (SILICON)

NPN silicon annular micro-miniature transistor designed for VHF and UHF amplifier, mixer and oscillator applications.



CASE 28 (1)

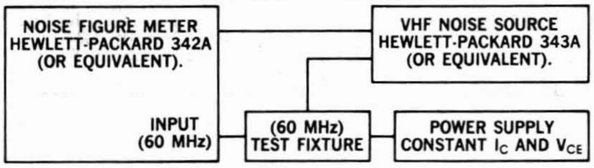
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current - Continuous	I_C	50	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.490	°C/mW

FIGURE 1 — NOISE FIGURE TEST BLOCK DIAGRAM


NOISE FIGURE METER
HEWLETT-PACKARD 342A
(OR EQUIVALENT).
VHF NOISE SOURCE
HEWLETT-PACKARD 343A
(OR EQUIVALENT).
INPUT
(60 MHz)
(60 MHz)
TEST FIXTURE
POWER SUPPLY
CONSTANT I_C AND V_{CE}

The test fixture shall consist of a 60 MHz tuned amplifier and suitable biasing circuits. It should be constructed utilizing good very-high-frequency design techniques.

The effective source susceptance should be tuned for each device being tested to obtain minimum noise figure. Note that because the HP 343A has a 50-ohm output resistance, a suitable impedance transformer must be used to obtain an effective source conductance of 2.5 mmho at the transistor with minimum losses.

FIGURE 2 — NEUTRALIZED 200 MHz POWER AMPLIFIER GAIN TEST CIRCUIT

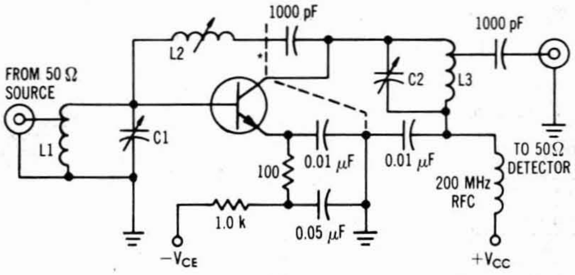
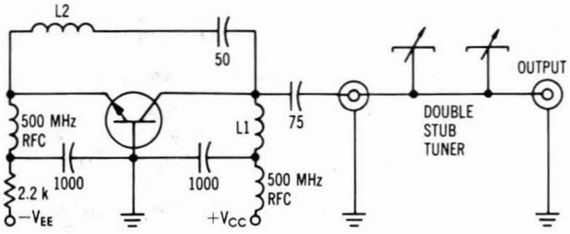

1000 pF
L2
1000 pF
FROM 50 Ω
SOURCE
C2
L3
L1
C1
100
0.01 μF
0.01 μF
TO 50Ω
DETECTOR
200 MHz
RFC
1.0 k
0.05 μF
$-V_{CE}$
$+V_{CC}$

FIGURE 3 — 500 MHz OSCILLATOR TEST CIRCUIT

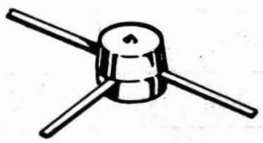

L2
50
OUTPUT
500 MHz
RFC
L1
75
DOUBLE
STUB
TUNER
2.2 k
1000
1000
500 MHz
RFC
$-V_{EE}$
$+V_{CC}$

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 3.0 mAdc, I_B = 0)	BV_{CEO}	15	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 1.0 μAdc, I_E = 0)	BV_{CBO}	30	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	3.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)	I_{CBO}	-	-	10	nAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 3.0 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}*	20	-	-	-
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$*	-	-	0.4	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$*	-	-	1.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (V_{CE} = 10 Vdc, I_C = 4.0 mAdc, f = 100 MHz)	f_T	600	-	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f ≥ 0.1 MHz and ≤ 1.0 MHz)	C_{ob}	-	-	1.7	pF
(V_{CB} = 0, I_E = 0, f ≥ 0.1 MHz and ≤ 1.0 MHz)		-	-	3.0	
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f ≥ 0.1 MHz and ≤ 1.0 MHz)	C_{ib}	-	-	2.0	pF
Noise Figure (Figure 1) (I_C = 1.0 mAdc, V_{CE} = 6.0 Vdc, R_S = 400 ohms, f = 60 MHz)	NF	-	-	6.0	dB
FUNCTIONAL TESTS					
Common-Emitter Amplifier Power Gain (Figure 2) (V_{CC} = 12 Vdc, I_C = 6.0 mAdc, f = 200 MHz)	G_{pe}	-	23	-	dB
Power Output (Figure 3) (V_{CB} = 15 Vdc, I_C = 8.0 mAdc, f = 500 MHz)	P_{out}	-	60	-	mW
Collector Efficiency (Figure 3) (V_{CB} = 15 Vdc, I_C = 8.0 mAdc, f = 500 MHz)	η	-	50	-	%

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

MMT930 (SILICON)
MMT2484



CASE 28 (1)

NPN silicon annular micro-miniature transistor designed for low-level, low noise amplifier applications.

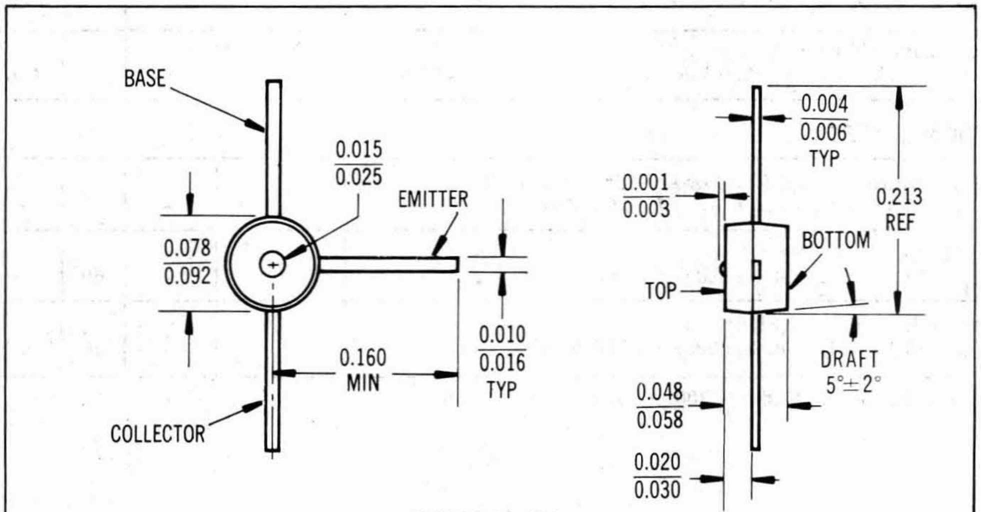
MAXIMUM RATINGS

Rating	Symbol	MMT930	MMT2484	Unit
Collector-Emitter Voltage	V_{CEO}	45	60	Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	6.0		Vdc
Collector Current	I_C	50		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	225 2.05		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.490	°C/mW

OUTLINE DIMENSIONS


BASE
0.015
0.025
EMITTER
0.078
0.092
0.160
MIN
0.010
0.016
TYP
COLLECTOR
0.004
0.006
TYP
0.001
0.003
0.213
REF
BOTTOM
TOP
DRAFT
5°± 2°
0.048
0.058
0.020
0.030

CASE 28 (1)

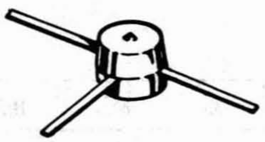
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0) MMT930 MMT2484	$BV_{CEO(sus)}$*	45 60	- -	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	6.0	-	Vdc
Collector Cutoff Current (V_{CB} = 45 Vdc, I_E = 0)	I_{CBO}	-	0.01	μAdc
Emitter Cutoff Current (V_{BE} = 5.0 Vdc, I_C = 0)	I_{EBO}	-	0.01	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) MMT930 MMT2484	h_{FE}	100 175	- -	-
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc) MMT930 MMT2484		125 200	- -	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc) MMT930 MMT2484		150 250	- -	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc)* Both Types		-	800	
Collector-Emitter Saturation Voltage (I_C = 1.0 mAdc, I_B = 0.1 mAdc)	$V_{CE(sat)}$	-	0.35	Vdc
Base-Emitter On Voltage (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	$V_{BE(on)}$	0.5	0.7	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 30 MHz)	f_T	60	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0)	C_{ob}	-	6.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0)	C_{ib}	-	6.0	pF
Noise Figure (I_C = 10 μAdc, V_{CE} = 5.0 Vdc, R_S = 10 k ohms, f = 10 Hz to 10 kHz, Power Bandwidth = 15.7 kHz) MMT2484	NF	-	3.0	dB

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

MMT2222 (SILICON)

NPN silicon annular micro-miniature transistor designed for high-speed switching circuits and DC to VHF amplifier applications.



CASE 28 (1)

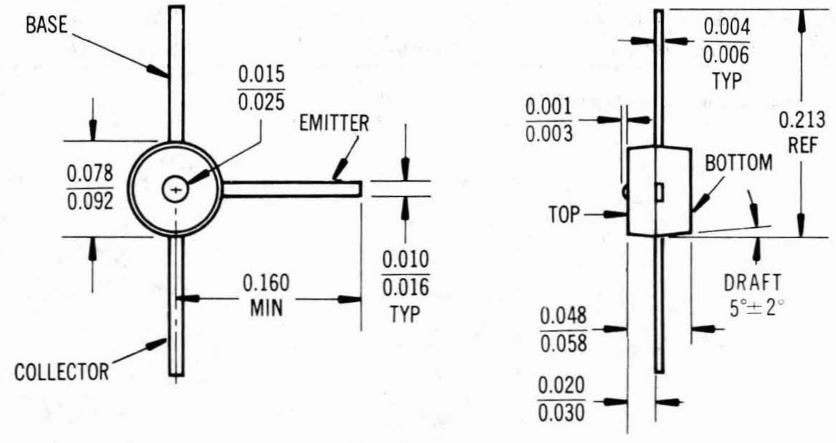
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.490	°C/W

OUTLINE DIMENSIONS


BASE
0.015
0.025
EMITTER
0.078
0.092
0.010
0.016
TYP
0.160
MIN
COLLECTOR
0.004
0.006
TYP
0.001
0.003
0.213
REF
BOTTOM
TOP
DRAFT
5°± 2°
0.048
0.058
0.020
0.030

CASE 28 (1)

MMT2222 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)	BV_{CEO}	30	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0)	I_{CBO}	-	-	0.05	μAdc
ON CHARACTERISTICS					
DC Current Gain	h_{FE}				
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)		50	-	-	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)		75	-	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)*		100	-	300	
(I_C = 300 mAdc, V_{CE} = 10 Vdc)*		30	-	-	
Collector-Emitter Saturation Voltage*	$V_{CE(sat)}$*				Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	0.2	0.4	
(I_C = 300 mAdc, I_B = 30 mAdc)		-	0.9	1.6	
Base-Emitter Saturation Voltage*	$V_{BE(sat)}$*				Vdc
(I_C = 150 mAdc, I_B = 15 mAdc)		-	0.85	1.3	
(I_C = 300 mAdc, I_B = 30 mAdc)		-	1.4	2.6	
DYNAMIC CHARACTERISTICS					
Current-Gain-Bandwidth Product (I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	200	-	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 MHz)	C_{ob}	-	3.5	8.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 MHz)	C_{ib}	-	-	30	pF
SWITCHING CHARACTERISTICS					
Turn-On Time (Figure 1)	t_{on}	-	16	-	ns
Turn-Off Time (Figure 2)	t_{off}	-	160	-	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 1 – SATURATED TURN-ON SWITCHING TIME TEST CIRCUIT

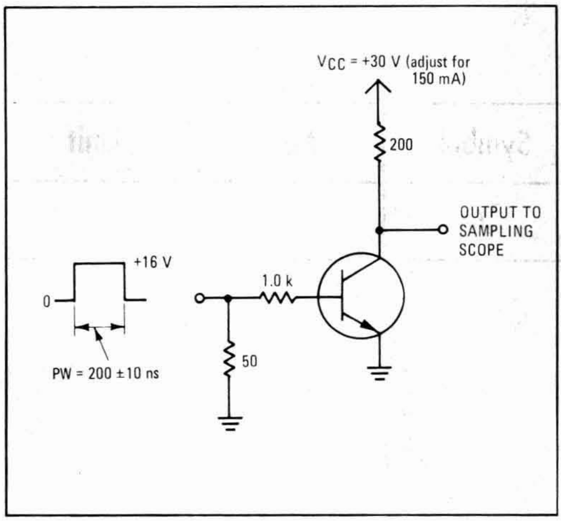
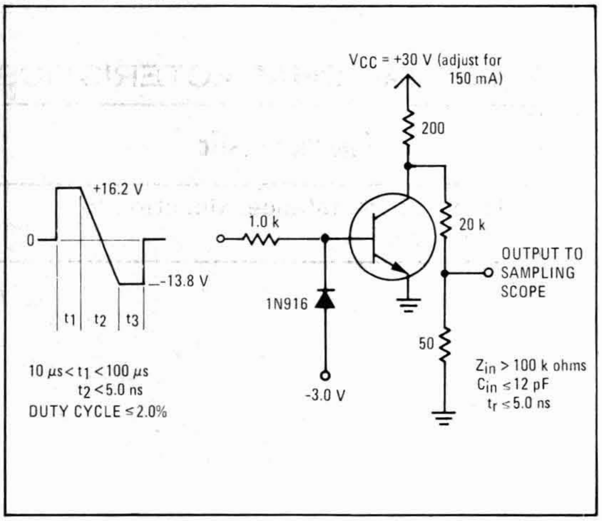
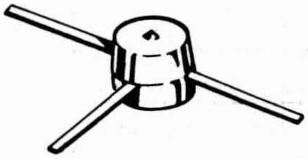

VCC = +30 V (adjust for 150 mA)
200
OUTPUT TO SAMPLING SCOPE
+16 V
0
1.0 k
PW = 200 ±10 ns
50

FIGURE 2 – SATURATED TURN-OFF SWITCHING TIME TEST CIRCUIT


VCC = +30 V (adjust for 150 mA)
200
+16.2 V
0
1.0 k
20 k
-13.8 V
1N916
t1
t2
t3
OUTPUT TO SAMPLING SCOPE
10 μs< t1 < 100 μs
t2 <5.0 ns
DUTY CYCLE ≤2.0%
-3.0 V
50
Zin > 100 k ohms
Cin ≤12 pF
tr ≤5.0 ns

Rise time (t_r) of applied pulse shall be 2.0 ns max; duty cycle ≤ 2.0%.

MMT2369 (SILICON)



CASE 28 (1)

NPN silicon micro-miniature annular transistor designed for high-speed, low current switching applications where high-density packaging is required.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Collector Current – Continuous	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.490	°C/mW

MMT2369 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	15	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4.5	-	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	-	100	nAdc
ON CHARACTERISTICS				
DC Current Gain*	h_{FE}*			-
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)		40	120	
(I_C = 100 mAdc, V_{CE} = 2.0 Vdc)		20	-	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	-	0.25	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	0.70	0.85	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	500	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	4.0	pF
SWITCHING CHARACTERISTICS				
Turn-On Time (V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = 1.5 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc)	t_{on}	-	12	ns
Turn-Off Time (V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.5 mAdc)	t_{off}	-	18	ns
Storage Time (I_C = I_{B1} = I_{B2} = 10 mAdc)	$t_{s(\tau s)}$	-	13	ns

* Pulse Test: Pulse Width = 300 μs, Duty Cycle ≦ 2.0%.

FIGURE 1 — t_{on} CIRCUIT

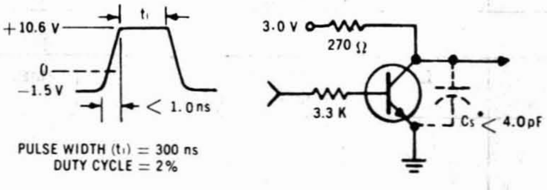
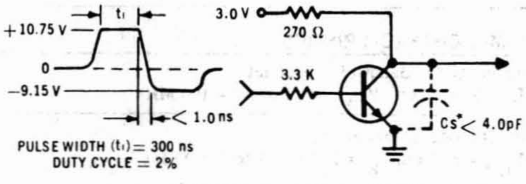

+10.6 V
t₁
0
−1.5 V
< 1.0 ns
PULSE WIDTH (t₁) = 300 ns
DUTY CYCLE = 2%
3.0 V
270 Ω
3.3 K
Cs* < 4.0 pF

FIGURE 2 — t_{off} CIRCUIT


+10.75 V
t₁
0
−9.15 V
< 1.0 ns
PULSE WIDTH (t₁) = 300 ns
DUTY CYCLE = 2%
3.0 V
270 Ω
3.3 K
Cs* < 4.0 pF

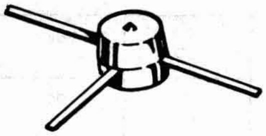
* Total shunt capacitance of test jig and connectors.

MMT2484

For Specifications, See MMT930 Data.

MMT2857 (SILICON)

NPN silicon annular micro-miniature transistor designed for high-gain, low-noise amplifier, oscillator and mixer applications.



CASE 28 (1)

MAXIMUM RATINGS

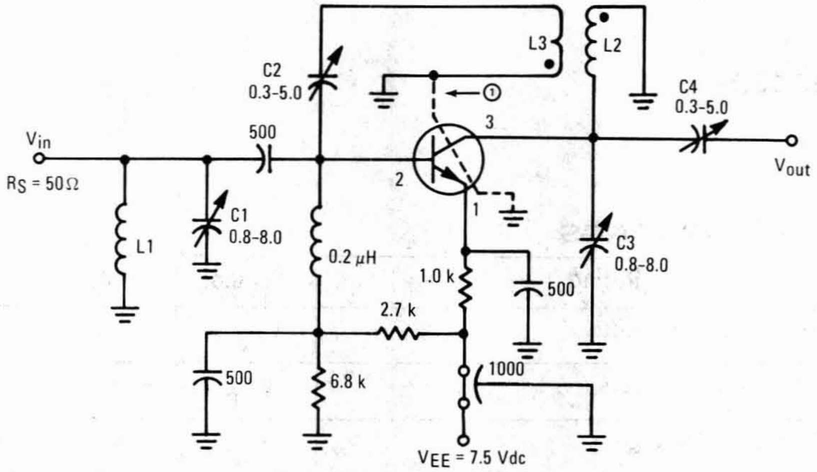
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	40	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ and case grounded unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage ($I_C = 3.0$ mAdc, $I_B = 0$)	BV_{CEO}	15	-	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 10\ \mu$Adc, $I_E = 0$)	BV_{CBO}	30	-	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10\ \mu$Adc, $I_C = 0$)	BV_{EBO}	3.0	-	-	Vdc
Collector Cutoff Current ($V_{CB} = 15$ Vdc, $I_E = 0$)	I_{CBO}	-	-	50	nAdc
ON CHARACTERISTICS					
DC Current Gain ($I_C = 3.0$ mAdc, $V_{CE} = 1.0$ Vdc)	h_{FE}	30	-	-	-
DYNAMIC CHARACTERISTICS					
Current-Gain-Bandwidth Product ($I_C = 4.0$ mAdc, $V_{CE} = 10$ Vdc, f = 100 MHz	f_T	1,000	1,300	-	MHz
Collector-Base Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 0.1 to 1.0 MHz) (Emitter and Case Guarded)	C_{cb}	-	0.5	1.0	pF
Collector-Base Time Constant ($I_E = 4.0$ mAdc, $V_{CB} = 10$ Vdc, f = 31.9 MHz)	$r_b'C_c$	-	8.0	-	ps
Noise Figure* ($I_C = 1.5$ mAdc, $V_{CE} = 10$ Vdc, $R_S = 50$ ohms, f = 450 MHz)	NF*	-	3.8	-	dB
FUNCTIONAL TEST					
Common-Emitter Amplifier Power Gain (Figure 1) ($I_C = 1.5$ mAdc, $V_{CE} = 10$ Vdc, f = 450 MHz)	G_{pe}	-	18	-	dB

*Measured in circuit of Figure 1 with no connections for input circuit losses or post amplifier contribution.

FIGURE 1 – TEST CIRCUIT FOR NOISE FIGURE AND POWER GAIN


C2
0.3-5.0
L3
L2
①
C4
0.3-5.0
3
V_in
R_S = 50Ω
500
2
V_out
L1
C1
0.8-8.0
0.2 μH
1
1.0 k
C3
0.8-8.0
500
2.7 k
500
6.8 k
1000
V_EE = 7.5 Vdc

Capacitance values in pF

L1, L2 – Silver-plated brass rod, 1-1/2" long and 1/4" dia. Install at least 1/2" from nearest vertical chassis surface.

L3 – 1/2 turn #16 AWG wire, located 1/4" from and parallel to L2.

① – External interlead shield to isolate collector lead from emitter and base leads.

Neutralization Procedure:

(A) Connect 450-MHz signal generator (with R_S = 50 ohms) to input terminals of amplifier.

(B) Connect 50-ohm RF voltmeter across output terminals of amplifier.

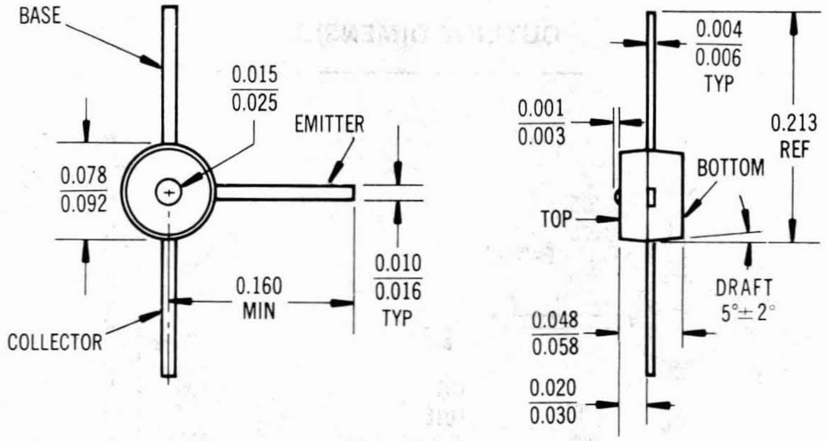
(C) Apply V_{EE}, and with signal generator adjusted for 5 mV output from amplifier, tune C1, C3, and C4 for maximum output.

(D) Interchange connections to signal generator and RF voltmeter.

(E) With sufficient signal applied to output terminals of amplifier, adjust C2 for minimum indication at input.

(F) Repeat steps (A), (B), and (C) to determine if retuning is necessary.

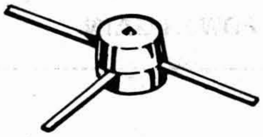
OUTLINE DIMENSIONS


BASE
0.015
0.025
EMITTER
0.078
0.092
0.010
0.016
TYP
0.160
MIN
COLLECTOR
0.004
0.006
TYP
0.001
0.003
0.213
REF
BOTTOM
TOP
DRAFT
5°±2°
0.048
0.058
0.020
0.030

CASE 28 (1)

MMT2907 (SILICON)

PNP silicon annular micro-miniature transistor designed for general-purpose switching and amplifier applications, where high-density packaging is required.



CASE 28 (1)

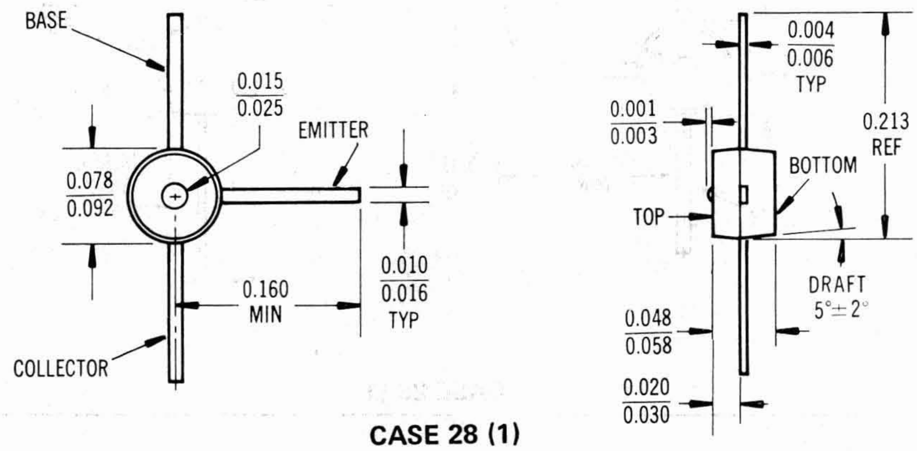
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current - Continuous	I_C	600	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.490	°C/mW

OUTLINE DIMENSIONS


BASE
0.015
0.025
EMITTER
0.078
0.092
0.010
0.016
TYP
0.160
MIN
COLLECTOR
0.004
0.006
TYP
0.001
0.003
0.213
REF
BOTTOM
TOP
DRAFT
5°±2°
0.048
0.058
0.020
0.030

CASE 28 (1)

MMT2907 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	40	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0)	I_{CBO}	-	-	50	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc) (I_C = 10 mAdc, V_{CE} = 10 Vdc) (I_C = 150 mAdc, V_{CE} = 10 Vdc)* (I_C = 300 mAdc, V_{CE} = 10 Vdc)*	h_{FE}	 50 75 100 30	 - - - -	 - - 300 -	-
Collector-Emitter Saturation Voltage* (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 300 mAdc, I_B = 30 mAdc)	$V_{CE(sat)}$*	 - -	 0.2 -	 0.4 1.6	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)* (I_C = 300 mAdc, I_B = 30 mAdc)	$V_{BE(sat)}$	 - -	 0.85 -	 1.3 2.6	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	200	260	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 MHz)	C_{ob}	-	4.8	8.0	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 100 MHz)	C_{ib}	-	-	30	pF
SWITCHING CHARACTERISTICS					
Turn-On Time (Figure 1)	t_{on}	-	20	-	ns
Turn-Off Time (Figure 2)	t_{off}	-	150	-	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 1—SATURATED TURN—ON SWITCHING TIME TEST CIRCUIT

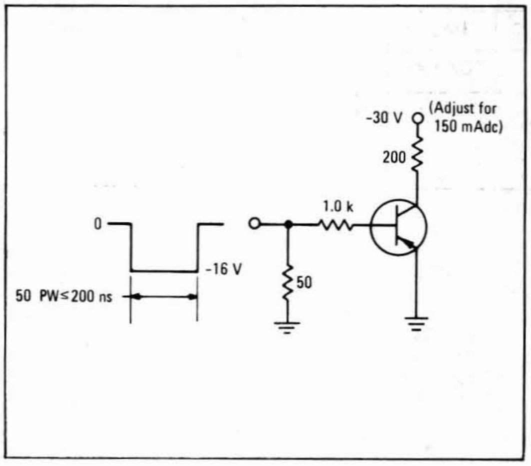
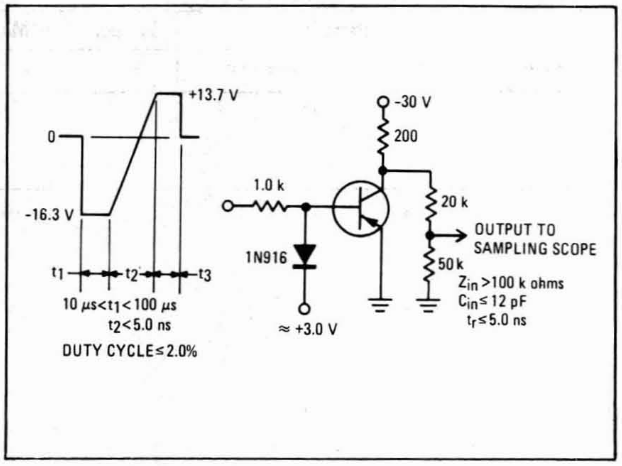

-30 V
(Adjust for 150 mAdc)
200
1.0 k
0
-16 V
50
50 PW≤200 ns

FIGURE 2—SATURATED TURN-OFF SWITCHING TIME TEST CIRCUIT


+13.7 V
0
-16.3 V
t1
t2
t3
10 μs<t1<100 μs
t2<5.0 ns
DUTY CYCLE≤2.0%
1.0 k
1N916
≈ +3.0 V
-30 V
200
20 k
50 k
OUTPUT TO SAMPLING SCOPE
Zin >100 k ohms
Cin≤12 pF
tr≤5.0 ns

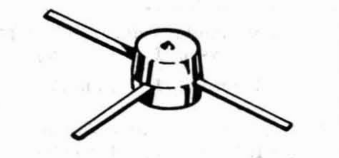
MMT3546 (SILICON)

PNP SILICON ANNULAR TRANSISTOR

. . . designed for high-speed, low-level switching applications, where high-density packaging is required.

- Space Saving Micro-Miniature Package
- Ideal for Thick Film Digital Circuit Applications
- Total Switching Time = 60 ns @ I_C = 50 mAdc
- One-Piece, Injection-Molded Unibloc Package for High Reliability

MICRO-MINIATURE
PNP SILICON SWITCHING TRANSISTOR

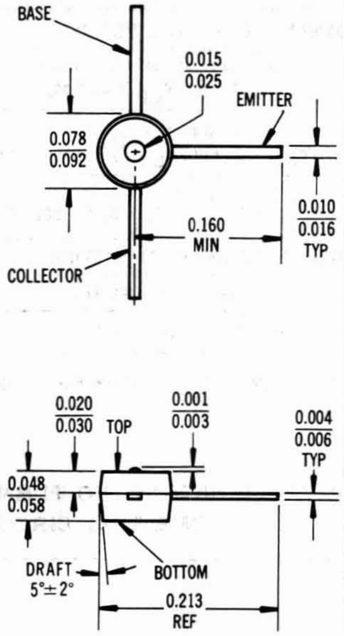


MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Collector Current - Continuous	I_C	250	mAdc
Total Device Dissipation @T_A = 25°C Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.490	°C/mW


BASE
0.015
0.025
EMITTER
0.078
0.092
0.010
0.016
TYP
0.160
MIN
COLLECTOR
0.020
0.030
TOP
0.001
0.003
0.004
0.006
TYP
0.048
0.058
DRAFT
5°±2°
BOTTOM
0.213
REF

CASE 28
Style 1

MMT3546 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	12	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	15	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4.5	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	100	nAdc
Emitter Cutoff Current (V_{EB} = 3.0 Vdc, I_C = 0)	I_{EBO}	-	100	nAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 100 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}*	 30 15	 - -	-
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{CE(sat)}$*	 - -	 0.15 0.5	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 100 mAdc, I_B = 10 mAdc)	$V_{BE(sat)}$*	 0.7 -	 0.9 1.6	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain-Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	700	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1.0 MHz)	C_{ob}	-	6.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ib}	-	8.0	pF
SWITCHING CHARACTERISTICS				
Delay Time (V_{CC} = 3.0 Vdc, V_{BE} = 2.0 Vdc, I_C = 50 mAdc, I_{B1} = 5.0 mAdc)	t_d	-	10	ns
Rise Time	t_r	-	15	ns
Storage Time (V_{CC} = 3.0 Vdc, I_C = 50 mAdc, I_{B1} = I_{B2} = 5.0 mAdc)	t_s	-	20	ns
Fall Time	t_f	-	15	ns

*Pulse Test: Pulse Width = 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 1 – DELAY AND RISE TIME EQUIVALENT TEST CIRCUIT

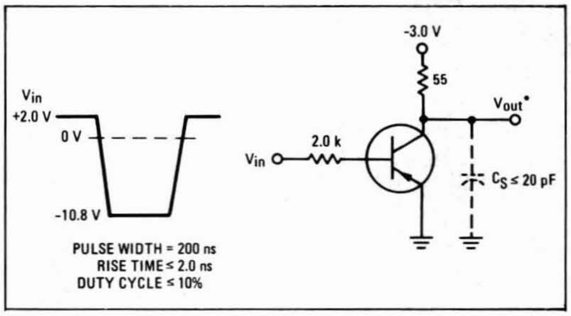
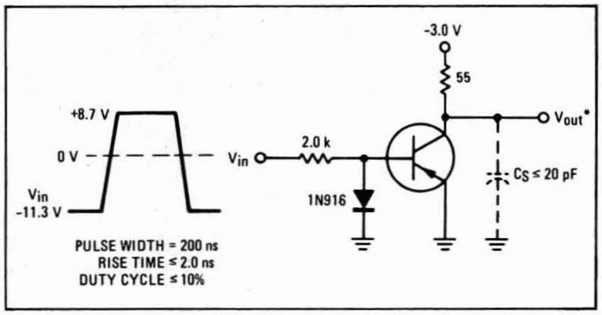

Vin
+2.0 V
0 V
-10.8 V
-3.0 V
55
Vout*
2.0 k
Vin
CS ≤ 20 pF
PULSE WIDTH = 200 ns
RISE TIME ≤ 2.0 ns
DUTY CYCLE ≤ 10%

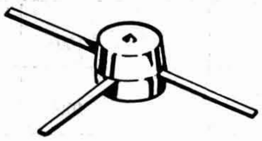
FIGURE 2 – STORAGE AND FALL TIME EQUIVALENT TEST CIRCUIT


+8.7 V
0 V
Vin
-11.3 V
-3.0 V
55
Vout*
2.0 k
Vin
1N916
CS ≤ 20 pF
PULSE WIDTH = 200 ns
RISE TIME ≤ 2.0 ns
DUTY CYCLE ≤ 10%

*OSCILLOSCOPE RISE TIME ≤ 1.0 ns

MMT3798 (SILICON)
MMT3799

PNP silicon annular micro-miniature transistors designed for low-level, low-noise amplifier applications.



CASE 28 (1)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	60	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current - Continuous Peak	I_C	50 100	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.490	°C/mW

MMT3798, MMT3799 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0)		BV_{CEO}	60		-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	60	-	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0)		I_{CBO}	-	-	50	nAdc
Emitter Cutoff Current (V_{BE} = 3.0 Vdc, I_C = 0)		I_{EBO}	-	-	50	nAdc
ON CHARACTERISTICS						
DC Current Gain* (I_C = 10 μAdc, V_{CE} = 5.0 Vdc)	MMT3798 MMT3799	h_{FE}*	75 150	- -	- -	-
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	MMT3798 MMT3799		150 300	- -	450 900	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)	MMT3798 MMT3799		150 300	- -	- -	
(I_C = 10 mAdc, V_{CE} = 5.0 Vdc)	MMT3798 MMT3799		125 250	- -	- -	
Collector-Emitter Saturation Voltage* (I_C = 1.0 mAdc, I_B = 100 μAdc)		$V_{CE(sat)}$*	-	-	0.25	Vdc
Base-Emitter Saturation Voltage* (I_C = 1.0 mAdc, I_B = 100 μAdc)		$V_{BE(sat)}$*	-	-	0.8	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain–Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 20 MHz)	MMT3798 MMT3799	f_T	40 40	120 150	- -	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	2.0	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	-	-	8.0	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	MMT3798 MMT3799	h_{ie}	- -	8.0 16	- -	k ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	MMT3798 MMT3799	h_{re}	- -	2.0 4.0	- -	$X\,10^{-4}$
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	MMT3798 MMT3799	h_{fe}	- -	275 475	- -	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	MMT3798 MMT3799	h_{oe}	- -	18 30	- -	μmhos
Noise Figure (I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, f = 100 Hz)	MMT3798 MMT3799	NF	- -	4.0 2.5	- -	dB
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, f = 1.0 kHz)	MMT3798 MMT3799		- -	1.5 0.8	- -	
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, f = 10 kHz)	MMT3798 MMT3799		- -	1.0 0.8	- -	
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, BW = 10 Hz to 15.7 kHz)	MMT3798 MMT3799		- -	2.5 1.5	3.5 2.5	

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

MMT3823

MICRO-T SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

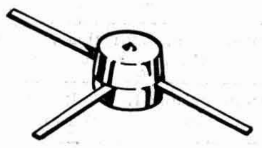
Depletion Mode (Type A) Field-Effect Transistor designed for RF amplifier and mixer applications where high density packaging is required.

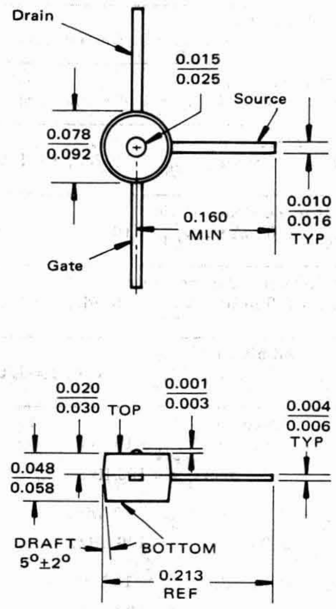
- Low Cross-Modulation and Intermodulation Distortion
- Drain and Source Interchangeable
- Low 100-MHz Noise Figure – 2.0 dB (Typ)
- Low Transfer and Input Capacitances
  C_{rss} = 1.0 pF (Typ); C_{iss} = 4.0 pF (Typ)
- Space Saving Micro-Miniature Package – Ideal for Thick Film Circuit Applications

MICRO-MINIATURE JUNCTION FIELD-EFFECT TRANSISTOR

SYMMETRICAL SILICON N-CHANNEL

Type A




Drain
0.015
0.025
Source
0.078
0.092
0.160
MIN
0.010
0.016
TYP
Gate
0.020
0.030
TOP
0.001
0.003
0.004
0.006
TYP
0.048
0.058
DRAFT
5°±2°
BOTTOM
0.213
REF

CASE 28
Style 5

Drain and Source may be Interchanged

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	30	Vdc
Drain-Gate Voltage	V_{DG}	30	Vdc
Gate-Source Voltage	V_{GS}	-30	Vdc
Gate Current	I_G	10	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.490	°C/mW

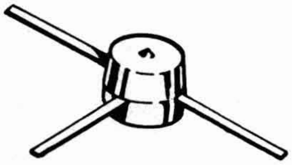
MMT3823 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Gate-Source Breakdown Voltage (I_G = −1.0 µAdc, V_{DS} = 0)	$V_{(BR)GSS}$	-30	–	–	Vdc
Gate Reverse Current (V_{GS} = −20 Vdc, V_{DS} = 0)	I_{GSS}	–	–	-1.0	nAdc
Gate-Source Cutoff Voltage (I_D = 1.0 nAdc, V_{DS} = 15 Vdc)	$V_{GS(off)}$	–	–	-8.0	Vdc
Gate-Source Voltage (I_D = 0.5 mAdc, V_{DS} = 15 Vdc)	V_{GS}	-1.0	–	-8.0	Vdc
ON CHARACTERISTICS					
Zero-Gate-Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0)	I_{DSS}*	5.0	–	20	mAdc
DYNAMIC CHARACTERISTICS					
Forward Transfer Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	$\|y_{fs}\|$*	3000 –	– 4000	8000 –	µmhos
Input Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	$Re(y_{is})$	–	500	–	µmhos
Output Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 200 MHz)	$\|y_{os}\|$* $Re(y_{os})$	– –	25 125	– –	µmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	–	4.0	–	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	–	1.0	–	pF
Common-Source Spot Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_S = 1000 ohms, f = 100 MHz)	NF	–	2.0	–	dB

*Pulse Test: Pulse Width = 100 ms, Duty Cycle ≤ 10%.

MMT3903 (SILICON)
MMT3904



CASE 28(1)

NPN silicon micro-miniature annular transistors designed for general purpose switching and amplifier applications and for complementary circuitry with type MMT3905 and MMT3906, where high-density packaging is required.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector-Current — Continuous	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.490	°C/mW

FIGURE 1 — DELAY AND RISE TIME EQUIVALENT TEST CIRCUIT

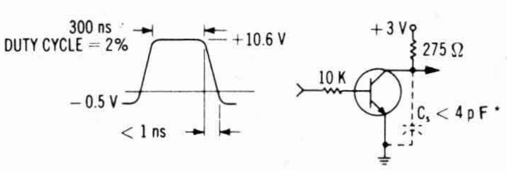
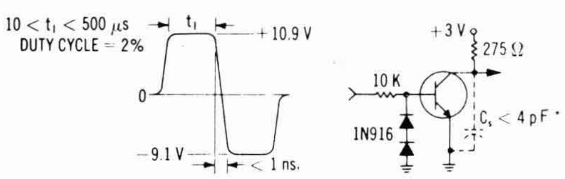

300 ns
DUTY CYCLE = 2%
+10.6 V
−0.5 V
< 1 ns
+3 V
275 Ω
10 K
C_s < 4 pF *

FIGURE 2 — STORAGE AND FALL TIME EQUIVALENT TEST CIRCUIT


10 < t_1 < 500 µs
DUTY CYCLE = 2%
t_1
+10.9 V
0
−9.1 V
< 1 ns.
+3 V
275 Ω
10 K
1N916
C_s < 4 pF *

*Total shunt capacitance of test jig and connectors

MMT3903, MMT3904 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

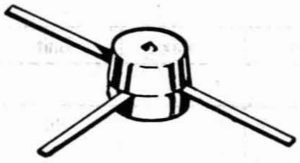
Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage* (I_C = 1.0 mAdc, I_B = 0)		BV_{CEO}*	40	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	60	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	6.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0)		I_{CBO}	-	-	50	nAdc
Emitter Cutoff Current ($V_{EB(off)}$ = 4.0 Vdc, I_C = 0)		I_{EBO}	-	-	50	nAdc
ON CHARACTERISTICS						
DC Current Gain* (I_C = 100 μAdc, V_{CE} = 1.0 Vdc)	MMT3903	h_{FE}*	20	-	-	
	MMT3904		40	-	-	
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc)	MMT3903		35	-	-	
	MMT3904		70	-	-	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	MMT3903		50	-	150	
	MMT3904		100	-	300	
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{CE(sat)}$*	-	-	0.2	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{BE(sat)}$*	-	-	0.85	Vdc
SMALL-SIGNAL CHARACTERISTICS						
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	MMT3903	f_T	250	-	-	MHz
	MMT3904		300	-	-	
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	-	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	-	-	8.0	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{ie}	-	3.0	-	k ohm
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{re}	-	2.0	-	X 10^{-4}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	MMT3903	h_{fe}	-	100	-	-
	MMT3904		-	200	-	
Output Admittance (I_C = 1.0 Adc, V_{CE} = 10 Vdc, f = 1.0 kHz)		h_{oe}	-	10	-	μmhos
Noise Figure (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, R_S = 1.0 k ohms Noise Bandwidth — f = 10 Hz to 15.7 kHz)		NF	-	3.0	-	dB

SWITCHING CHARACTERISTICS

Delay Time	(V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = 0.5 Vdc,	t_d	-	24	-	ns
Rise Time	I_C = 10 mAdc, I_{B1} = 1.0 mAdc)	t_r	-	13	-	ns
Storage Time	(V_{CC} = 3.0 Vdc, I_C = 10 mAdc,	t_s	-	125	-	ns
Fall Time	I_{B1} = I_{B2} = 1.0 mAdc)	t_f	-	11	-	ns

* Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2.0%.
For characteristic curves, see 2N3903/2N3904 Data.

MMT3905 (SILICON)
MMT3906



CASE 28 (1)

PNP silicon micro-miniature annular transistors designed for general purpose switching and amplifier applications and for complementary circuitry with types MMT3903 and MMT3904 where high-density packaging is required.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5	Vdc
Collector Current - Continuous	I_C	200	mAdc
Total Device Dissipation $T_A = 25°C$ Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.490	°C/mW

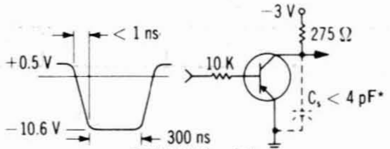


FIGURE 1 — DELAY AND RISE TIME EQUIVALENT TEST CIRCUIT

< 1 ns
+0.5 V
−10.6 V
300 ns
DUTY CYCLE = 2%
−3 V
275 Ω
10 K
C_s < 4 pF*

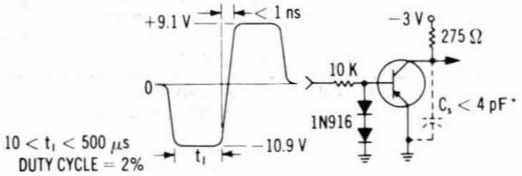


FIGURE 2 — STORAGE AND FALL TIME EQUIVALENT TEST CIRCUIT

+9.1 V
< 1 ns
0
−10.9 V
10 < t_1 < 500 μs
DUTY CYCLE = 2%
t_1
10 K
1N916
−3 V
275 Ω
C_s < 4 pF*

*Total shunt capacitance of test jig and connectors

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage* (I_C = 1.0 mAdc, I_B = 0)	BV_{CEO}*	40	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)	I_{CBO}		-	50	nAdc
Emitter Cutoff Current ($V_{BE(off)}$ = 4.0 Vdc, I_C = 0	I_{EBO}	-	-	50	nAdc

ON CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
DC Current Gain*	h_{FE}*				-
(I_C = 100 μAdc, V_{CE} = 1.0 Vdc) MMT3905 MMT3906		30 60	- -	- -	
(I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc) MMT3905 MMT3906		40 80	- -	- -	
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc) MMT3905 MMT3906		50 100	- -	150 300	
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$*	-	-	0.25	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$*	-	-	0.85	Vdc

SMALL-SIGNAL CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz) MMT3905 MMT3906	f_T	200 250	- -	- -	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	-	4.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	-	10	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}	-	4.0	-	k ohm
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{re}	-	2.0	-	X 10^{-4}
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) MMT3905 MMT3906	h_{fe}	- -	100 200	- -	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	-	15	-	μmhos
Noise Figure (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, R_S = 1.0 k ohms, Noise Bandwidth — f = 10 Hz to 15.7 kHz)	NF	-	1.0	-	dB

SWITCHING CHARACTERISTICS

Characteristic	Conditions	Symbol	Min	Typ	Max	Unit
Delay Time	(V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = 0.5 Vdc,	t_d	-	25	-	ns
Rise Time	I_C = 10 mAdc, I_{B1} = 1.0 mAdc)	t_r	-	18	-	ns
Storage Time	(V_{CC} = 3.0 Vdc, I_C = 10 mAdc,	t_s	-	140	-	ns
Fall Time	I_{B1} = I_{B2} = 1.0 mAdc)	t_f	-	15	-	ns

* Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2.0%.
For characteristic curves, see 2N3905/2N3906 Data.

MMT3960A (SILICON)

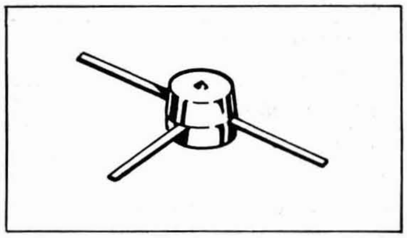
NPN SILICON ANNULAR TRANSISTOR

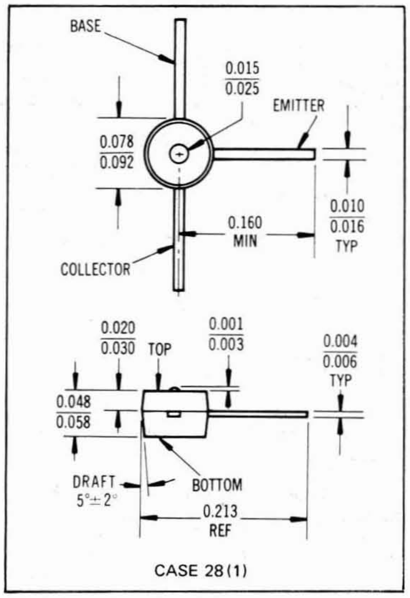
. . . designed for high-speed current-mode logic switching applications.

- High Current-Gain—Bandwidth Product —
  f_T = 2250 MHz (Typ) @ I_C = 10 mAdc
- Low Input and Output Capacitance —
  C_{ob} = 1.3 pF (Typ) @ V_{CB} = 4.0 Vdc
  C_{ib} = 1.2 pF (Typ) @ V_{BE} = 0.5 Vdc
- Excellent Current-Mode Performance —
  t_r = 0.75 ns (Typ)
- Low Collector-Base Time Constant —
  $r_b'C_c$ = 15 ps (Typ) @ I_C = 30 mAdc
- One-Piece, Injection-Molded Unibloc Package for High Reliability

MICRO-MINIATURE

NPN SILICON HIGH-SPEED SWITCHING TRANSISTOR




BASE
0.015
0.025
EMITTER
0.078
0.092
0.010
0.016
TYP
0.160
MIN
COLLECTOR
0.020
0.030
TOP
0.001
0.003
0.004
0.006
TYP
0.048
0.058
DRAFT
5°±2°
BOTTOM
0.213
REF

CASE 28(1)

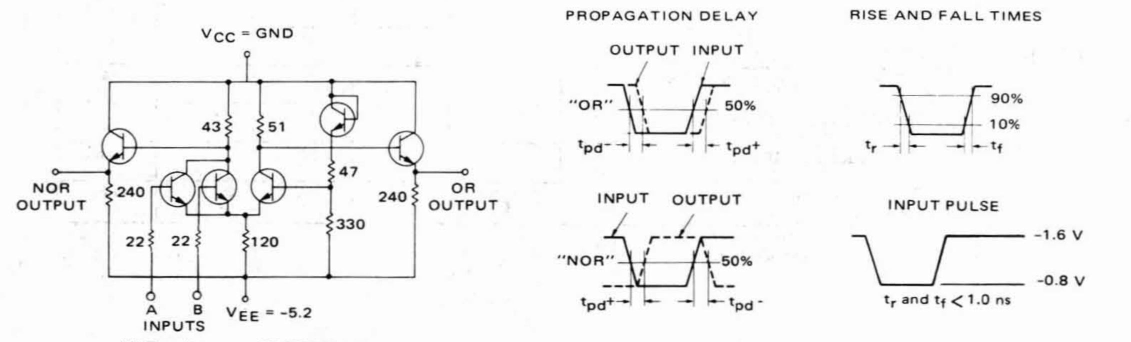
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	8.0	Vdc
Collector-Base Voltage	V_{CB}	15	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	225 2.05	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.490	°C/mW

FIGURE 1 — TWO INPUT OR/NOR ECL GATE


VCC = GND
43
51
47
NOR
OUTPUT
240
240
OR
OUTPUT
330
22
22
120
A
B
INPUTS
VEE = -5.2
PROPAGATION DELAY
OUTPUT INPUT
"OR"
50%
tpd-
tpd+
INPUT OUTPUT
"NOR"
50%
tpd+
tpd-
RISE AND FALL TIMES
90%
10%
tr
tf
INPUT PULSE
-1.6 V
-0.8 V
tr and tf < 1.0 ns

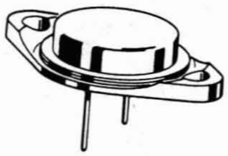
All Transistors are MMT3960A Types

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	8.0	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	15	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	3.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	-	50	nAdc
Emitter Cutoff Current (V_{EB} = 1.5 Vdc, I_C = 0)	I_{EBO}	-	-	50	nAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 1.0 mAdc, V_{CE} = 1.0 Vdc) (I_C = 10 mAdc, V_{CE} = 1.0 Vdc) (I_C = 30 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}*	 30 30 30	 - - -	 - 200 -	-
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$*	-	-	0.2	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 0.5 mAdc)	$V_{BE(sat)}$*	0.75	-	0.9	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product (I_C = 5.0 mAdc, V_{CE} = 4.0 Vdc, f = 100 MHz) (I_C = 10 mAdc, V_{CE} = 5.0 Vdc, f = 100 MHz) (I_C = 30 mAdc, V_{CE} = 2.0 Vdc, f = 100 MHz)	f_T	 - - 1600	 2000 2250 2500	 - - -	MHz
Output Capacitance (V_{CB} = 4.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	1.3	2.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	1.2	3.0	pF
Collector-Base Time Constant (I_E = 30 mAdc, V_{CB} = 2.0 Vdc, f = 100 MHz)	$r_b'C_c$	-	15	-	ps
SWITCHING CHARACTERISTICS					
Turn-On Delay Time (Figure 1)	$t_{on(delay)}$	-	1.0	-	ns
Rise Time (Figure 1)	t_r	-	0.75	-	ns
Turn-Off Delay Time (Figure 1)	$t_{off(delay)}$	-	1.1	-	ns
Fall Time (Figure 1)	t_f	-	0.85	-	ns

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

MP110 (GERMANIUM)



CASE 11
(TO-3)

PNP germanium power transistor designed for high-gain power amplification in the audio range.

Collector connected to case

MAXIMUM RATINGS (Tc = 25°C unless otherwise noted)

Rating	Symbol	MP110	Unit
Collector-Emitter Voltage	V_{CEX}	65	Vdc
Collector-Emitter Voltage	V_{CER}	40	Vdc
Collector-Emitter Voltage	V_{CES}	50	Vdc
Collector Current-Continuous Peak	I_C	7 15	Adc
Base Current	I_B	2	Adc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25^oC	P_D	106 1.25	Watts $W/^oC$
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110	^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	$^oC/W$

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 25 mAdc, $V_{BE(off)}$ = 2 Vdc)	BV_{CEX}	65	—	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 0.6 Adc, R_{BE} = 68 ohms)	BV_{CER}	40	—	—	Vdc
Collector-Emitter Breakdown Voltage (I_C = 0.2 Adc, V_{BE} = 0)	BV_{CES}	50	—	—	Vdc
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0) (V_{CB} = 40 Vdc, I_E = 0) (V_{CB} = 40 Vdc, I_E = 0, $T_J = 75^oC$)	I_{CBO}	 — — —	 — — —	 0.2 2.0 15	mAdc
Emitter Cutoff Current (V_{BE} = 20 Vdc, I_C = 0)	I_{EBO}	—	—	8.0	mAdc
Floating Potential (V_{CB} = 40 Vdc, I_E = 0)	V_{FL}	—	—	0.8	Vdc
ON CHARACTERISTICS					
DC Current Gain (See Note) (I_C = 50 mAdc, V_{CE} = 2 Vdc) (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	 60 74	 — —	 — 250	—
Collector-Emitter Saturation Voltage (I_C = 2.0 Adc, I_B = 0.2 Adc)	$V_{CE(sat)}$	—	—	0.5	Vdc
Base-Emitter "On" Voltage (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)	$V_{BE(on)}$	—	—	0.5	Vdc
SMALL SIGNAL CHARACTERISTICS					
Current-Gain Bandwidth Product (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)	f_T	—	320	—	kHz

MP110 (Continued)

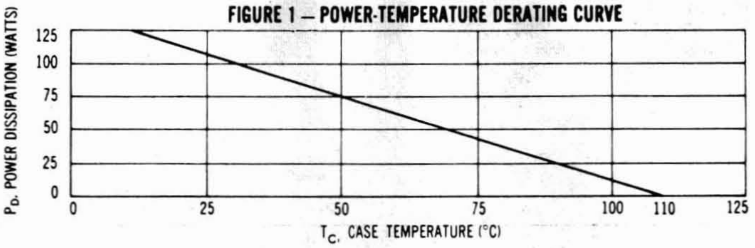


FIGURE 1 — POWER-TEMPERATURE DERATING CURVE

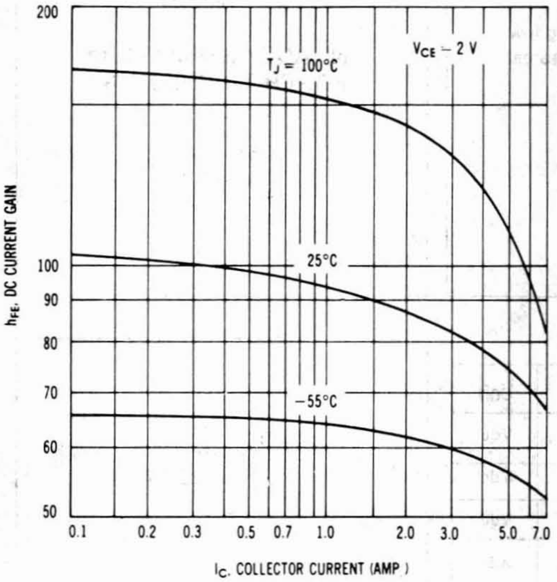


FIGURE 2 — DC CURRENT GAIN

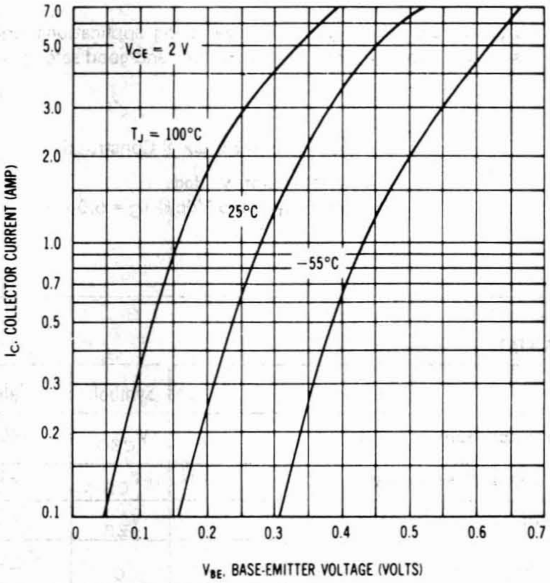


FIGURE 3 — TRANSCONDUCTANCE

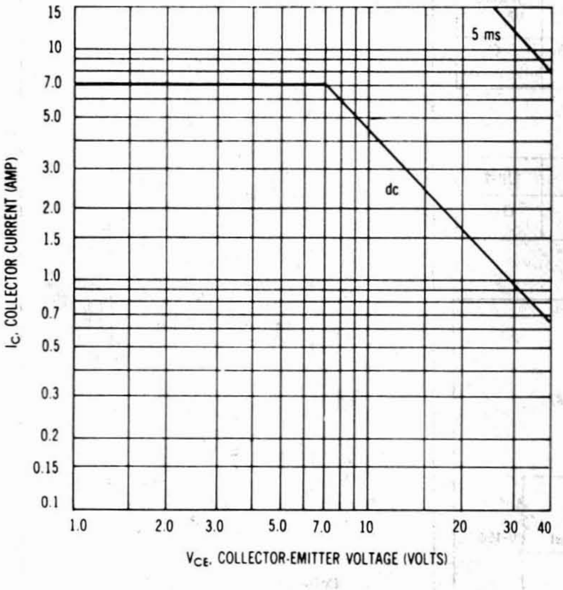


FIGURE 4 — ACTIVE REGION SAFE OPERATING AREA

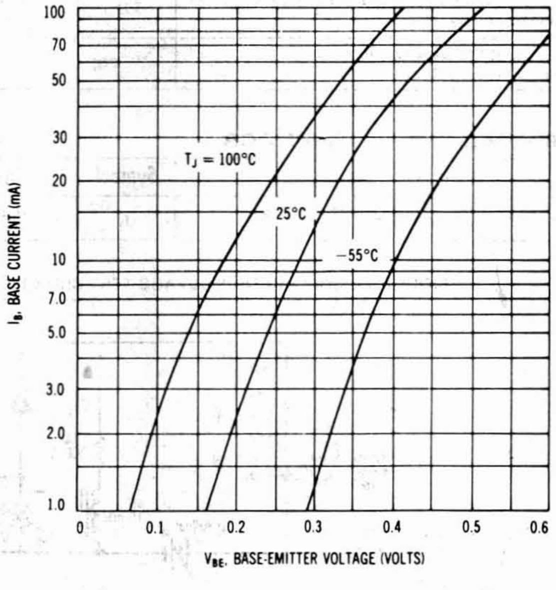


FIGURE 5 — INPUT ADMITTANCE

NOTE: Transistors are color coded to identify gain ranges as shown. No guarantee is made of gain distribution.
I_C = 1 Adc, V_{CE} = 2 Vdc

COLOR CODE	h_{FE}	
	Min.	**Max.**
red	74	111
orange	100	133
yellow	119	164
green	145	200
blue	179	250

MP110B

PNP GERMANIUM POWER SWITCHING TRANSISTOR

. . . designed for high-current switching applications requiring low saturation voltages, fast switching times and good safe operating area.

- Alloy-Diffused Epitaxial Construction
- Low Saturation Voltage –
  $V_{CE(sat)}$ = 0.5 Vdc @ I_C = 5.0 Adc

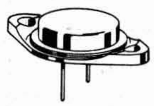
25 AMPERE

PNP ADE GERMANIUM
POWER TRANSISTOR

90 VOLTS
106 WATTS

MAXIMUM RATINGS

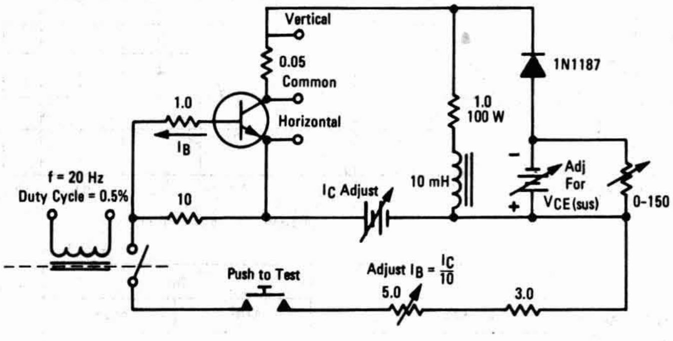
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	90	Vdc
Emitter-Base Voltage	V_{EB}	2.0	Vdc
Collector Current - Continuous	I_C	25	Adc
Base Current - Continuous	I_B	5.0	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	106 1.25	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110	°C

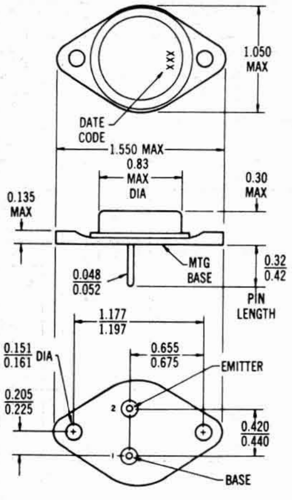


THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	°C/W

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT


Vertical
0.05
Common
Horizontal
1.0
I_B
f = 20 Hz
Duty Cycle = 0.5%
10
I_C Adjust
10 mH
1.0
100 W
1N1187
–
+
Adj
For
$V_{CE(sus)}$
0-150
Push to Test
Adjust $I_B = \frac{I_C}{10}$
5.0
3.0


XXX
DATE CODE
1.050 MAX
1.550 MAX
0.83 MAX DIA
0.30 MAX
0.135 MAX
MTG BASE
$\frac{0.048}{0.052}$
$\frac{0.32}{0.42}$
PIN LENGTH
$\frac{1.177}{1.197}$
$\frac{0.151}{0.161}$ DIA
$\frac{0.655}{0.675}$
EMITTER
$\frac{0.205}{0.225}$
2
1
$\frac{0.420}{0.440}$
BASE

Collector Connected to Case

CASE 11A
(TO-3)

Except Pin Diameter

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	BV_{CEO}	40	-	Vdc
Collector-Emitter Sustaining Voltage (I_C = 5.0 Adc) (See Figure 1)	$V_{CE(sus)}$	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 mAdc, I_C = 0)	BV_{EBO}	2.0	-	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 50 Vdc, R_{EB} = 100 Ohms)	I_{CER}	-	10	mAdc
Collector Cutoff Current (V_{CE} = 90 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	I_{CEX}	-	20	mAdc
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)	I_{CBO}	-	200	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc)* Red Green Blue (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	65 100 150 55	120 200 300 -	-
Collector-Emitter Saturation Voltage (I_C = 5.0 Adc, I_B = 100 mAdc)	$V_{CE(sat)}$	-	0.5	Vdc
Base-Emitter On Voltage (I_C = 1.0 Adc, V_{CE} = 2.0 Vdc) (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	$V_{BE(on)}$	- -	0.45 0.60	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 0.5 Adc, V_{CE} = 10 Vdc)	f_T	500	-	kHz

*For desired h_{FE} range, specify color code.

MP500 thru MP502 (GERMANIUM)
MP504 thru MP506

CASE 7

PNP germanium power transistors for high-gain, high-power amplifier and switching applications in high reliability industrial equipment.

MAXIMUM RATINGS

Rating	Symbol	MP500 MP504	MP501 MP505	MP502 MP506	Unit
Collector-Base Voltage	V_{CB}	45	60	75	Volts
Collector-Emitter Voltage	V_{CES}	45	60	75	Volts
Collector-Emitter Voltage	V_{CEO}	30	45	60	Volts
Emitter-Base Voltage	V_{EB}	25	30	40	Volts
Collector Current	I_C	60	60	60	Amp
Power Dissipation at $T_C = 25^{\circ}C$	P_D	170	170	170	Watts
Junction Temperature Range	T_J	← -65 to + 110 →			$^{\circ}C$

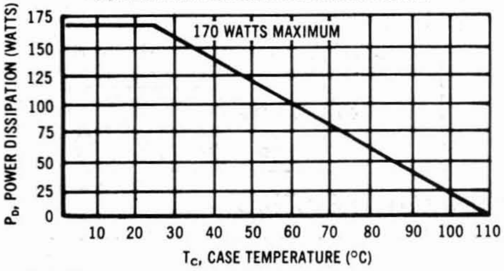
POWER DERATING

The maximum continuous power is related to maximum junction temperature by the thermal resistance factor.

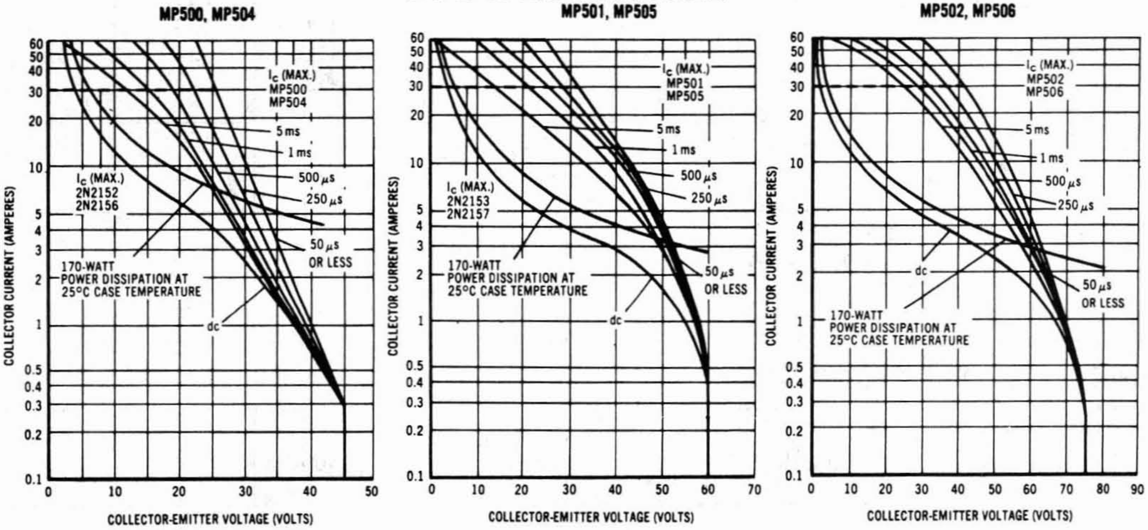
This curve has a value of 170 Watts at case temperatures of 25°C and is 0 Watts at 110°C with a linear relation between the two temperatures such that:

$$\text{allowable } P_D = \frac{110^{\circ} - T_C}{0.5}$$

POWER-TEMPERATURE DERATING CURVE



SAFE OPERATING AREA


MP500, MP504

MP501, MP505

MP502, MP506

The Safe Operating Area Curves indicate I_C — V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Duty cycle of the excursions make no significant change in these safe areas.) To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

MP500 thru MP502 MP504 thru MP506 (continued)

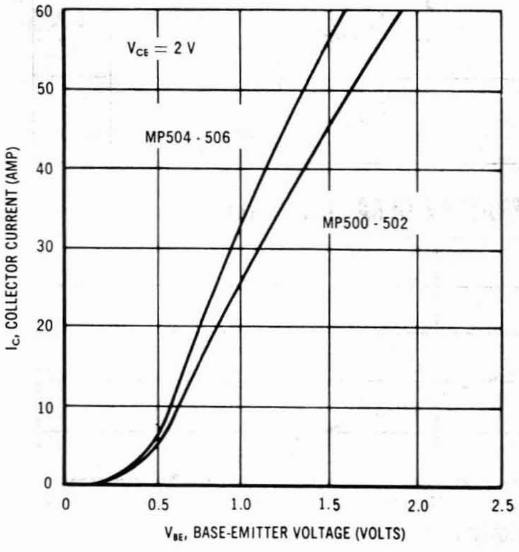
ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Base Cutoff Current (V_{CB} = -45 V, I_E = 0) MP500 MP504 (V_{CB} = -60 V, I_E = 0) MP501 MP505 (V_{CB} = -75 V, I_E = 0) MP502 MP506	I_{CBO1}	— — —	0.9 0.9 0.9	4.0 4.0 4.0	mAdc
Collector-Base Cutoff Current (V_{CB} = V_{CBmax}, I_E = 0, T_C = +71°C)	I_{CBO}	—	4.0	15	mAdc
Collector-Base Cutoff Current (V_{CB} = -2 V, I_E = 0)	I_{CBO}	—	80	200	μAdc
Emitter-Base Cutoff Current (V_{EB} = -25 V, I_C = 0) MP500 MP504 (V_{EB} = -30 V, I_C = 0) MP501 MP505 (V_{EB} = -40 V, I_C = 0) MP502 MP506	I_{EBO}	— — —	0.2 0.2 0.2	4.0 4.0 4.0	mAdc
Emitter-Base Cutoff Current (V_{EB} = $V_{EB\,max}$, I_C = 0, T_C = +71°C)	I_{EBO}	—	2.7	15	mAdc
Collector-Emitter Breakdown Voltage* (I_C = 300 mA, V_{EB} = 0) MP500 MP504 MP501 MP505 MP502 MP506	BV_{CES}*	-45 -60 -75	— — —	— — —	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 1.0 A, I_B = 0) MP500 MP504 MP501 MP505 MP502 MP506	BV_{CEO}*	-30 -45 -60	— — —	— — —	Vdc
Floating Potential (V_{CB} = 45 V, I_E = 0) MP500 MP504 (V_{CB} = 60 V, I_E = 0) MP501 MP505 (V_{CB} = 75 V, I_E = 0) MP502 MP506	V_{EBF}	— — —	— — —	1.0 1.0 1.0	Vdc
DC Current Transfer Ratio (I_C = 15 A, V_{CE} = 2 V) MP500 through MP502 MP504 through MP506 (I_C = 50 A, V_{CE} = 2 V) All Types	h_{FE1} h_{FE}	30 50 12	47 63 20	60 100 —	—
Collector-Emitter Saturation Voltage (I_C = 15 A, I_B = 1 A) (I_C = 50 A, I_B = 5 A)	$V_{CE(sat)}$	— —	0.11 0.2	0.2 0.45	Vdc
Base-Emitter Saturation Voltage (I_C = 15 A, I_B = 1 A) (I_C = 50 A, I_B = 5 A)	$V_{BE(sat)}$	— —	0.7 2.0	1.5 2.5	Vdc
Common Emitter Cutoff Frequency (I_C = 15 A, V_{CE} = 2 V)	$f_{\alpha e}$	2	3.6	—	kHz

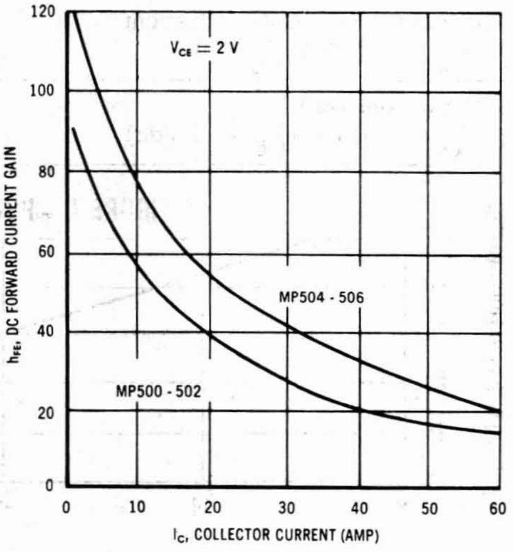
*To avoid excessive heating of collector junction, perform this test with a sweep method.

INPUT AND TRANSFER CHARACTERISTICS

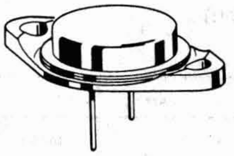
COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE



DC CURRENT GAIN versus COLLECTOR CURRENT



MP525 (GERMANIUM)



CASE 3
(TO-3 modified)

Germanium PNP power transistor designed for audio amplifier applications requiring gains of 30 – 150 at I_C = 3 amp.

MAXIMUM RATINGS

Rating	Symbol	MP525	Unit
Collector-Emitter Voltage	V_{CEX}	60	Vdc
Collector Current (Continuous)	I_C	7	Adc
Total Device Dissipation @ $T_C = 25^oC$ Derate above 25°C	P_D	 106 1.25	 Watts W/°C
Junction Temperature Range	T_J	-65 to +110	°C
Thermal Resistance, Junction to Case	θ_{JC}	0.8	°C/W

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 300 mA, R_{BE} = 10 ohms)	BV_{CER}	35	-	Vdc
Collector-Emitter Cutoff Current (V_{CE} = 30 Vdc, V_{EB} = 0)	I_{CES}	-	15	mA
Collector-Emitter Cutoff Current (V_{CE} = 60 Vdc, V_{BE} = 1.5 Vdc)	I_{CEX}	-	15	mA
Collector-Base Cutoff Current (V_{CB} = 2 Vdc, I_E = 0)	I_{CBO}	-	200	μA
DC Current Gain (I_C = 3 Adc, V_{CE} = 2 Vdc)	h_{FE}	30	150	-

FIGURE 1 – POWER-TEMPERATURE DERATING CURVE

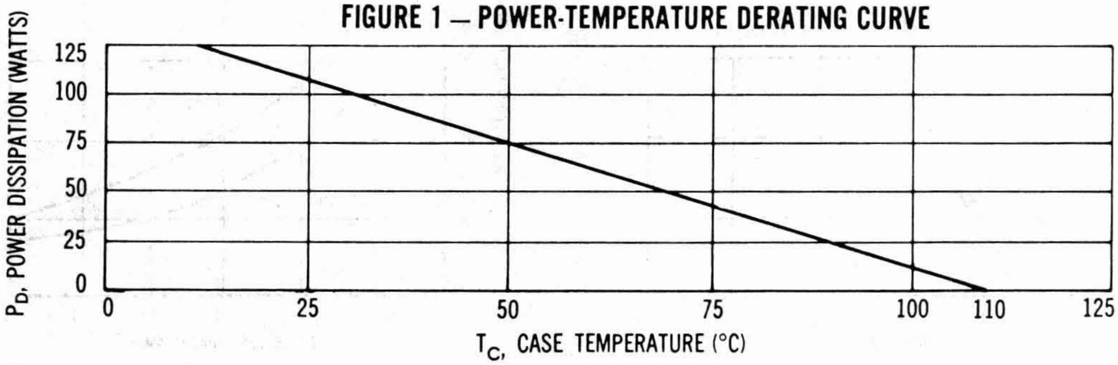


FIGURE 2 — DC CURRENT GAIN

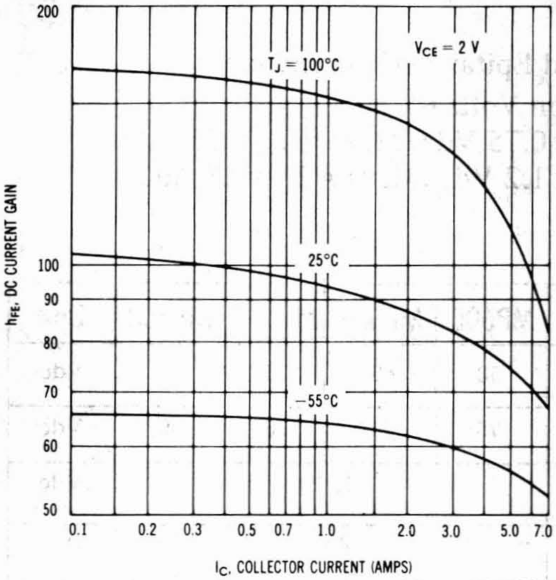


FIGURE 3 — TRANSCONDUCTANCE

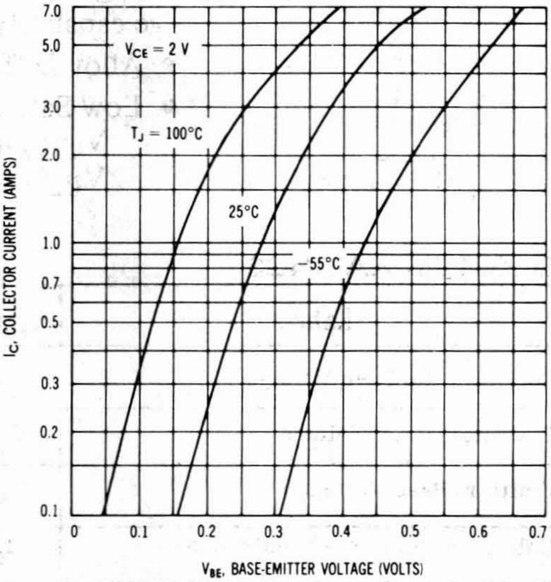


FIGURE 4 — ACTIVE REGION SAFE OPERATING AREA

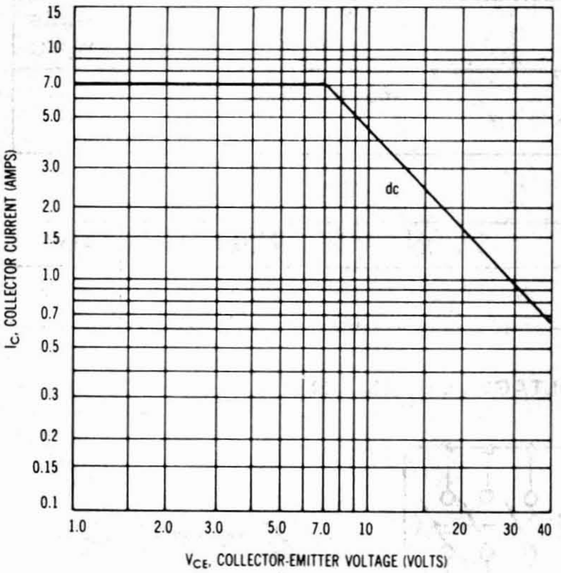
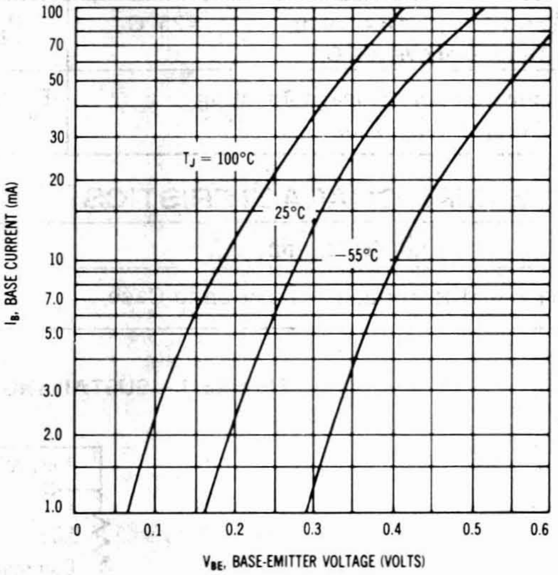


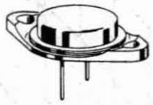
FIGURE 5 — INPUT ADMITTANCE



NOTE: Transistors are numerically coded to identify gain ranges as shown. No guarantee is made of gain distribution.
$I_C = 3$ Adc, $V_{CE} = 2$ Vdc

	h_{FE}	
Bracket	**Min.**	**Max.**
MP525-1	30	45
-2	40	60
-3	50	75
-4	60	90
-5	80	120
-6	100	150

MP600 (GERMANIUM)
thru
MP603



Collector Connected to Case
CASE 11A
(TO-3 modified)

PNP Germanium power transistors designed for high-current switching applications requiring low saturation voltages, short switching times and good sustaining voltage capability.

- Alloy Diffused Epitaxial Construction
- Low Saturation Voltages –
  $V_{CE(sat)} = 0.75$ Vdc (Max) @ $I_C = 25$ Adc
  $V_{BE(sat)} = 1.2$ Vdc (Max) @ $I_C = 25$ Adc

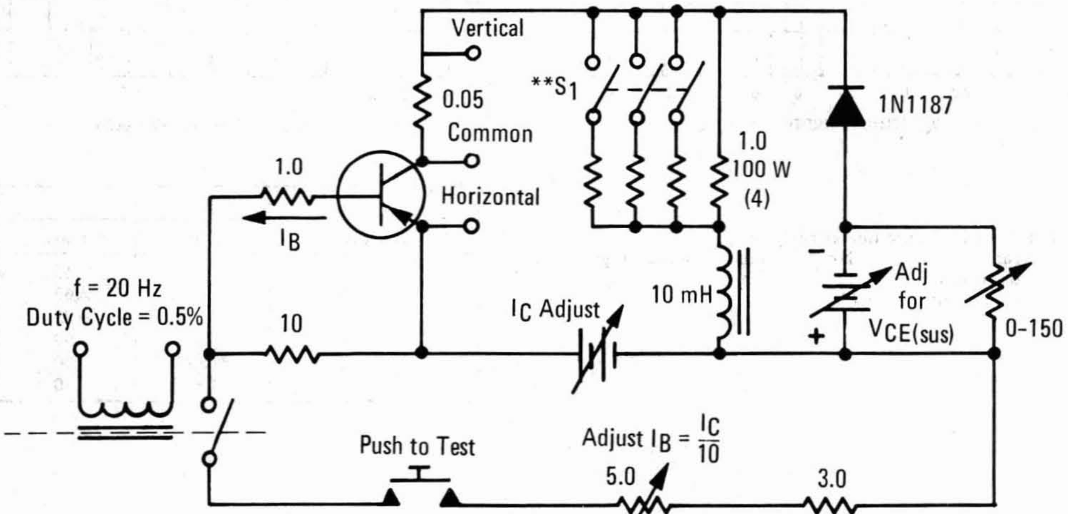
MAXIMUM RATINGS

Rating	Symbol	MP600	MP601	MP602	MP603	Unit
Collector-Emitter Voltage	V_{CEO}	50	60	70	80	Vdc
Collector-Base Voltage	V_{CB}	75	75	90	90	Vdc
Emitter-Base Voltage	V_{EB}	1.5				Vdc
Collector Current - Continuous	I_C	25				Adc
Base Current - Continuous	I_B	5.0				Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	85 1.0				Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110				°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.0	°C/W

FIGURE 1 – SUSTAINING VOLTAGE TEST CIRCUIT



Vertical
0.05
Common
**S1
1N1187
1.0
100 W
(4)
1.0
I_B
Horizontal
f = 20 Hz
Duty Cycle = 0.5%
10
I_C Adjust
10 mH
–
+
Adj for V_CE(sus)
0-150
Push to Test
Adjust I_B = I_C/10
5.0
3.0

**Close Switch S_1 for $I_C = 25A$ Test

MP600 thru MP603 (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 100 mAdc, I_B = 0)	MP600 MP601 MP602 MP603	BV_{CEO}	50 60 70 80	- - - -	Vdc
Collector-Emitter Sustaining Voltage (See Figure 1) (I_C = 5.0 Adc)	MP600 MP601 MP602 MP603	$V_{CE(sus)}$	50 60 70 80	- - - -	Vdc
(I_C = 25 Adc)	MP600 MP601 MP602 MP603		30 40 40 50	- - - -	
Emitter-Base Breakdown Voltage (I_E = 100 mAdc, I_C = 0)		BV_{EBO}	1.5	-	Vdc
Floating Potential (V_{CB} = 60 Vdc, I_E = 0)		V_{EBF}	-	0.4	Vdc
Collector Cutoff Current (V_{CE} = 75 Vdc, $V_{BE(off)}$ = 0.2 Vdc) (V_{CE} = 90 Vdc, $V_{BE(off)}$ = 0.2 Vdc)	 MP600, MP601 MP602, MP603	I_{CEX}	 - -	 10 10	mAdc
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)		I_{CBO}	-	200	μAdc
Emitter Cutoff Current (V_{EB} = 0.5 Vdc, I_C = 0)		I_{EBO}	-	5.0	mAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)		h_{FE}	50	-	-
Collector-Emitter Saturation Voltage (I_C = 25 Adc, I_B = 1.25 Adc)		$V_{CE(sat)}$	-	0.75	Vdc
Base-Emitter Saturation Voltage (I_C = 25 Adc, I_B = 1.25 Adc)		$V_{BE(sat)}$	-	1.2	Vdc
Emitter-Base On Voltage (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)		$V_{EB(on)}$	-	0.6	Vdc
Pulse Energy Test* (See Figure 2) (I_C = 3.3 Adc, V_{CE} = 30 Vdc)		PET*	1.0	-	Joule
SWITCHING CHARACTERISTICS					
Rise Time	(V_{CC} = 22 Vdc, I_C = 15 Adc, I_{B1} = I_{B2} = 1.5 Adc) See Figure 3	t_r	-	10	μs
Storage Time		t_s	-	6.0	μs
Fall Time		t_f	-	13	μs

*Pulse Test: Pulse Width = 10 ms, Duty Cycle = 2.5%.

FIGURE 2 – PULSE ENERGY TEST CIRCUIT

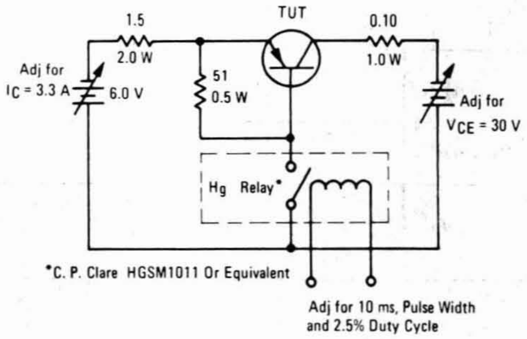
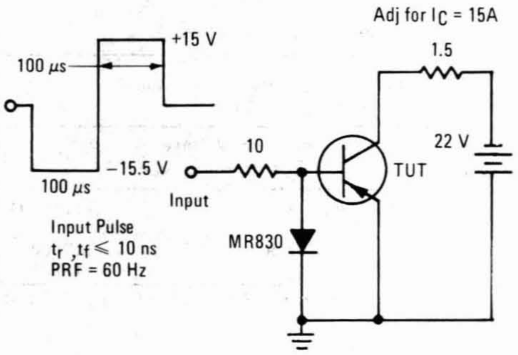
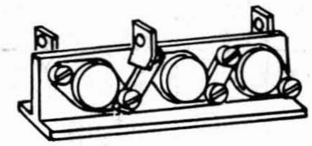

1.5
2.0 W
TUT
0.10
1.0 W
Adj for
I_C = 3.3 A
6.0 V
51
0.5 W
Adj for
V_{CE} = 30 V
Hg Relay*
*C. P. Clare HGSM1011 Or Equivalent
Adj for 10 ms, Pulse Width
and 2.5% Duty Cycle

FIGURE 3 – SWITCHING TIME TEST CIRCUIT


Adj for I_C = 15A
1.5
+15 V
100 μs
−15.5 V
100 μs
10
22 V
TUT
Input
Input Pulse
t_r, t_f ≤ 10 ns
PRF = 60 Hz
MR830

MP800 (GERMANIUM)
MP801


CASE 118

PNP germanium power transistor designed for ultra-high current applications requiring high gain and extremely low saturation voltage. Collector electrically isolated from heat sink.

MAXIMUM RATINGS

Rating	Symbol	MP800	MP801	Unit
Collector-Emitter Voltage	V_{CEO}	60	45	Vdc
Collector-Emitter Voltage	V_{CES}	75	60	Vdc
Emitter-Base Voltage	V_{EB}	20		Vdc
Collector Current*	I_C*	150		Amp
Total Device Dissipation @ T_C = 25°C	P_D	250		Watts
Operating Junction Temperature Range	T_J	-65 to +110		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.33	°C/W

ELECTRICAL CHARACTERISTICS

** For Epoxy Encapsulated unit, add "A" to device type, i.e. MP800A

(T_C = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 1.0 Adc, I_B = 0) MP800	BV_{CEO}	60	-	Vdc
MP801		45	-	
Collector Cutoff Current (V_{CB} = 75 Vdc, I_E = 0) MP800	I_{CBO}	-	12	mAdc
(V_{CB} = 60 Vdc, I_E = 0) MP801		-	12	
ON CHARACTERISTICS				
DC Current Gain (I_C = 150 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	15	-	-
Collector-Emitter Saturation Voltage (I_C = 150 Adc, I_B = 15 Adc)	$V_{CE(sat)}$	-	0.30	Vdc
Base-Emitter Saturation Voltage (I_C = 150 Adc, I_B = 15 Adc)	$V_{BE(sat)}$	-	1.0	Vdc
Safe Operating Area (Figure 1) 100% Test - Clamped V_{CE} MP800	SOA	-	45	Volts
MP801		-	40	

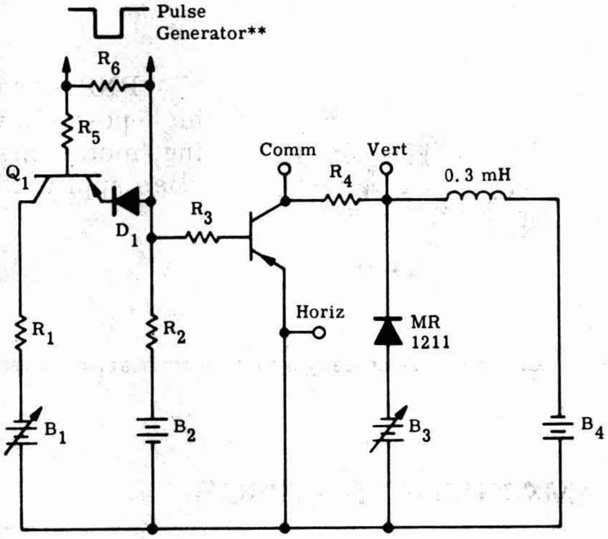
* For currents above 150 Amp, contact your local representative.

FIGURE 1 — SAFE OPERATING AREA TEST CURRENT

R_1 = 1.0Ω, 200 W
R_2 = 10Ω, 2.0 W
R_3 = 0.1Ω, 1%, 20 W
R_4 = 0.001Ω
R_5 = 10Ω, 2.0 W
R_6 = 50Ω, 1.0 W
Q_1 = 2N2832
D_1 = 1N1183

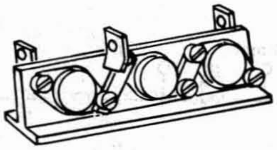
B_1 = Adj for $I_{B(on)}$ = 15 A
B_2 = 6.0 V
B_3 = Adj for clamped V_{CE}
B_4 = 20 V

** Adj P. W. to obtain I_C = 150 A



Pulse
Generator**
R6
R5
Q1
D1
R3
Comm
R4
Vert
0.3 mH
Horiz
R1
R2
MR
1211
B1
B2
B3
B4

MP900 (GERMANIUM)
MP901
MP902



CASE 118

PNP germanium power transistors designed for high-power inverters up to 2.0 kW, high-current switching, motor speed control, and high-current power supplies applications.

Collector is electrically isolated from heat sink chassis

MAXIMUM RATINGS

Rating	Symbol	MP900	MP901	MP902	Unit
Collector-Emitter Voltage	V_{CEO}	60	90	120	Vdc
Collector-Base Voltage	V_{CB}	80	110	140	Vdc
Emitter-Base Voltage	V_{EB}	2.0			Vdc
Collector Current	I_C	150			Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	250 2.94			Watts W/°C
Operating Junction Temperature Range	T_J	-65 to +110			°C

THERMAL CHARACTERISTICS

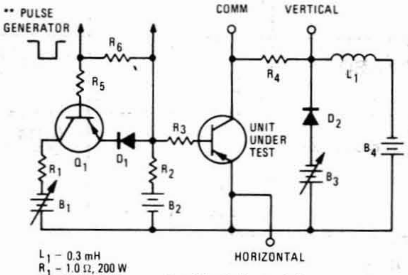
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.33	°C/W

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector Cutoff Current		I_{CEO}				mAdc
(V_{CE} = 60 Vdc, I_B = 0)	MP900		-	-	300	
(V_{CE} = 90 Vdc, I_B = 0)	MP901		-	-	300	
(V_{CE} = 120 Vdc, I_B = 0)	MP902		-	-	300	
Collector Cutoff Current		I_{CEX}				mAdc
(V_{CE} = 80 Vdc, V_{BE} = 0.2 Vdc, T_C = 70°C)	MP900		-	-	50	
(V_{CE} = 110 Vdc, V_{BE} = 0.2 Vdc, T_C = 70°C)	MP901		-	-	50	
(V_{CE} = 140 Vdc, V_{BE} = 0.2 Vdc, T_C = 70°C)	MP902		-	-	50	
Collector Cutoff Current		I_{CBO}				mAdc
(V_{CB} = 2.0 Vdc, I_E = 0)	All Types		-	-	0.6	
(V_{CB} = 80 Vdc, I_E = 0)	MP900		-	-	10	
(V_{CB} = 110 Vdc, I_E = 0)	MP901		-	-	10	
(V_{CB} = 140 Vdc, I_E = 0)	MP902		-	-	10	
ON CHARACTERISTICS						
DC Current Gain (I_C = 70 Adc, V_{CE} = 2.0 Vdc)		h_{FE}	20	-	-	-
Collector-Emitter Saturation Voltage (I_C = 150 Adc, I_B = 30 Adc)		$V_{CE(sat)}$	-	-	0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 150 Adc, I_B = 30 Adc)		$V_{BE(sat)}$	-	-	1.3	Vdc
Safe Operating Area* (Figure 1)		SOA*				Vdc
(I_C = 50 Adc)	MP900		80	-	-	
	MP901		85	-	-	
	MP902		100	-	-	
(I_C = 150 Adc)	MP900		35	-	-	
	MP901		45	-	-	
	MP902		55	-	-	
SWITCHING CHARACTERISTICS						
Rise Time	(I_C = 75 Adc, I_{B1} = I_{B2} = 7.5 Adc, (Figure 2)	t_r	-	25	-	µs
Storage Time		t_s	-	5	-	µs
Fall Time		t_f	-	15	-	µs

*100% Test-Clamped V_{CE}

FIGURE 1 – SAFE OPERATING AREA TEST CIRCUIT

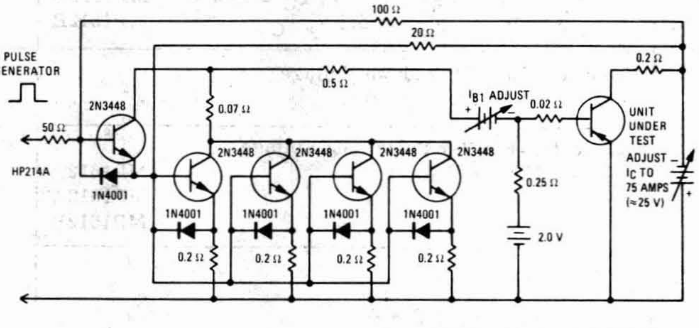

** PULSE GENERATOR
COMM
VERTICAL
R_6
R_5
R_4
L_1
R_3
UNIT UNDER TEST
D_2
B_4
R_1
Q_1
D_1
R_2
B_3
B_1
B_2
HORIZONTAL

L_1 – 0.3 mH
R_1 – 1.0 Ω, 200 W
R_2 – 3.2 Ω, 4.0 W
R_3 – 0.1 Ω, 20 W
R_4 – 0.001 Ω, 20 W
R_5 – 10 Ω, 2.0 W
R_6 – 100 Ω, 2.0 W
D_1 – 1N1183
D_2 – MR1213
Q_1 – MP3105

B_1 = Adjust for $I_{B(on)} = I_C/5$
B_2 = 2.0 Volts
B_3 = Adjust for Specified V_{CE}
B_4 = 20 Volts

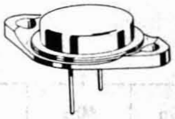
**Pulse ≥ 12 Volts, 20 pps
Adjust Pulse Width to obtain the Specified I_C
(0.5 ms ≤ PW ≤ 5.0 ms)

FIGURE 2 – SWITCHING TIME TEST CIRCUIT


100 Ω
20 Ω
* PULSE GENERATOR
0.2 Ω
0.5 Ω
2N3448
0.07 Ω
I_{B1} ADJUST
0.02 Ω
50 Ω
UNIT UNDER TEST
HP214A
2N3448
2N3448
2N3448
2N3448
1N4001
0.25 Ω
ADJUST I_C TO 75 AMPS (≈25 V)
1N4001
1N4001
1N4001
1N4001
0.2 Ω
0.2 Ω
0.2 Ω
0.2 Ω
2.0 V

*INPUT PULSE REPETITION RATE = 20 Hz, PULSE WIDTH = 100 µs.

MP1612, A, B (GERMANIUM)



CASE 11A
(TO-3 modified)

High-current, germanium PNP power transistor developed specially for high-speed, high-frequency, applications such as television horizontal deflection circuits.

MAXIMUM RATINGS

Rating	Symbol	MP1612	MP1612A	MP1612B	Unit
Collector-Base Voltage	V_{CB}	100	140	160	Volts
Collector-Emitter Voltage	V_{CEO}	50	75	100	Volts
Emitter-Base Voltage	V_{EB}	2.5	2.5	2.5	Volts
Collector Current (Continuous)	I_C	20	20	20	Amp
Base Current (Continuous)	I_B	5	5	5	Amp
Power Dissipation	P_D	85	85	85	Watts
Operating Junction Temperature Range	T_J	-65 to +110			^{o}C

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Base Cutoff Current		I_{CBO}			mA
(V_{CB} = 80 V, I_E = 0)	MP1612		—	10	
(V_{CB} = 120 V, I_E = 0)	MP1612A		—	10	
(V_{CB} = 140 V, I_E = 0)	MP1612B		—	10	
Collector-Emitter Current		I_{CES}			mA
(V_{CE} = 100 V, V_{BE} = 0)	MP1612		—	20	
(V_{CE} = 140 V, V_{BE} = 0)	MP1612A		—	20	
(V_{CE} = 160 V, V_{BE} = 0)	MP1612B		—	20	
Collector-Emitter Cutoff Current		I_{CEX}			mA
(V_{CE} = 50 V, V_{BE} = 0.2 V, T_C = +85°C)	MP1612		—	40	
(V_{CE} = 75 V, V_{BE} = 0.2 V, T_C = +85°C)	MP1612A		—	40	
(V_{CE} = 100 V, V_{BE} = 0.2 V, T_C = +85°C)	MP1612B		—	40	
Emitter-Base Breakdown Voltage (I_E = 50 mAdc, I_C = 0)		BV_{EBO}	2.5	—	Vdc
Collector-Emitter Sustaining Voltage		$BV_{CEO(sus)}$			Volts
(I_E = 100 mA, I_B = 0)	MP1612		50	—	
	MP1612A		75	—	
	MP1612B		100	—	
DC Current Gain		h_{FE}			—
(I_C = 5.0 A, V_{CB} = 2 V)			40	—	
(I_C = 10 A, V_{CB} = 2 V)			25	100	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 10 Adc, I_B = 1.0 Adc)			—	0.30	
(I_C = 20 Adc, I_B = 2.0 Adc)			—	0.5	
Fall Time (Figure 5)		t_f			μs
(I_C = 5 Adc, I_{B1} = 0.5 Adc, I_{B2} = 1.0 Adc)			—	1.25	
(I_C = 10 Adc, I_{B1} = 0.5 Adc, I_{B2} = 1.0 Adc)			—	1.5	

SAFE OPERATING AREAS

FIGURE 1 — MP1612

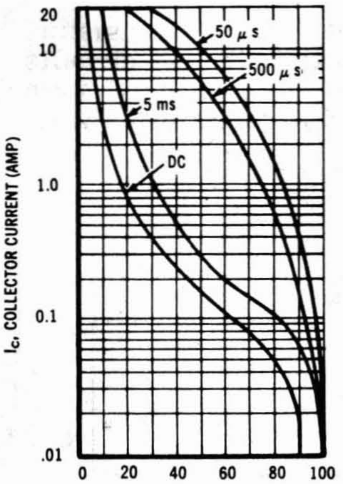


FIGURE 2 — MP1612A

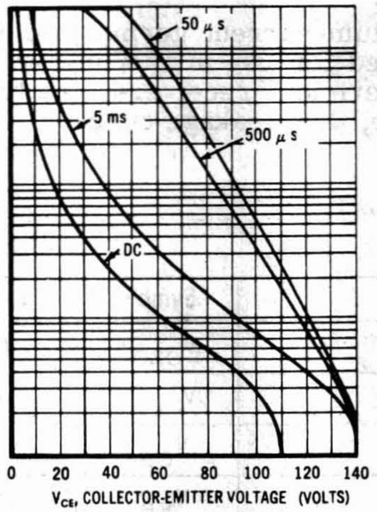
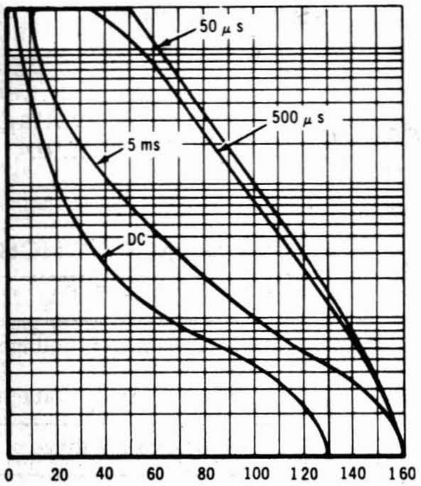
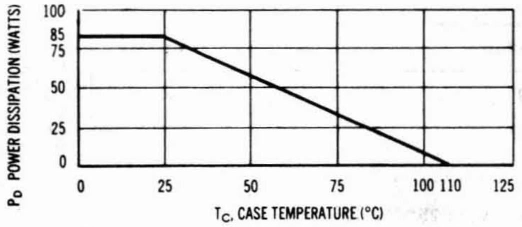


FIGURE 3 — MP1612B



The Safe Operating Area Curves indicate the I_C-V_{CE} limits below which the devices will not go into secondary breakdown. As secondary breakdown is independent of temperature and duty cycle, these curves can be used as long as the average power derating curve (Figure 4) is also taken into consideration to insure operation below the maximum junction temperature.

FIGURE 4 — POWER – TEMPERATURE DERATING CURVE



THESE TRANSISTORS ARE ALSO SUBJECT TO SAFE AREA CURVES AS INDICATED BY FIGURES 1, 2, 3.

FIGURE 5 — FALL TIME TEST CIRCUIT

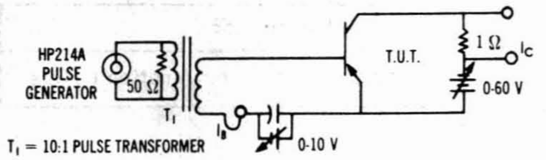
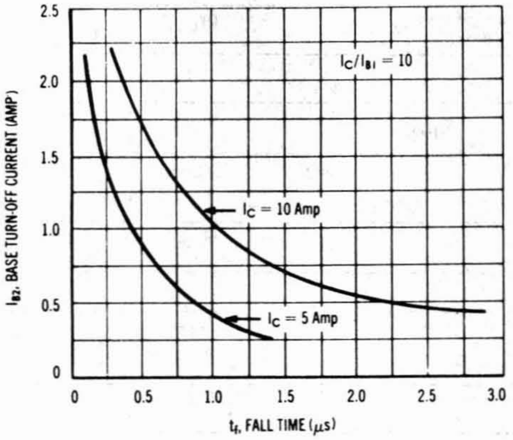
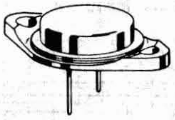

HP214A
PULSE
GENERATOR
50 Ω
T_1
I_B
0-10 V
T.U.T.
1 Ω
I_C
0-60 V
T_1 = 10:1 PULSE TRANSFORMER

FIGURE 6 — BASE TURN-OFF CURRENT versus FALL TIME



MP1613 (GERMANIUM)



CASE 11
(TO-3)

Medium-current germanium PNP power transistor, designed for use in 12 Volt vertical deflection circuits in television receivers; features: high breakdown voltage, low leakage current, and low saturation voltage.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	75	Vdc
Collector-Emitter Voltage	V_{CES}	90	Vdc
Collector-Base Voltage	V_{CB}	100	Vdc
Emitter-Base Voltage	V_{EB}	50	Vdc
Collector Current — Continuous — Peak	I_C	7.0 15	Adc Adc
Base Current — Continuous	I_B	2.0	Adc
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	85 1.0	Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110	°C

THERMAL CHARACTERISTICS

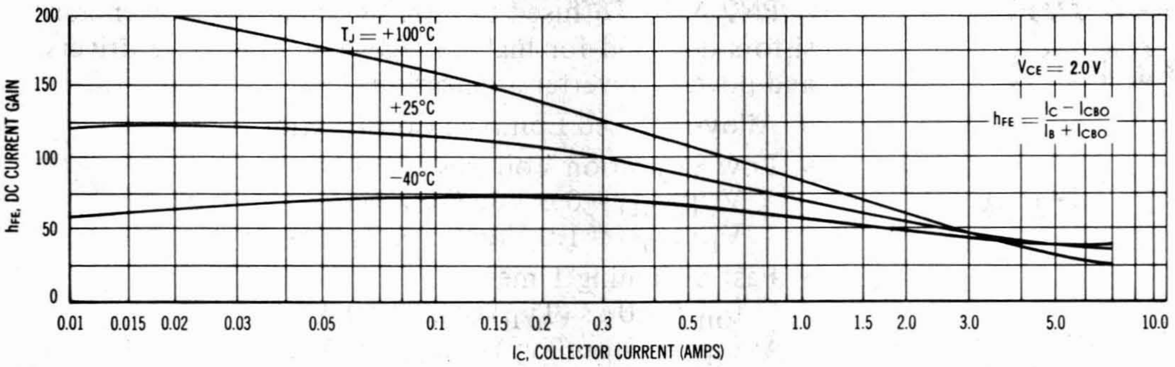
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.0	°C/W

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

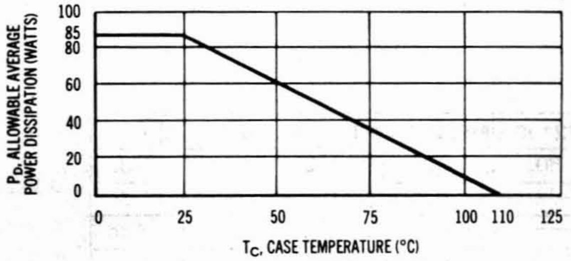
Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* ($I_C = 300$ mAdc, $I_B = 0$)	BV_{CEO}*	75	-	-	Vdc
Collector-Emitter Breakdown Voltage* ($I_C = 250$ mAdc, $V_{BE} = 0$)	BV_{CES}*	90	-	-	Vdc
Collector Cutoff Current ($V_{CE} = 37.5$ Vdc, $I_B = 0$)	I_{CEO}	-	-	30	mAdc
Collector Cutoff Current ($V_{CE} = 90$ Vdc, $V_{BE} = 1.0$ Vdc, $T_C = +100°C$)	I_{CEX}	-	-	10	mAdc
Collector Cutoff Current ($V_{CB} = 2.0$ Vdc, $I_E = 0$) ($V_{CB} = V_{CB}$ max, $I_E = 0$)	I_{CBO}	- -	- -	0.06 5.0	mAdc
Emitter Cutoff Current ($V_{BE} = 12$ Vdc, $I_C = 0$)	I_{EBO}	-	-	100	µAdc
ON CHARACTERISTICS					
DC Current Gain ($I_C = 50$ mAdc, $V_{CE} = 2.0$ Vdc) ($I_C = 1.0$ Adc, $V_{CE} = 2.0$ Vdc)	h_{FE}	- 40	120 70	200 -	-
Collector-Emitter Saturation Voltage ($I_C = 3.0$ Adc, $I_B = 300$ mAdc)	$V_{CE(sat)}$	-	-	0.25	Vdc

* Sweep Test: 1/2 sine wave, 60 Hz.

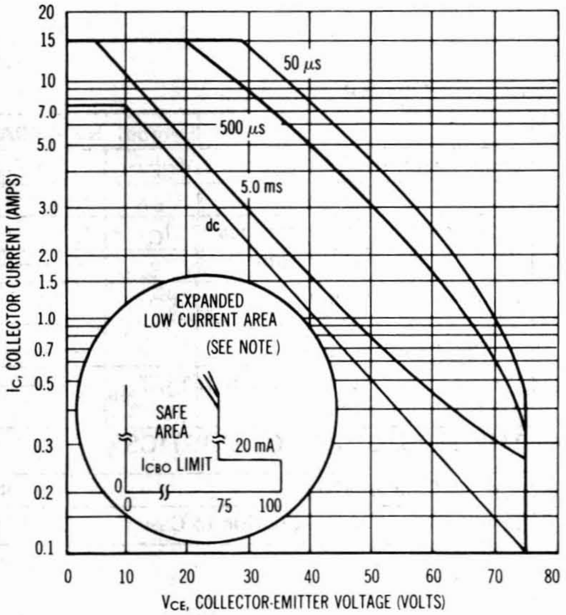
DC CURRENT GAIN versus COLLECTOR CURRENT



POWER-TEMPERATURE DERATING CURVE

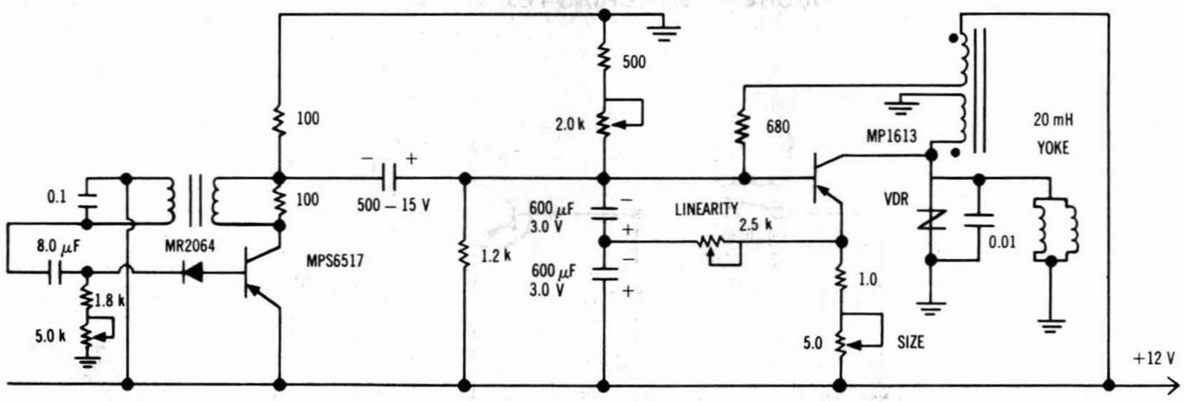


SAFE OPERATING AREAS



NOTE: — The Safe Operating Area Curves indicate I_C-V_{CE} limits below which the device will not go into secondary breakdown. Collector load lines for specific circuits must fall within the applicable Safe Area to avoid causing a collector-emitter short. (Case temperature and duty cycle of the excursions make no significant change in these safe areas.) The load line may exceed the BV_{CES} voltage limit only if the collector current has been reduced to 20 mA or less before or at the BV_{CES} limit; then and only then may the load line be extended to the absolute maximum voltage rating of BV_{CBO}. To insure operation below the maximum T_J, the power-temperature derating curve must be observed for both steady state and pulse power conditions.

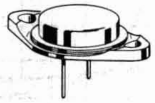
12 VOLT VERTICAL DEFLECTION CIRCUIT


500
2.0 k
100
100
680
MP1613
20 mH
YOKE
0.1
8.0 μF
MR2064
MPS6517
500 − 15 V
− +
1.2 k
600 μF
3.0 V
600 μF
3.0 V
LINEARITY
2.5 k
VDR
0.01
1.8 k
5.0 k
1.0
5.0
SIZE
+12 V

MP2000A (GERMANIUM)
MP2100A
MP2200A
MP2300A
MP2400A

PNP Alloy-Diffused Epitaxial Germanium power transistors designed for high-voltage switching, core drivers, and power converter applications.

- Alloy-Diffused Epitaxial Construction
- Low Saturation Voltages –
  $V_{CE(sat)}$ = 0.6 Vdc (Max) @ I_C = 25 Adc
  $V_{BE(sat)}$ = 1.0 Vdc (Max) @ I_C = 25 Adc
- Fast Switching Times –
  t_{on} = 9.0 μs (Typ) @ I_C = 10 Adc
  t_{off} = 17 μs (Typ) @ I_C = 10 Adc



Collector Connected To Case
CASE 11A
(TO-3 modified)

MAXIMUM RATINGS

Rating	Symbol	MP2000A	MP2100A	MP2200A	MP2300A	MP2400A	Unit
Collector-Emitter Voltage	V_{CEO}	30	60	80	100	120	Vdc
Emitter-Base Voltage	V_{EB}	2.0					Vdc
Collector Current-Continuous	I_C	25					Adc
Base Current – Continuous	I_B	5.0					Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	106 1.25					Watts W/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	–65 to +110					°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.8	°C/W

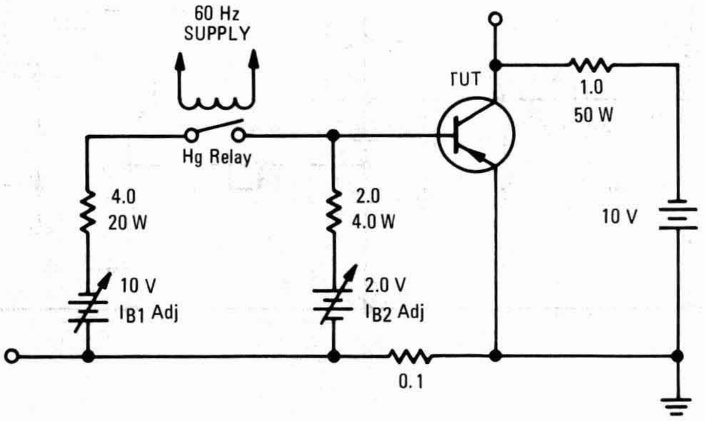


FIGURE 1 – SWITCHING TEST CIRCUIT

MP2000A, MP2100A, MP2200A, MP2300A, MP2400A (continued)

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

OFF CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 0.1 Adc, I_E = 0) MP2000A	BV_{CEO}	30	–	–	Vdc
MP2100A		60	–	–	
MP2200A		80	–	–	
MP2300A		100	–	–	
MP2400A		120	–	–	
Collector-Emitter Sustaining Voltage (Figure 2) (I_C = 8.0 Adc) MP2000A	$V_{CE(sus)}$	30	–	–	Vdc
MP2100A		60	–	–	
MP2200A		80	–	–	
MP2300A		100	–	–	
MP2400A		120	–	–	
(I_C = 25 Adc) MP2000A		30	–	–	
MP2100A, MP2200A, MP2300A		60	–	–	
MP2400A		80	–	–	
Emitter-Base Breakdown Voltage (I_E = 0.5 Adc, I_C = 0)	BV_{EBO}	2.0	–	–	Vdc
Collector Cutoff Current (V_{CE} = 60 Vdc, $V_{BE(off)}$ = 0.2 Vdc) MP2000A	I_{CEX}	–	–	10	mAdc
(V_{CE} = 60 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C) MP2000A		–	–	25	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc) MP2100A		–	–	10	
(V_{CE} = 80 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C) MP2100A		–	–	25	
(V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc) MP2200A		–	–	10	
(V_{CE} = 100 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C) MP2200A		–	–	25	
(V_{CE} = 120 Vdc, $V_{BE(off)}$ = 0.2 Vdc) MP2300A		–	–	10	
(V_{CE} = 120 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C) MP2300A		–	–	25	
(V_{CE} = 140 Vdc, $V_{BE(off)}$ = 0.2 Vdc) MP2400A		–	–	10	
(V_{CE} = 140 Vdc, $V_{BE(off)}$ = 0.2 Vdc, T_C = 85°C) MP2400A		–	–	25	
Collector Cutoff Current (V_{CB} = 2.0 Vdc, I_E = 0)	I_{CBO}	–	–	200	μAdc

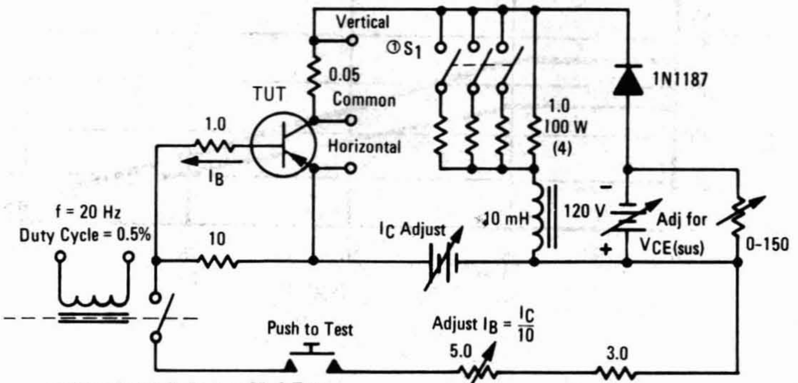
ON CHARACTERISTIC

Characteristic	Symbol	Min	Typ	Max	Unit
DC Current Gain (I_C = 8.0 Adc, V_{CE} = 2.0 Vdc)	h_{FE}	25	–	–	–
Collector-Emitter Saturation Voltage (I_C = 25 Adc, I_B = 2.5 Adc)	$V_{CE(sat)}$	–	–	0.6	Vdc
Base-Emitter Saturation Voltage (I_C = 25 Adc, I_B = 2.5 Adc)	$V_{BE(sat)}$	–	–	1.0	Vdc
Base-Emitter On Voltage (I_C = 8.0 Adc, V_{CE} = 2.0 Vdc)	$V_{BE(on)}$	–	–	0.8	Vdc

DYNAMIC CHARACTERISTICS

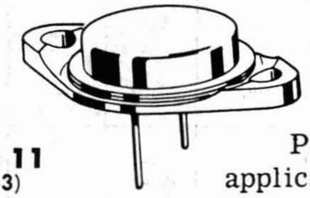
Characteristic	Symbol	Min	Typ	Max	Unit
Current-Gain—Bandwidth Product (I_C = 5.0 Adc, V_{CE} = 2.0 Vdc)	f_T	–	210	–	kHz
Turn-On Time (Figure 1) (I_C = 10 Adc, I_{B1} = I_{B2} = 1.0 Adc)	t_{on}	–	9.0	–	μs
Turn-Off Time (Figure 1) (I_C = 10 Adc, I_{B1} = I_{B2} = 1.0 Adc)	t_{off}	–	17	–	μs

FIGURE 2 – SUSTAINING VOLTAGE TEST CIRCUIT



① Close Switch S_1 for I_C = 25 A Test.

MP2060 thru MP2063 (GERMANIUM)

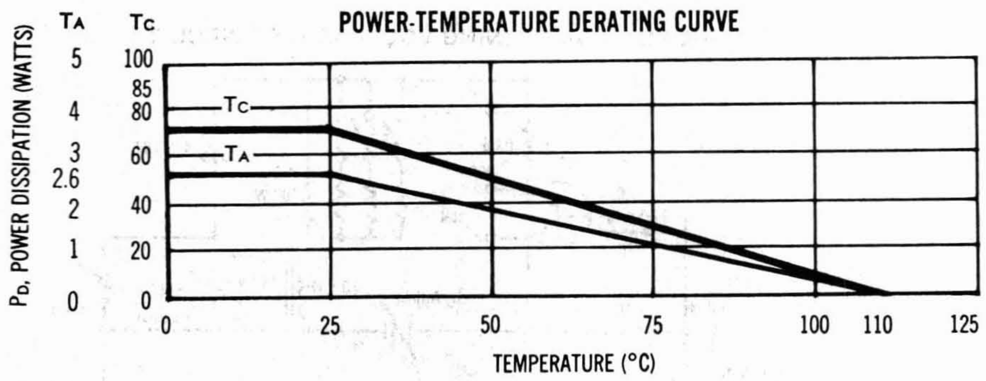


CASE 11
(TO-3)

PNP germanium power transistors for audio amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	MP2060	MP2061	MP2062	MP2063	Unit
Collector-Emitter Voltage	V_{CES}	30	45	60	75	Vdc
Collector-Emitter Voltage (Open Base)	V_{CEO}	25	35	50	60	Vdc
Collector-Base Voltage	V_{CB}	40	60	75	90	Vdc
Emitter-Base Voltage	V_{EB}	20				Vdc
Collector Current (Continuous)	I_C	7				Adc
Peak Collector Current (PW ≦ 5 ms)	I_C	15				Adc
Base Current (Continuous)	I_B	2				Adc
Storage Temperature	T_{stg}	-65 to +110				°C
Operating Case Temperature	T_C	-65 to +110				°C
Total Device Dissipation @T_C = 25°C Derate above 25°C	P_D	 77 1				 Watts W/°C
Thermal Resistance Junction to Case	θ_{JC}	1.0				°C/W
Thermal Resistance Case to Ambient	θ_{CA}	32.7				°C/W



ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristics		Symbol	Min	Typ	Max	Unit
DC Forward Current Gain (Note 1) (I_C = 3 Adc, V_{CE} = 2 Vdc)		h_{FE}	30	—	150	—
Current Gain-Bandwidth Product (I_C = 0.5 Adc, V_{CE} = 12 Vdc)		f_T	—	600	—	kc
Collector-Emitter Saturation Voltage (I_C = 3.0 Adc, I_B = 0.3 Adc)		$V_{CE(sat)}$	—	—	0.25	Vdc
Base-Emitter Saturation Voltage (I_C = 3.0 Adc, I_B = 0.3 Adc)		$V_{BE(sat)}$	—	—	0.70	Vdc
DC Transconductance (I_C = 3.0 Adc, V_{CE} = 2 Vdc)		g_{FE}	3.0	—	—	mhos
Collector-Emitter Breakdown Voltage* (I_C = 250 mAdc)	MP2060 MP2061 MP2062 MP2063	BV_{CES}*	30 45 60 75	— — — —	— — — —	Vdc
Collector-Emitter Sustaining Voltage* (I_C = 500 mAdc)	MP2060 MP2061 MP2062 MP2063	$BV_{CEO(sus)}$*	25 35 40 60	— — — —	— — — —	Vdc
Collector-Base Breakdown Voltage (I_C = 20 mAdc)	MP2060 MP2061 MP2062 MP2063	BV_{CBO}	40 60 75 90	— — — —	— — — —	Vdc
Collector-Base Cutoff Current (V_{CB} = 2 Vdc) (V_{CB} = 25 Vdc) (V_{CB} = 35 Vdc) (V_{CB} = 40 Vdc) (V_{CB} = 60 Vdc)	 MP2060 MP2061 MP2062 MP2063	I_{CBO}	— — — — —	— — — — —	0.060 1.0 1.0 1.0 1.0	mAdc
Collector-Emitter Cutoff Current (V_{CE} = 30 Vdc, $V_{BE(off)}$ = 1 Vdc, T_C = 100°C) (V_{CE} = 45 Vdc, $V_{BE(off)}$ = 1 Vdc, T_C = 100°C) (V_{CE} = 60 Vdc, $V_{BE(off)}$ = 1 Vdc, T_C = 100°C) (V_{CE} = 75 Vdc, $V_{BE(off)}$ = 1 Vdc, T_C = 100°C)	MP2060 MP2061 MP2062 MP2063	I_{CEX}	— — — —	— — — —	10 10 10 10	mAdc
Emitter-Base Cutoff Current (V_{BE} = 20 Vdc)		I_{EBO}	—	—	1.0	mAdc
Input Impedance (I_C = -500 mAdc, V_{CE} = -12 Vdc, i_b = 1 mAdc, f = 1 kHz)		h_{ie}	—	25	—	ohms
Distortion (I_C = -500 mAdc, V_{CE} = -12 Vdc, R_S = 30 ohms, R_L = 25 ohms, R_E (unbypassed) = 0.33 ohm, P_{out} = 2 watts)		η	—	3	—	%

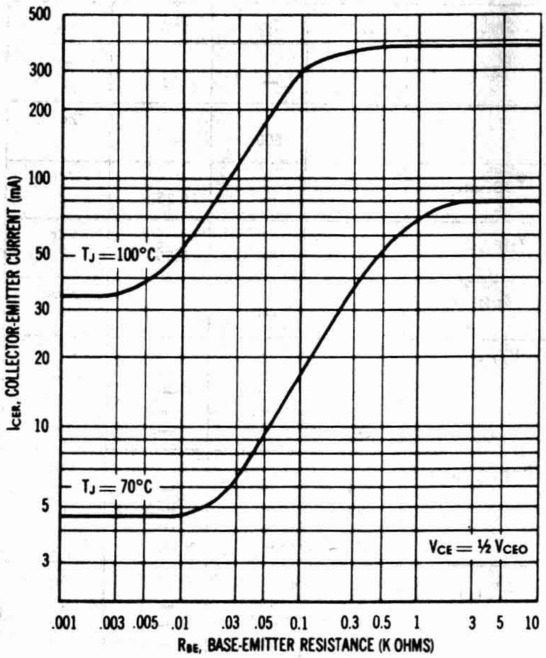
*Sweep Test: 1/2 sine wave, 60 Hz

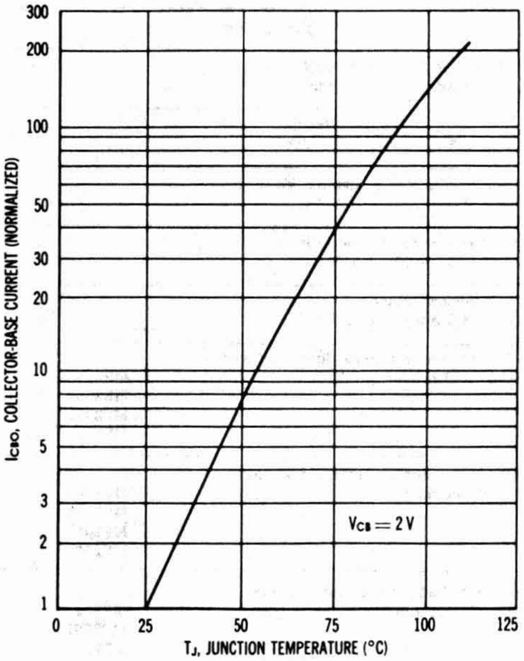
NOTE: upon customer's request the transistors will be numerically coded to identify matched pairs. The dc current transfer ratios are sorted into approximately 1:1.5 ranges. Any two devices within a bracket constitute a matched pair. No guarantee is made of gain distribution.

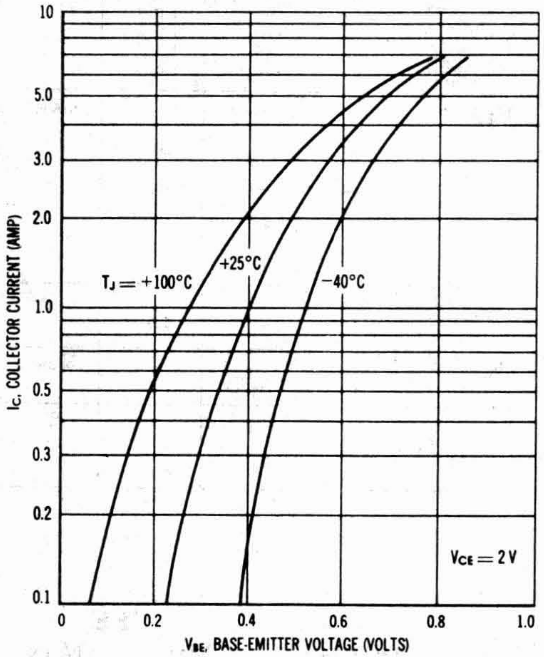
I_C = 3 Adc, V_{CE} = 2 Vdc

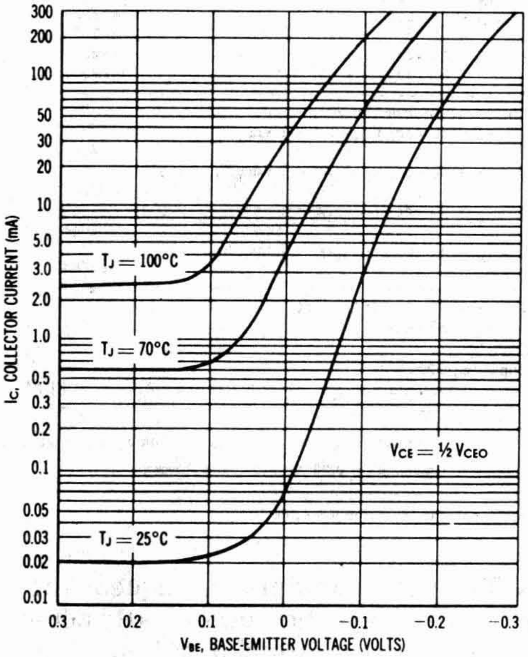
	h_{FE}	
Bracket	Min	Max
-1	30	45
-2	40	60
-3	50	75
-4	60	90
-5	80	120
-6	100	150

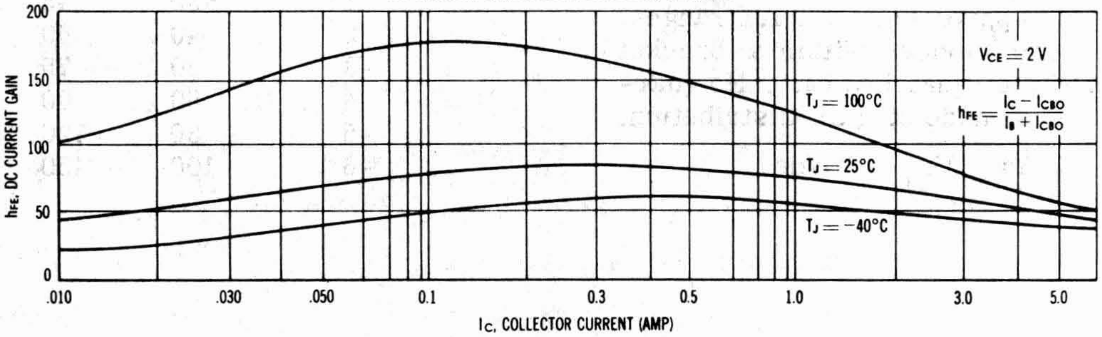
MP2060 thru MP2063 (continued)


COLLECTOR-EMITTER CURRENT versus BASE-EMITTER RESISTANCE


NORMALIZED COLLECTOR-BASE CURRENT

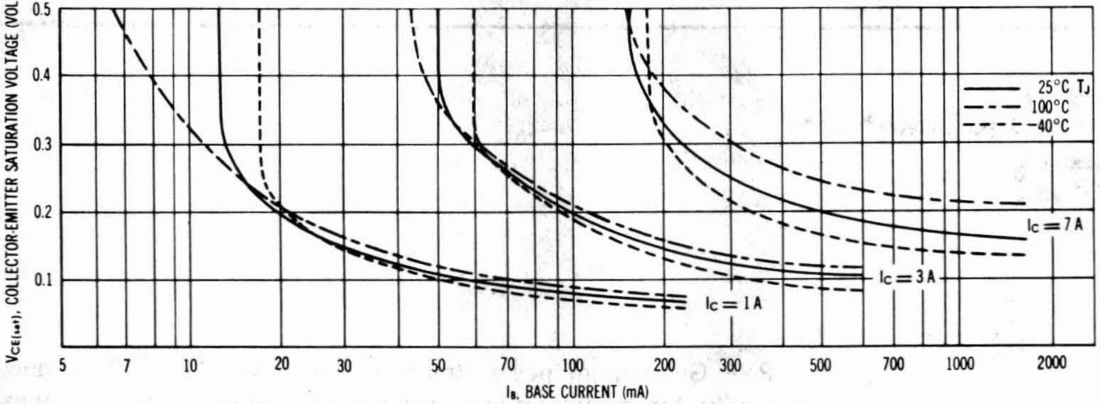

COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE


COLLECTOR CURRENT versus BASE-EMITTER VOLTAGE

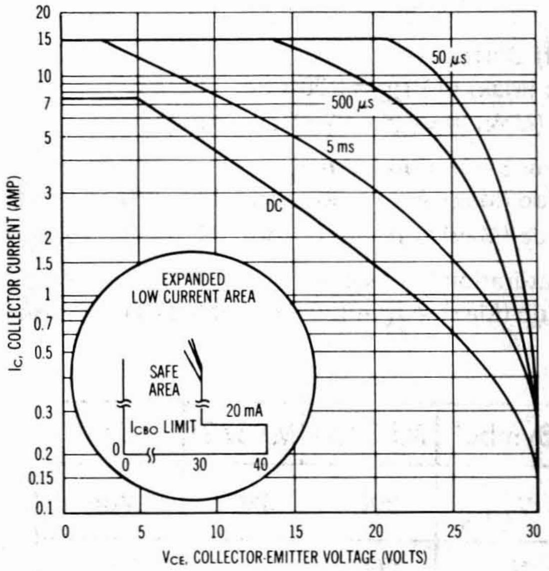

DC CURRENT GAIN versus COLLECTOR CURRENT

MP2060 thru MP2063 (continued)

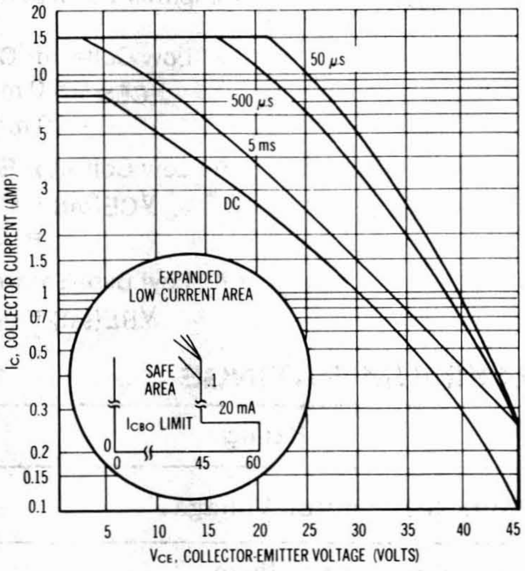
COLLECTOR-EMITTER SATURATION VOLTAGE VARIATIONS versus JUNCTION TEMPERATURE



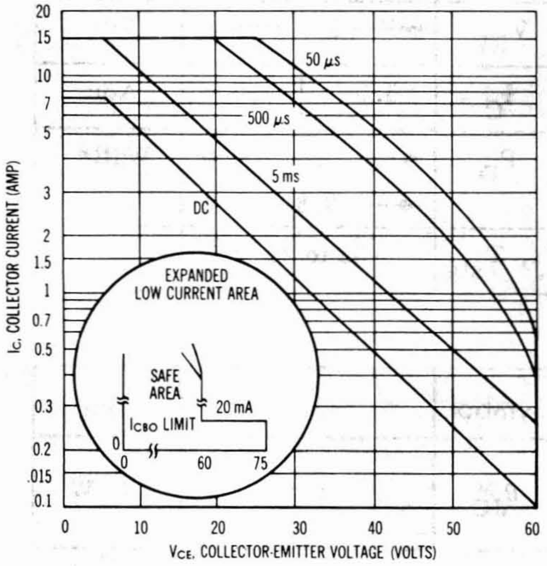
MP2060



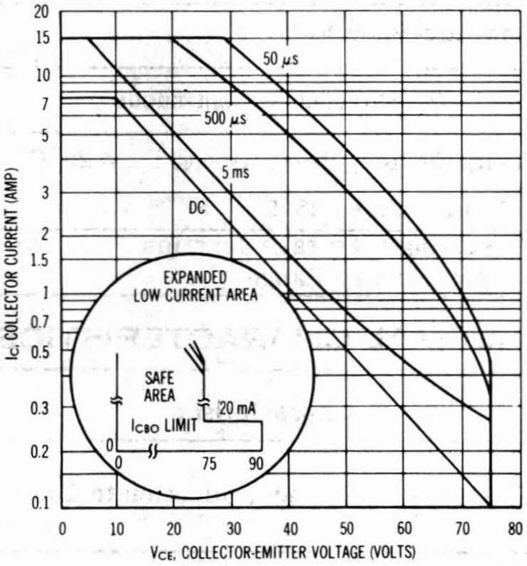
MP2061



MP2062



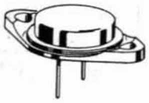
MP2063



MP2100A, MP2200A, MP2300A, MP2400A

For Specifications, See MP2000A Data.

MP3730 (GERMANIUM)
MP3731



Collector Connected to Case
CASE 11
(TO-3)

PNP Germanium power transistors with the MP3730 designed primarily for medium-power, vertical deflection amplifier applications in television receivers and the MP3731 designed for horizontal amplifier applications.

- Low Collector Cutoff Current –
  I_{CES} = 5.0 mAdc (Max) @ V_{CE} = 200 Vdc MP3730
  = 10 mAdc (Max) @ V_{CE} = 320 Vdc MP3731
- Low Collector Emitter Saturation Voltage –
  $V_{CE(sat)}$ = 0.5 Vdc (Max) @ I_C = 50 mAdc MP3730
  = 0.5 Vdc (Max) @ I_C = 6.0 Adc MP3731
- Low Base-Emitter Saturation Voltage –
  $V_{BE(sat)}$ = 0.8 Vdc (Max) @ I_C = 6.0 Adc MP3731

MAXIMUM RATINGS

Rating	Symbol	MP3730	MP3731	Unit
Collector-Emitter Voltage	V_{CES}	200	320	Vdc
Collector-Base Voltage	V_{CB}	200	320	Vdc
Emitter-Base Voltage	V_{EB}	← 2.0 →		Vdc
Collector Current – Continuous	I_C	5.0	10	Adc
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	← 56 → ← 0.67 →		Watts W/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-65 to +110		°C

THERMAL CHARACTERISTICS

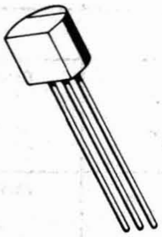
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	1.5	°C/W

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector Cutoff Current		I_{CES}			mAdc
(V_{CE} = 200 Vdc, V_{BE} = 0)	MP3730		-	5.0	
(V_{CE} = 320 Vdc, V_{BE} = 0)	MP3731		-	10	
Collector Cutoff Current		I_{CBO}			mAdc
(V_{CB} = 10 Vdc, I_E = 0)			-	0.4	
Emitter Cutoff Current		I_{EBO}			mAdc
(V_{BE} = 0.5 Vdc, I_C = 0)	MP3730		-	50	
(V_{BE} = 2.0 Vdc, I_C = 0)	MP3731		-	50	
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			-
(I_C = 50 mAdc, V_{CE} = 4.0 Vdc)	MP3730		10	200	
(I_C = 2.25 Adc, V_{CE} = 4.0 Vdc)	MP3730		15	-	
(I_C = 6.0 Adc, V_{CE} = 3.0 Vdc)	MP3731		15	-	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 50 mAdc, I_B = 5.0 mAdc)	MP3730		-	0.5	
(I_C = 2.25 Adc, I_B = 150 mAdc)	MP3730		-	0.75	
(I_C = 6.0 Adc, I_B = 400 mAdc)	MP3731		-	0.5	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			Vdc
(I_C = 6.0 Adc, I_B = 400 mAdc)	MP3731		-	0.8	
Base-Emitter On Voltage		$V_{BE(on)}$			Vdc
(I_C = 50 mAdc, V_{CE} = 4.0 Vdc)	MP3730		-	0.6	
DYNAMIC CHARACTERISTICS					
Current-Gain – Bandwidth Product		f_T			MHz
(I_C = 0.5 Adc, V_{CE} = 5.0 Vdc)			1.0	-	

MPF102 (SILICON)

Silicon N-channel junction field-effect transistor designed for VHF amplifier and mixer applications.



CASE 29(5)
(TO-92)

Drain and Source may be interchanged

MAXIMUM RATINGS (T_A = 25°C)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	25	Vdc
Gate-Source Voltage	V_{GS}	25	Vdc
Gate Current	I_G	10	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.82	mW mW/°C
Operating Junction Temperature	T_J	125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)	BV_{GSS}	25	—	Vdc
Gate Reverse Current (V_{GS} = 15 Vdc, V_{DS} = 0) (V_{GS} = 15 Vdc, V_{DS} = 0, T_A = 100 C)	I_{GSS}	— —	2.0 2.0	nAdc μAdc
Gate-Source Cutoff Voltage (V_{DS} = 15 Vdc, I_D = 2.0 nAdc)	$V_{GS(off)}$	—	8	Vdc
Gate-Source Voltage (V_{DS} = 15 Vdc, I_D = 0.2 mAdc)	V_{GS}	0.5	7.5	Vdc
ON CHARACTERISTICS				
Zero-Gate-Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0 Vdc)	I_{DSS}*	2	20	mAdc
DYNAMIC CHARACTERISTICS				
Forward Transfer Admittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 kHz)	$\|y_{fs}\|$*	2000	7500	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)	C_{iss}	—	7	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1 MHz)	C_{rss}	—	3	pF
Forward Transfer Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)	$\|y_{fs}\|$	1600	—	μmhos
Input Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)	$Re(y_{is})$	—	800	μmhos
Output Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)	$Re(y_{os})$	—	200	μmhos

*Pulse Test: Pulse Width ≲ 630 ms; Duty Cycle ≤ 10%

MPF 108 (SILICON)

SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

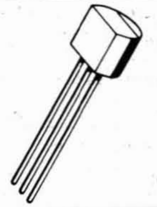
Depletion mode (Type A) transistor designed for VHF amplifier and mixer applications.

- Devices are Classified and Identified in 2:1 I_{DSS} Ranges
- Low Cross-Modulation and Intermodulation Distortion
- Guaranteed 100 MHz Parameters
- Drain and Source Interchangeable
- Low Transfer and Input Capacitance —
  C_{rss} = 1.2 pF (Typ) @ V_{DS} = 15 Vdc
  C_{iss} = 5.0 pF (Typ) @ V_{DS} = 15 Vdc
- Low Leakage Current
- Unibloc Plastic Encapsulated Package

JUNCTION FIELD-EFFECT TRANSISTOR

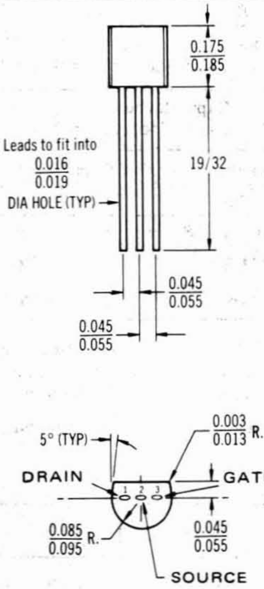
SYMMETRICAL SILICON N-CHANNEL

Type A



MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	25	Vdc
Gate-Source Voltage	V_{GS}	-25	Vdc
Forward Gate Current	$I_{G(f)}$	10	mAdc
Total Device Dissipation @ T_A = 25° C Derate above 25° C	P_D	310 2.82	mW mW/°C
Operating Junction Temperature Range	T_J	-65 to +135	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C


0.175
0.185
Leads to fit into
0.016
0.019
DIA HOLE (TYP)
19/32
0.045
0.055
0.045
0.055
5° (TYP)
0.003
0.013 R.
DRAIN
GATE
1 2 3
0.085
0.095 R.
0.045
0.055
SOURCE

CASE 29(5)
TO-92

Drain and Source may be Interchanged.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	-25	-	Vdc
Gate-Source Cutoff Voltage* (V_{DS} = 15 Vdc, I_D = 10 μAdc)	$V_{GS(off)}$*	0.5	8.0	Vdc
Gate Reverse Current (V_{GS} = -15 Vdc, V_{DS} = 0) (V_{GS} = -15 Vdc, V_{DS} = 0, T_A = 100°C)	I_{GSS}	- -	1.0 -1.0	nAdc μAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0)	I_{DSS}*	1.5	24	mAdc
SMALL-SIGNAL CHARACTERISTICS				
Forward Transadmittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	y_{fs}*	2000	7500	μmhos
Forward Transadmittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)	$\|y_{fs}\|$	1600	-	μmhos
Output Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	$\|y_{os}\|$	-	75	μmhos
Output Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)	$Re(y_{os})$	-	200	μmhos
Input Conductance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 100 MHz)	$Re(y_{is})$	-	800	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	-	6.5	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	-	2.5	pF
Common-Source Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_G = 1.0 Megohm, f = 1.0 kHz) (V_{DS} = 15 Vdc, V_{GS} = 0, R_G = 1.0 k ohm, f = 100 MHz)	NF	- -	2.5 3.0	dB

*To characterize these devices to narrower limits, regarding I_{DSS}, $V_{GS(off)}$ and y_{fs}, the entire production lot is tested and divided into color-coded groups, with each color dot representing a relatively small range compared with the total min-max limit of the whole distribution. The color codes and their associated limits are given in the following table.

When packaged for shipment, the colors are randomly selected and no specific color distribution is implied or guaranteed.

Color	I_{DSS}	$V_{GS(off)}$	y_{fs}
Orange	1.5 mAdc Min, 3.0 mAdc Max	0.5 Vdc Min, 5.0 Vdc Max	2000 to 6500 μmhos
Yellow	2.5 mAdc Min, 5.0 mAdc Max	0.5 Vdc Min, 5.0 Vdc Max	2000 to 6500 μmhos
Green	4.0 mAdc Min, 8.0 mAdc Max	1.0 Vdc Min, 7.0 Vdc Max	2500 to 7000 μmhos
Blue	7.0 mAdc Min, 14 mAdc Max	1.0 Vdc Min, 7.0 Vdc Max	2500 to 7000 μmhos
Violet	12 mAdc Min, 24 mAdc Max	2.0 Vdc Min, 8.0 Vdc Max	3000 to 7500 μmhos

MPF109 (SILICON)

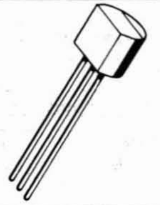
SILICON N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

Depletion mode (Type A) transistor designed for general-purpose audio and switching applications.

- Devices are Classified and Identified in 2:1 Zero-Gate Voltage Drain Current Ranges (2:1 I_{DSS} Ranges)
- Drain and Source Interchangeable
- High AC Input Impedance
- High DC Input Resistance
- Low Transfer and Input Capacitance
- Low Cross-Modulation and Intermodulation Distortion
- Unibloc Plastic Encapsulated Package

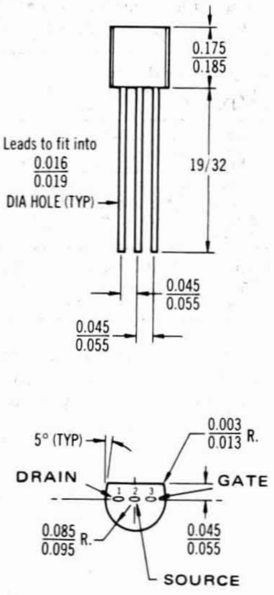
JUNCTION FIELD-EFFECT TRANSISTOR

SYMMETRICAL SILICON N-CHANNEL



MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	25	Vdc
Drain-Gate Voltage	V_{DG}	25	Vdc
Gate-Source Voltage	V_{GS}	-25	Vdc
Forward Gate Current	$I_{G(f)}$	10	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.82	mW mW/°C
Operating Junction Temperature Range	T_J	-65 to +135	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C


0.175
0.185
Leads to fit into
0.016
0.019
DIA HOLE (TYP)
19/32
0.045
0.055
0.045
0.055
5° (TYP)
0.003
0.013 R.
DRAIN
GATE
1 2 3
0.085
0.095 R.
0.045
0.055
SOURCE

CASE 29(5)
TO-92

Drain and Source may be Interchanged

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage (I_G = 10 μAdc, V_{DS} = 0)	$V_{(BR)GSS}$	-25	-	Vdc
Gate-Source Cutoff Voltage* (V_{DS} = 15 Vdc, I_D = 10 μAdc)	$V_{GS(off)}$*	0.2	8.0	Vdc
Gate Reverse Current (V_{GS} = -15 Vdc, V_{DS} = 0)	I_{GSS}	-	-1.0	nAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current* (V_{DS} = 15 Vdc, V_{GS} = 0)	I_{DSS}*	0.5	24	mAdc
SMALL-SIGNAL CHARACTERISTICS				
Forward Transadmittance* (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	y_{fs}*	800	6000	μmhos
Output Admittance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 kHz)	y_{os}	-	75	μmhos
Input Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{iss}	-	7.0	pF
Reverse Transfer Capacitance (V_{DS} = 15 Vdc, V_{GS} = 0, f = 1.0 MHz)	C_{rss}	-	3.0	pF
Common-Source Noise Figure (V_{DS} = 15 Vdc, V_{GS} = 0, R_G = 1.0 Megohm, f = 1.0 kHz)	NF	-	2.5	dB

*To characterize these devices to narrower limits, regarding I_{DSS}, $V_{GS(off)}$ and y_{fs}, the entire production lot is tested and divided into color-coded groups, with each color dot representing a relatively small range compared with the total min-max limit of the whole distribution. The color codes and their associated limits are given in the following table.

When packaged for shipment, the colors are randomly selected and no specific color distribution is implied or guaranteed.

MPF161 (SILICON)

P-channel junction field-effect transistors depletion mode (Type A) designed for general-purpose amplifier applications.

CASE 29 (7)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Drain-Source Voltage	V_{DS}	40	Vdc
Drain-Gate Voltage	V_{DG}	40	Vdc
Reverse Gate-Source Voltage	$V_{GS(r)}$	40	Vdc
Drain Current	I_D	20	mAdc
Forward Gate Current	$I_{G(f)}$	10	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.82	mW mW/°C
Storage Temperature Range	T_{stg}	-65 to +150	°C
Operating Junction Temperature Range	T_J	-65 to +135	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Gate-Source Breakdown Voltage ($I_G = 10\ \mu Adc$, $V_{DS} = 0$)	$V_{(BR)GSS}$	40	-	Vdc
Gate-Source Cutoff Voltage* ($V_{DS} = 15$ Vdc, $I_D = 1.0\ \mu Adc$)	$V_{GS(off)}$*	0.2	8.0	Vdc
Gate Reverse Current ($V_{GS} = 30$ Vdc, $V_{DS} = 0$)	I_{GSS}	-	10	nAdc
ON CHARACTERISTICS				
Zero-Gate Voltage Drain Current* ($V_{DS} = 15$ Vdc, $V_{GS} = 0$)	I_{DSS}*	0.5	14	mAdc
SMALL-SIGNAL CHARACTERISTICS				
Forward Transadmittance* ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1.0 kHz)	$\lvert y_{fs} \rvert$*	800	6000	µmhos
Output Admittance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1.0 kHz)	$\lvert y_{os} \rvert$	-	75	µmhos
Input Capacitance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1.0 MHz)	C_{iss}	-	7.0	pF
Reverse Transfer Capacitance ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1.0 MHz)	C_{rss}	-	2.0	pF
Common-Source Noise Figure ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, $R_G = 1.0$ M ohm, f = 1.0 kHz, BW = 1.0 Hz)	NF	-	2.5	dB
Equivalent Short-Circuit Input Noise Voltage ($V_{DS} = 15$ Vdc, $V_{GS} = 0$, f = 1.0 kHz, BW = 1.0 Hz)	e_n	-	115	nV/$\sqrt{Hz}$

*To characterize these devices to narrower limits, regarding $V_{GS(off)}$, I_{DSS} and $\lvert y_{fs} \rvert$, the entire production lot is tested and divided into color-coded groups, with each color dot representing a relatively small range compared with the total min-max limit of the whole distribution. The color codes and their associated limits are given in the following table.

When packaged for shipment, the colors are randomly selected and no specific color distribution is implied or guaranteed.

Color	$V_{GS(off)}$	I_{DSS}	$\lvert y_{fs} \rvert$
White	0.2 Vdc Min, 2.0 Vdc Max	0.5 mAdc Min, 1.0 mAdc Max	800 to 3200 µmhos
Red	0.4 Vdc Min, 4.0 Vdc Max	0.8 mAdc Min, 1.6 mAdc Max	1000 to 4000 µmhos
Orange	0.4 Vdc Min, 4.0 Vdc Max	1.5 mAdc Min, 3.0 mAdc Max	1000 to 4000 µmhos
Yellow	1.0 Vdc Min, 6.0 Vdc Max	2.5 mAdc Min, 5.0 mAdc Max	1500 to 5000 µmhos
Green	1.0 Vdc Min, 6.0 Vdc Max	4.0 mAdc Min, 8.0 mAdc Max	1500 to 5000 µmhos
Blue	2.0 Vdc Min, 8.0 Vdc Max	7.0 mAdc Min, 14 mAdc Max	2000 to 6000 µmhos

DRAIN CURRENT versus GATE-SOURCE VOLTAGE

FIGURE 1

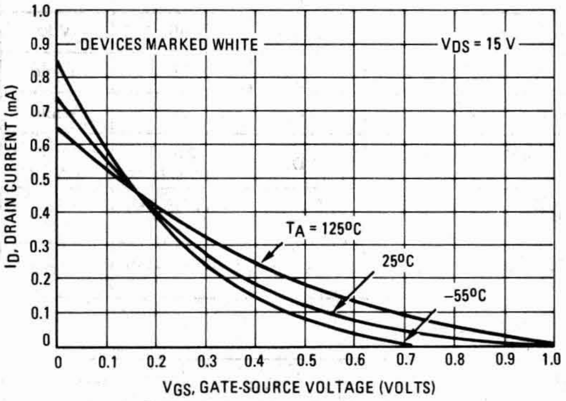


FIGURE 2

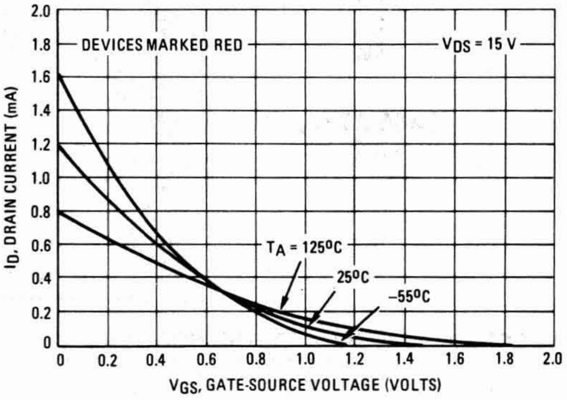


FIGURE 3

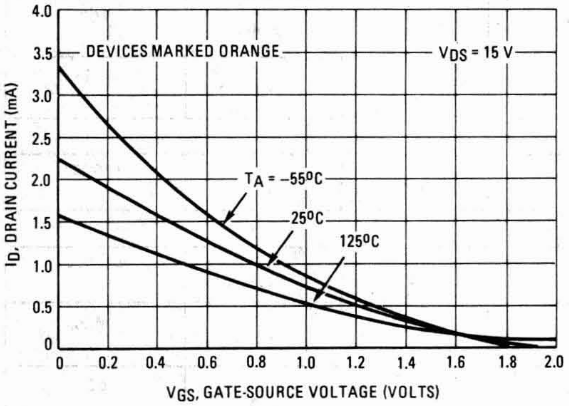


FIGURE 4

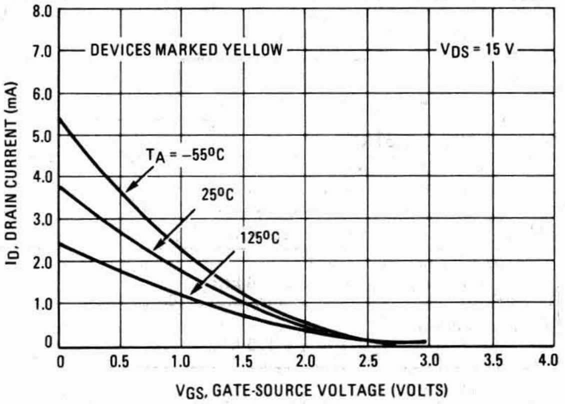


FIGURE 5

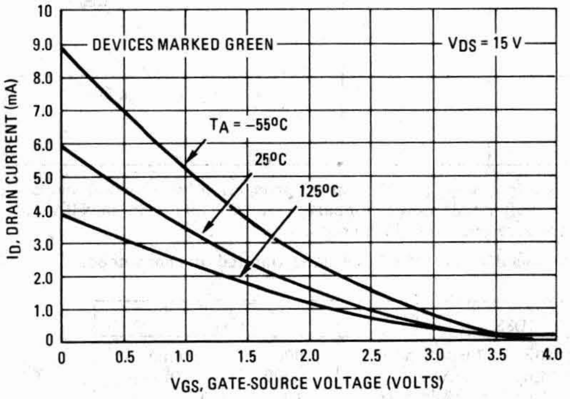


FIGURE 6

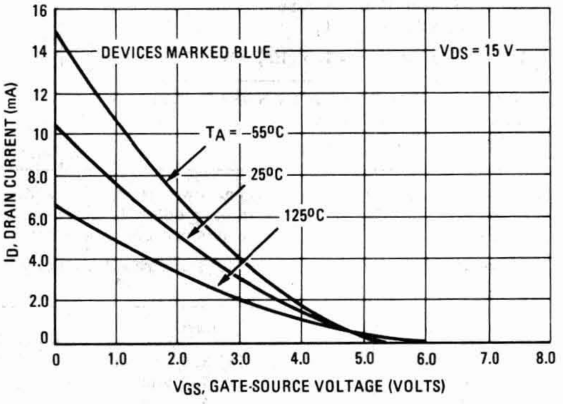


FIGURE 7 – OUTPUT RESISTANCE versus DRAIN CURRENT

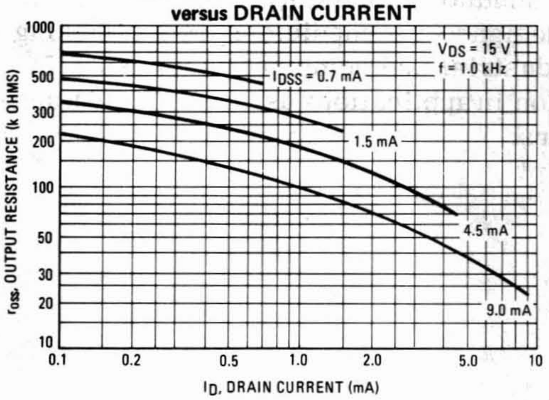


FIGURE 8 – NORMALIZED TRANSADMITTANCE versus NORMALIZED DRAIN CURRENT

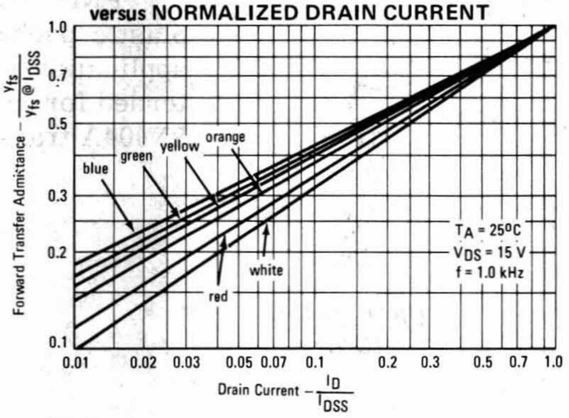


FIGURE 9 – NOISE FIGURE versus FREQUENCY

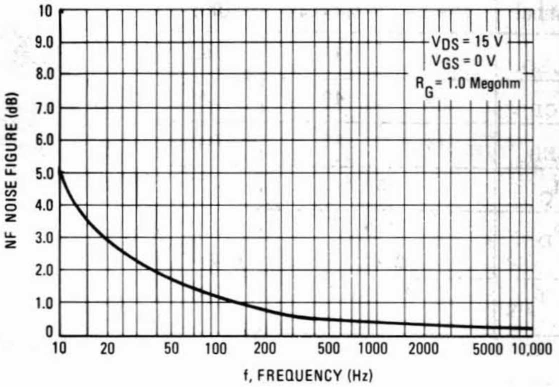


FIGURE 10 – NOISE FIGURE versus SOURCE RESISTANCE

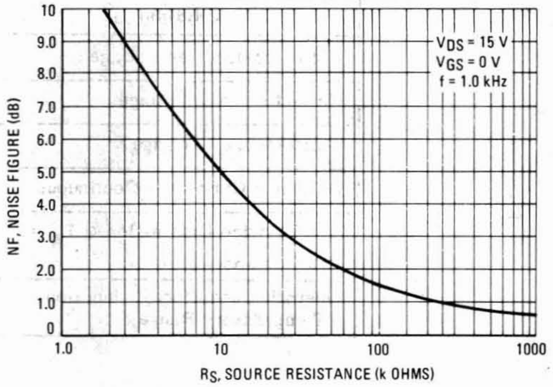
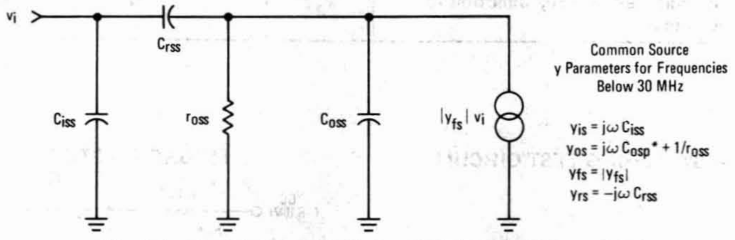


FIGURE 11 – EQUIVALENT LOW FREQUENCY CIRCUIT


vi
Crss
Ciss
ross
Coss
|yfs| vi
Common Source
y Parameters for Frequencies
Below 30 MHz

$y_{is} = j\omega C_{iss}$

$y_{os} = j\omega C_{osp}{}^{*} + 1/r_{oss}$

$y_{fs} = |y_{fs}|$

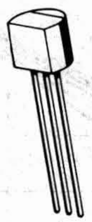
$y_{rs} = -j\omega C_{rss}$

*C_{osp} is C_{oss} in parallel with Series Combination of C_{iss} and C_{rss}.

NOTE:

Graphical data is presented for dc conditions. Tabular data is given for pulsed conditions (Pulse Width = 630 ms, Duty Cycle = 10%). Under dc conditions, self heating in higher I_{DSS} units reduces I_{DSS}.

MPS404 (SILICON)
MPS404A



CASE 29 (1)
(TO-92)

PNP silicon annular transistors encapsulated in plastic package designed for medium-speed switching applications in industrial and computer equipment. Intended for operation in applications using the 2N404 and 2N404A transistors.

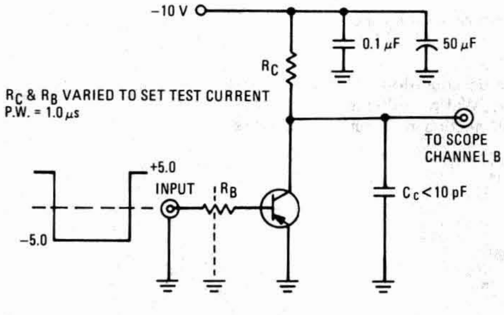
MAXIMUM RATINGS

Rating	Symbol	MPS404	MPS404A	Unit
Collector-Emitter Voltage	V_{CEO}	24	35	Vdc
Collector-Base Voltage	V_{CB}	25	40	Vdc
Emitter-Base Voltage	V_{EB}	12	25	Vdc
Collector Current — Continuous	I_C	150		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

THERMAL CHARACTERISTICS

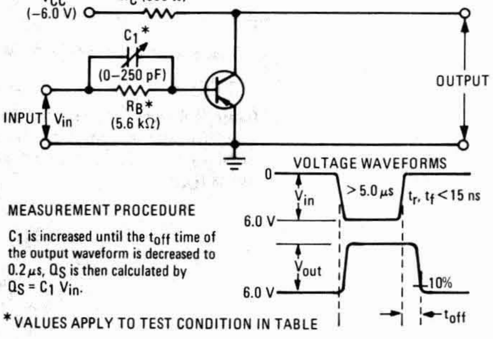
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

FIGURE 1 – SWITCHING TEST CIRCUIT


−10 V
0.1 μF
50 μF
RC
TO SCOPE
CHANNEL B
+5.0
INPUT
RB
−5.0
Cc<10 pF

RC & RB VARIED TO SET TEST CURRENT
P.W. = 1.0 μs

FIGURE 2 – STORED BASE CHARGE TEST CIRCUIT


VCC
(−6.0 V)
R*C (560 Ω)
C1*
(0–250 pF)
RB*
(5.6 kΩ)
INPUT
Vin
OUTPUT
VOLTAGE WAVEFORMS
0
Vin
> 5.0 μs
tr, tf < 15 ns
6.0 V
Vout
6.0 V
10%
toff

MEASUREMENT PROCEDURE

C_1 is increased until the t_{off} time of the output waveform is decreased to 0.2 μs, Q_S is then calculated by $Q_S = C_1 V_{in}$.

*VALUES APPLY TO TEST CONDITION IN TABLE

MPS404, MPS404A (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, I_B = 0) MPS404 MPS404A	BV_{CEO}	 24 35	 - -	 - -	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0) MPS404 MPS404A	BV_{CBO}	 25 40	 - -	 - -	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0) MPS404 MPS404A	BV_{EBO}	 12 25	 - -	 - -	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)	I_{CBO}	-	-	100	nAdc
Emitter Cutoff Current (V_{BE} = 10 Vdc, I_C = 0)	I_{EBO}	-	-	100	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 12 mAdc, V_{CE} = 0.15 Vdc)	h_{FE}	30	-	400	-
Collector-Emitter Saturation Voltage (I_C = 12 mAdc, I_B = 0.4 mAdc) (I_C = 24 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	 - -	 - -	 0.15 0.20	Vdc
Base-Emitter Saturation Voltage (I_C = 12 mAdc, I_B = 0.4 mAdc) (I_C = 24 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$	 - -	 - -	 0.85 1.0	Vdc
DYNAMIC CHARACTERISTICS					
Common-Base Cutoff Frequency (I_C = 1.0 mAdc, V_{CB} = 6.0 Vdc)	$f_{\alpha b}$	4.0	-	-	MHz
Output Capacitance (V_{CB} = 6.0 Vdc, I_E = 0)	C_{ob}	-	-	20	pF
SWITCHING CHARACTERISTICS					
Delay Time — (I_C = 10 mAdc, I_{B1} = 1.0 mAdc) (Figure 1)	t_d	-	75	-	ns
Rise Time	t_r	-	190	-	ns
Storage Time — (I_C = 10 mAdc, I_{B1} = I_{B2} = 1.0 mAdc) (Figure 1)	t_s	-	155	-	ns
Fall Time	t_f	-	230	-	ns
Total Control Charge (Figure 2) (I_C = 10 mAdc, I_B = 1.0 mAdc)	Q_S	-	-	1400	pC

FIGURE 3 – BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT

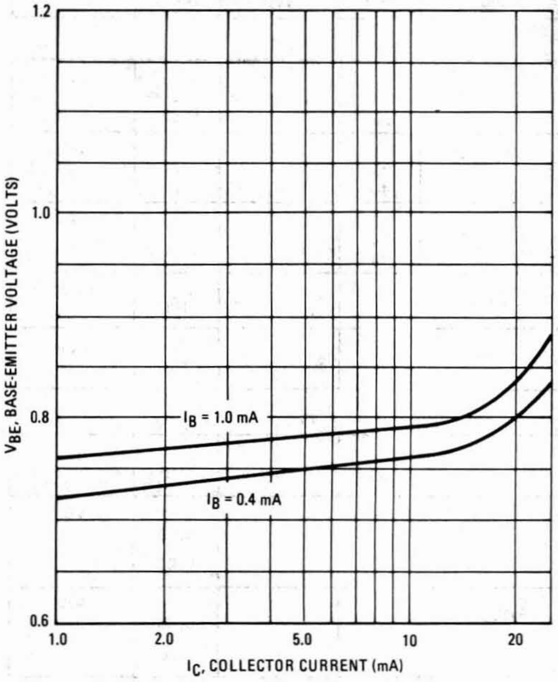


FIGURE 4 – BASE-EMITTER VOLTAGE versus TEMPERATURE

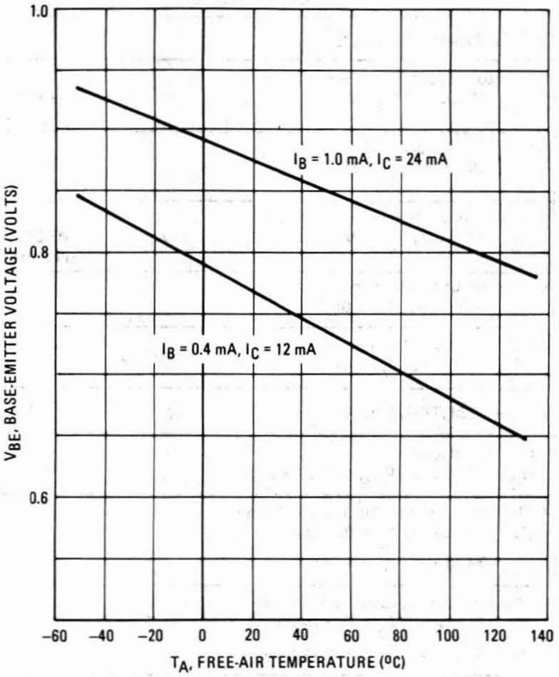


FIGURE 5 – COLLECTOR-EMITTER VOLTAGE versus COLLECTOR CURRENT

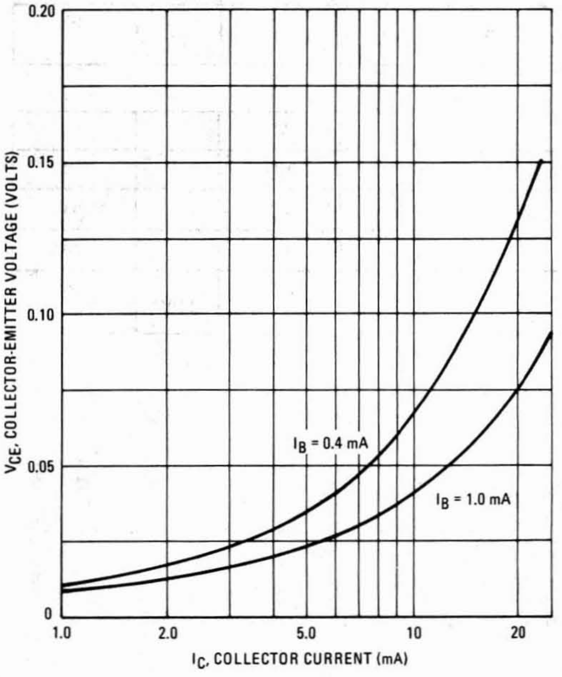


FIGURE 6 – COLLECTOR-EMITTER VOLTAGE versus TEMPERATURE

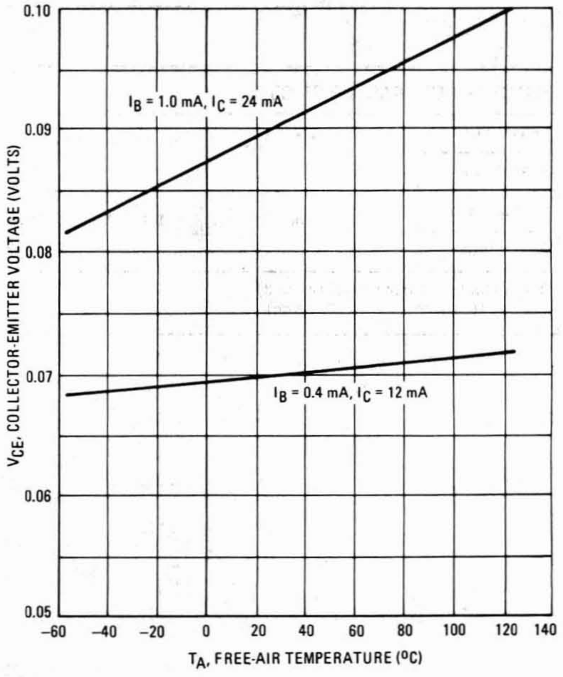


FIGURE 7 – NORMALIZED DC CURRENT GAIN

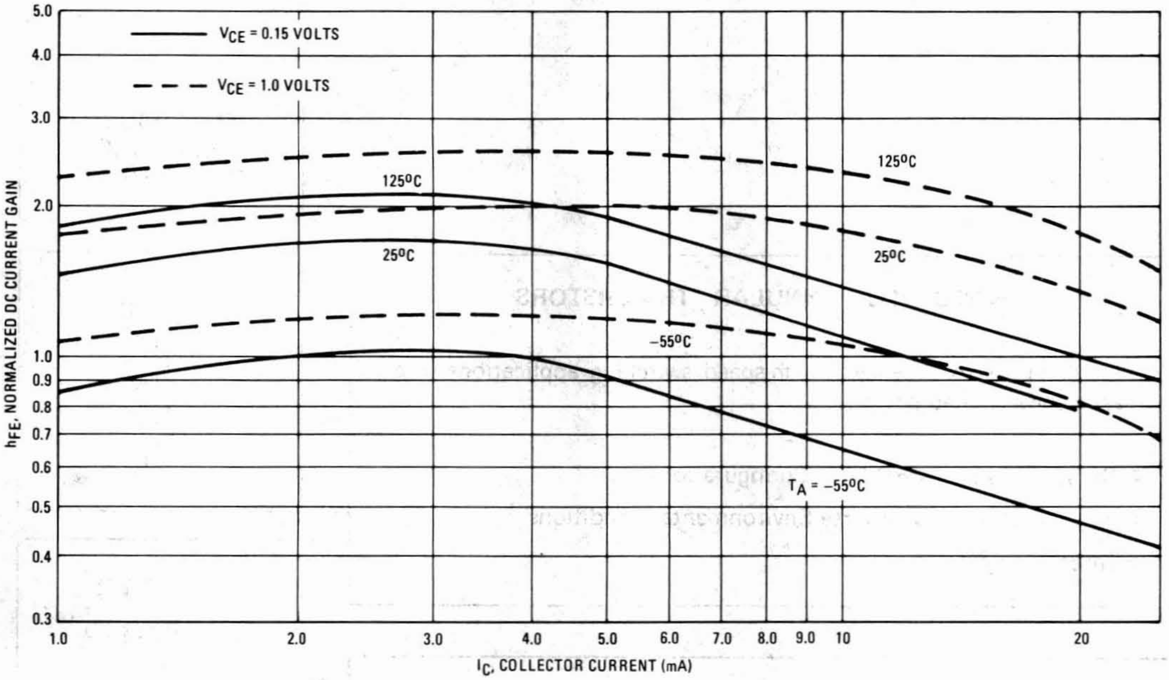


FIGURE 8 – COMMON-BASE CAPACITANCE

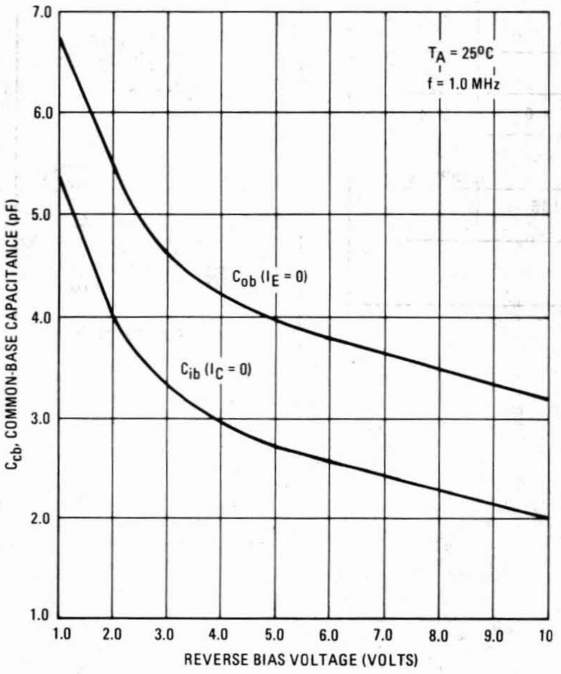
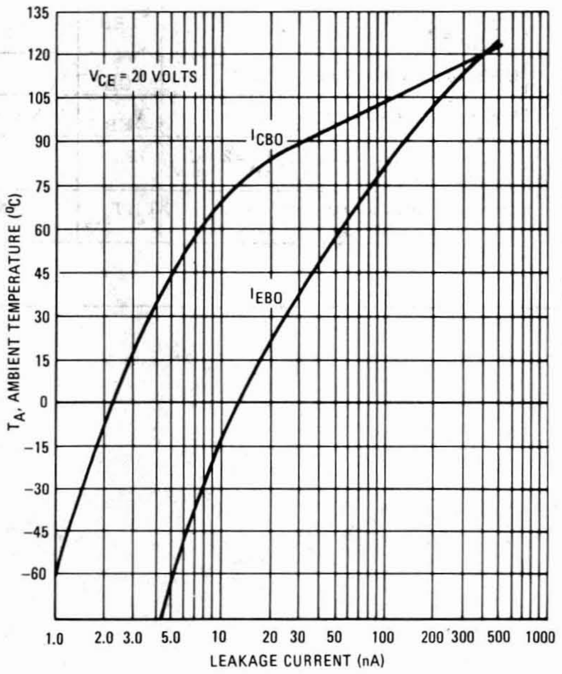


FIGURE 9 – TEMPERATURE versus LEAKAGE CURRENT



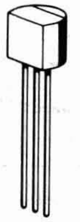
MPS 706 (SILICON)
MPS 706A

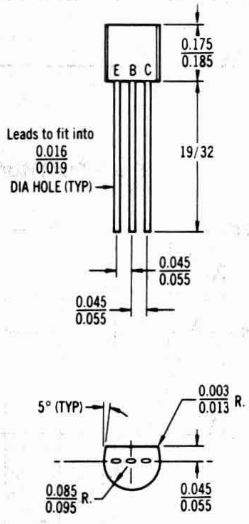
NPN SILICON SWITCHING TRANSISTORS

NPN SILICON ANNULAR TRANSISTORS

. . . designed for low-level, high-speed switching applications in a plastic encapsulated package.

- Standard In-Line EBC Lead Configurations
- High Resistance to Adverse Environmental Conditions
- Insensitivity to Light




E B C
0.175
0.185
Leads to fit into
0.016
0.019
DIA HOLE (TYP)
19/32
0.045
0.055
0.045
0.055
5° (TYP)
0.003
0.013 R.
0.085
0.095 R.
0.045
0.055

CASE 29(1)
TO-92

MAXIMUM RATINGS

Rating	Symbol	MPS706	MPS706A	Unit
Collector-Emitter Voltage (R_{BE} = 10 Ohms)	V_{CER}	20		Vdc
Collector-Base Voltage	V_{CB}	25		Vdc
Emitter-Base Voltage	V_{EB}	3.0	5.0	Vdc
Total Device Dissipation@ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

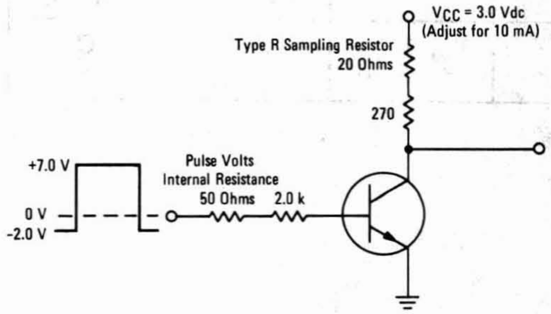
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)		BV_{CEO}*	15	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 mAdc, R_{BE} = 10 Ohms)		BV_{CER}	20	-	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)		I_{CBO}	-	0.5	μAdc
Emitter Cutoff Current (V_{EB} = 3.0 Vdc, I_C = 0)		I_{EBO}	-	10	μAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	MPS706 MPS706A	h_{FE}*	20 20	- 60	-
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)		$V_{CE(sat)}$*	-	0.6	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)	MPS706 MPS706A	$V_{BE(sat)}$*	- 0.7	0.9 0.9	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product (I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 100 MHz)		f_T	200	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	6.0	pF
Base Resistance (I_E = 10 mAdc, V_{CE} = 15 Vdc, f = 300 MHz)		r'_b	-	50	Ohms
SWITCHING CHARACTERISTICS					
Turn-On Time (See Figure 1)		t_{on}**	-	40	ns
Turn-Off Time (See Figure 1)		t_{off}**	-	75	ns
Charge Storage Time Constant** (See Figure 2)	MPS706 MPS706A	τ_s**	- -	60 25	ns

*Pulse Test: Pulse Width ≤ 12 ns, Duty Cycle ≤ 2.0%.

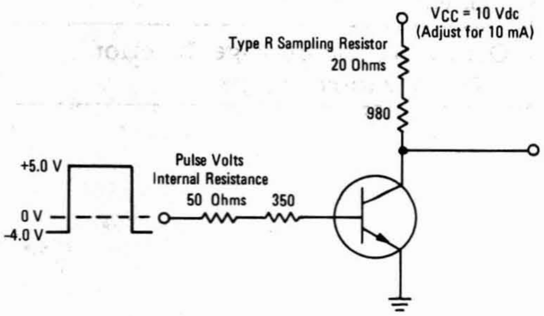
**Measured with Tektronix Type R Plug-In (50-Ohm Internal Impedance) and circuits shown.

FIGURE 1 – SWITCHING TIME TEST CIRCUIT



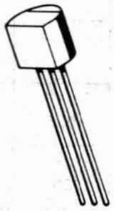
V_{CC} = 3.0 Vdc
(Adjust for 10 mA)
Type R Sampling Resistor
20 Ohms
270
+7.0 V
0 V
-2.0 V
Pulse Volts
Internal Resistance
50 Ohms
2.0 k

FIGURE 2 – STORAGE TIME TEST CIRCUIT



V_{CC} = 10 Vdc
(Adjust for 10 mA)
Type R Sampling Resistor
20 Ohms
980
+5.0 V
0 V
-4.0 V
Pulse Volts
Internal Resistance
50 Ohms
350

MPS834 (SILICON)



NPN silicon annular transistor designed for high-speed switching applications.

CASE 29 (1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CES}	30	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	500 4.55	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

MPS834 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

CHARACTERISTICS	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0)	I_{CES}	-	10	μAdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	-	0.5	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}*	25	-	-
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)	$V_{CE(sat)}$*	- -	0.25 0.4	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$*	-	0.9	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain–Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	350	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	4.0	pF
SWITCHING CHARACTERISTICS				
Turn-On Time (I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc) See Figure 1	t_{on}	-	16	ns
Turn-Off Time (I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.0 mAdc) See Figure 1	t_{off}	-	30	ns
Storage Time (I_C = 10 mAdc, I_{B1} = I_{B2} = 10 mAdc) See Figure 2	t_s	-	25	ns

*Pulse Test: Pulse Width ≤ 12 ns, Duty Cycle ≤ 2.0%.

FIGURE 1 – TURN-ON AND TURN-OFF TIME MEASUREMENT CIRCUIT

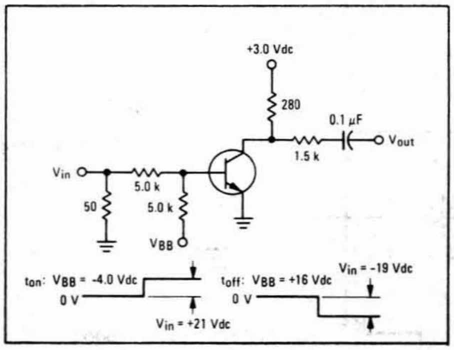
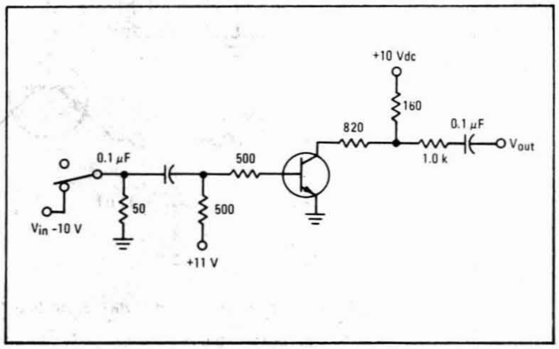
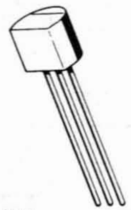

+3.0 Vdc
280
0.1 μF
Vout
1.5 k
Vin
5.0 k
50
5.0 k
VBB
ton: VBB = -4.0 Vdc
0 V
Vin = +21 Vdc
toff: VBB = +16 Vdc
Vin = -19 Vdc
0 V

FIGURE 2 – CHARGE STORAGE TIME CONSTANT MEASUREMENT CIRCUIT


+10 Vdc
160
820
0.1 μF
Vout
1.0 k
0.1 μF
500
50
500
Vin -10 V
+11 V

NOTE: ALL SWITCHING TIMES MEASURED WITH LUMATRON MODEL 420 SWITCHING TIME TEST SET OR EQUIVALENT.

MPS918 (SILICON)
MPS3563



CASE 29(1)
(TO-92)

NPN silicon annular, plastic encapsulated transistors for low-cost amplifier and oscillator applications at VHF and UHF.

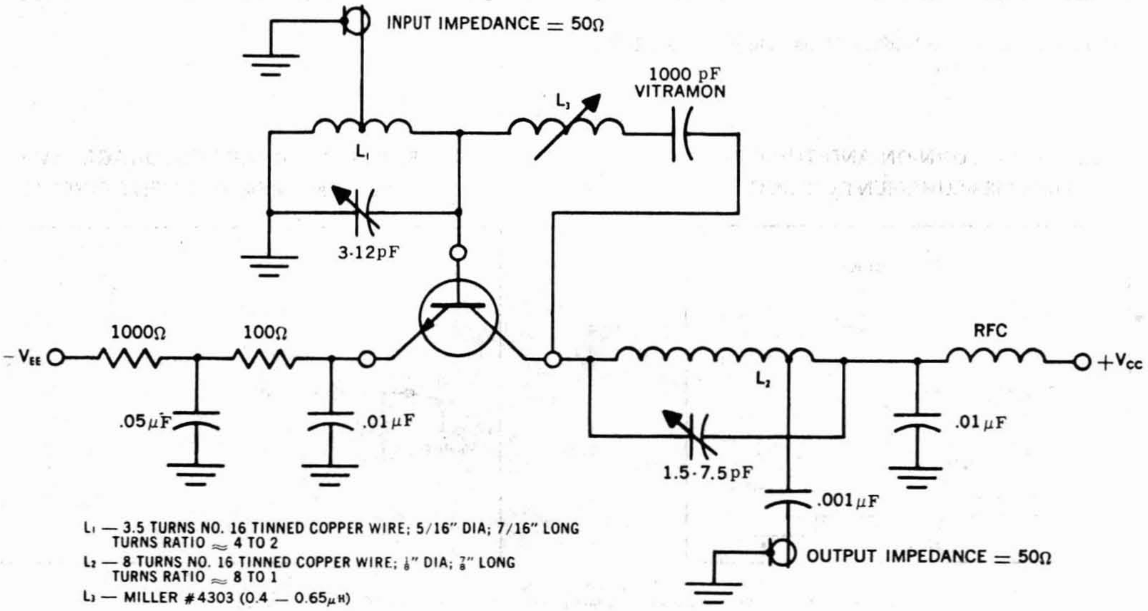
MAXIMUM RATINGS

Rating	Symbol	MPS918	MPS3563	Unit
Collector-Base Voltage	V_{CB}	30	30	Volts
Collector-Emitter Voltage	V_{CEO}	15	12	Volts
Emitter-Base Voltage	V_{EB}	3.0	2.0	Volts
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	310 2.81		mW mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	^oC/mW

200 MC POWER GAIN TEST CIRCUIT


INPUT IMPEDANCE = 50Ω
1000 pF
VITRAMON
L₃
L₁
3-12pF
1000Ω
100Ω
RFC
−V_EE
+V_CC
.05μF
.01μF
L₂
.01μF
1.5-7.5pF
.001μF
OUTPUT IMPEDANCE = 50Ω

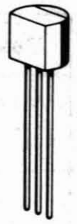
L_1 — 3.5 TURNS NO. 16 TINNED COPPER WIRE; 5/16" DIA; 7/16" LONG
TURNS RATIO ≈ 4 TO 2
L_2 — 8 TURNS NO. 16 TINNED COPPER WIRE; $\frac{1}{8}$" DIA; $\frac{7}{8}$" LONG
TURNS RATIO ≈ 8 TO 1
L_3 — MILLER #4303 (0.4 — 0.65μH)

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current	MPS918	I_{CBO}	–	10	nA
V_{CB} = 15V, I_E = 0	MPS3563		–	50	
Collector-Base Breakdown Voltage		BV_{CBO}			Volts
I_C = 1.0 μA, I_E = 0	MPS918		30	–	
I_C = 100 μA, I_E = 0	MPS3563		30	–	
Emitter-Base Breakdown Voltage		BV_{EBO}			Volts
I_E = 10 μA, I_C = 0	MPS918		3.0	–	
	MPS3563		2.0	–	
Collector-Emitter Voltage*		BV_{CEO*}			Volts
I_C = 3.0 mA, I_E = 0	MPS918		15	–	
	MPS3563		12	–	
DC Current Gain*		h_{FE*}			—
V_{CE} = 1V, I_C = 3mA	MPS918		20	–	
V_{CE} = 10V, I_C = 8mA	MPS3563		20	200	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Volts
I_C = 10mA, I_B = 1mA	MPS918		–	0.4	
Base-Emitter Saturation Voltage		$V_{BE(sat)}$			Volts
I_C = 10mA, I_B = 1mA	MPS918		–	1.0	
Small Signal Current Gain		h_{fe}			—
I_C = 4mA, V_{CE} = 10V, f = 100 MHz	MPS918		6.0	–	
I_C = 8mA, V_{CE} = 10V, f = 100 MHz	MPS3563		6.0	15	
I_C = 8mA, V_{CE} = 10V, f = 1 kHz	MPS3563		20	250	
Output Capacitance		C_{ob}			pF
V_{CB} = 10V. I_E = 0, f = 140 kHz	MPS918		–	1.7	
V_{CB} = 10V, I_E = 0, f = 1 MHz	MPS3563		–	1.7	
V_{CB} = 0V, I_E = 0, f = 140 kHz	MPS918		–	3.0	
Input Capacitance		C_{ib}			pF
V_{BE} = 0.5V, I_C = 0	MPS918		–	2.0	
Amplifier Power Gain		Gpe			dB
I_C = 6mA, f = 200 MHz, V_{CB} = 12V	MPS918		15	–	
I_C = 8mA, V_{CE} = 10V, f = 200 MHz	MPS3563		14	–	
$G_{fd} + G_{re} < -20$dB					
Power Output		Pout			mW
I_C = 8mA, V_{CB} = 15V, f = 500 MHz	MPS918		30		
Collector Efficiency		eff			%
I_C = 8mA, V_{CB} = 15V, f = 500 MHz	MPS918		25		
Noise Figure		NF			dB
I_C = 1mA, V_{CE} = 6V, f = 60 MHz	MPS918		–	6.0	
Rg = 400					

*PW ≤ 300 μs. DC ≤ 1%

MPS2369 (SILICON)



CASE 29(1)
(TO-92)

NPN silicon annular switching transistor designed for use in high-speed, low-current switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	15	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Base Voltage	V_{CB}	40	Vdc
Emitter-Base Voltage	V_{EB}	4.5	Vdc
Collector Current-Peak	I_C	500	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to + 135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.355	°C/mW

FIGURE 1 – t_{on} CIRCUIT

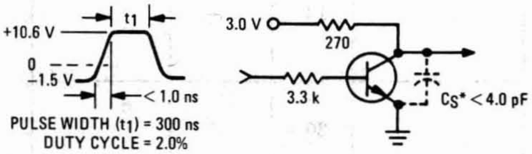

t1
+10.6 V
0
–1.5 V
< 1.0 ns
PULSE WIDTH (t1) = 300 ns
DUTY CYCLE = 2.0%
3.0 V
270
3.3 k
CS* < 4.0 pF

FIGURE 2 – t_{off} CIRCUIT

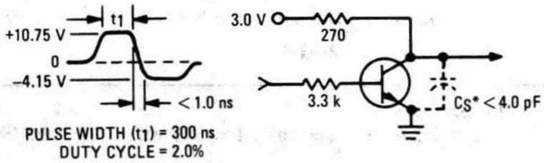
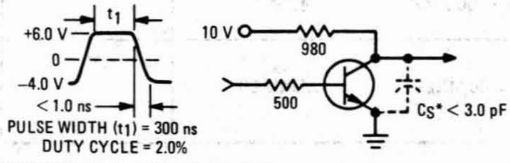

t1
+10.75 V
0
–4.15 V
< 1.0 ns
PULSE WIDTH (t1) = 300 ns
DUTY CYCLE = 2.0%
3.0 V
270
3.3 k
CS* < 4.0 pF

FIGURE 3 – STORAGE TEST CIRCUIT


t1
+6.0 V
0
–4.0 V
< 1.0 ns
PULSE WIDTH (t1) = 300 ns
DUTY CYCLE = 2.0%
10 V
980
500
CS* < 3.0 pF

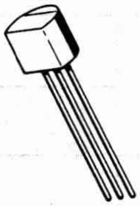
*Total shunt capacitance of test jig and connectors.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	15	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 10 μAdc, V_{BE} = 0)	BV_{CES}	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	40	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4.5	-	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	-	0.4	μAdc
(V_{CB} = 20 Vdc, I_E = 0, T_A = 125°C)		-	30	
ON CHARACTERISTICS				
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}*	40	120	-
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc, T_A = -55°C)		20	-	
(I_C = 100 mAdc, V_{CE} = 2.0 Vdc)		20	-	
Collector-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$*	-	0.25	Vdc
Base-Emitter Saturation Voltage* (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{BE(sat)}$*	0.70	0.85	Vdc
SMALL SIGNAL CHARACTERISTICS				
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	4.0	pF
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	h_{fe}	5.0	-	-
SWITCHING CHARACTERISTICS				
Turn-On Time (V_{CC} = 3.0 Vdc, $V_{BE(off)}$ = 1.5 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc) (Figure 1)	t_{on}	-	12	ns
Turn-Off Time (V_{CC} = 3.0 Vdc, I_C = 10 mAdc, I_{B1} = 3.0 mAdc, I_{B2} = 1.5 mAdc) (Figure 2)	t_{off}	-	18	ns
Storage Time (I_{B1} = I_{B2} = I_C = 10 mAdc) (Figure 3)	t_s	-	13	ns

* Pulse Test: Pulse Width = 300 μs, Duty Cycle = 2.0%

MPS2711 (SILICON)
MPS2712



CASE 29(1)
(TO-92)

NPN silicon epitaxial plastic encapsulated transistor designed for low-power, small-signal audio applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	18	Vdc
Collector-Base Voltage	V_{CB}	18	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	100	mAdc
Total Device Dissipation @ $T_A = 25^oC$	P_D	310	mW
Total Device Dissipation @ $T_C = 60^oC$	P_D	210	mW
Operating Junction Temperature	T_J	135	^oC
Storage Temperature Range	T_{stg}	-55 to +135	^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Rating	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	$^oC/W$

MPS2711, MPS2712 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector Cutoff Current (V_{CB} = 18 Vdc, I_E = 0) (V_{CB} = 18 Vdc I_E = 0, T_A = 100°C)		I_{CBO}	- -	0.5 1.5	μAdc
Emitter-Base Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)		I_{EBO}	-	0.5	μAdc
DC Current Gain (V_{CE} = 4.5 Vdc, I_C = 2 mAdc)	MPS2711 MPS2712	h_{FE}	30 75	90 225	-
Output Capacitance (V_{CB} = 10 V, I_E = 0, f = 1 MHz)		C_{ob}	-	4.0	pF
Small Signal Current Gain (V_{CE} = 10 Vdc, I_C = 2 mAdc, f = 1 kHz)	MPS2711 MPS2712	h_{fe}	30 80	120 200	-

MPS2713 (SILICON)
MPS2714

CASE 29(1)
(TO-92)

N P N Silicon annular transistor, designed for general purpose low-level switching applications. Features one-piece, injection-molded plastic package for high reliability.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	18	Vdc
Collector-Emitter Voltage	V_{CE}	18	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	200	mAdc
Total Device Dissipation @ $T_A = 60^{o}C$	P_D	210	mW
Total Device Dissipation @ $T_A = 25^{o}C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW
Junction Operating Temperature	T_J	135	°C
Storage Temperature Range	T_{stg}	-55 to +135	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit

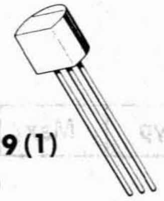
OFF CHARACTERISTICS

Collector Cutoff Current (V_{CB} = 18 Vdc, I_E = 0) (V_{CB} = 18 Vdc, I_E = 0, T_A = 100°C)	I_{CBO}	— —	— —	0.5 15	μAdc
Emitter Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)	I_{EBO}	—	—	0.5	μAdc

ELECTRICAL CHARACTERISTICS (continued)

Characteristic		Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS						
DC Current Gain (I_C = 2 mAdc, V_{CE} = 4.5 Vdc)	MPS2713	h_{FE}	30	60	90	—
	MPS2714		75	150	225	
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 3 mAdc)		$V_{CE(sat)}$	—	0.16	0.3	Vdc
Base-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 3 mAdc)		$V_{BE(sat)}$	0.6	0.75	1.3	Vdc
SMALL SIGNAL CHARACTERISTICS						
Small Signal Current Gain (I_C = 2 mAdc, V_{CE} = 4.5 Vdc, f = 1 kHz)	MPS2713	h_{fe}	30	—	120	—
	MPS2714		80	—	300	
Current-Gain—Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)		f_T	—	250	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	2.5	—	pF
Input Impedance (I_C = 0.5 mAdc, V_{CE} = 1 Vdc, f = 1 kHz)		h_{ie}	—	3000	—	ohms
SWITCHING CHARACTERISTICS						
Delay Time	I_C = 10 mA, I_{B1} = 3 mA, V_{CC} = 10 V	t_d	—	7.0	—	ns
Rise Time		t_r	—	6.0	—	ns
Storage Time	I_C = 10 mA, I_{B1} = 3 mA, I_{B2} = 1 mA, V_{CC} = 10 V	t_s	—	12	—	ns
Fall Time		t_f	—	9.0	—	ns

MPS2923 thru MPS2925 (SILICON)



CASE 29(1)
(TO-92)

NPN silicon annular, plastic encapsulated transistors for low-cost, medium-speed, general-purpose amplifier and oscillator applications.

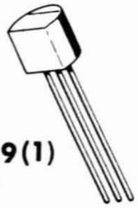
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	25	Vdc
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector dc Current	I_C	100	mAdc
Total Device Dissipation @ 25°C Ambient Temperature Derating Factor above 25°C	P_D	200 2.67	mW mW/°C
Total Device Dissipation @ 55°C Ambient Temperature Derating Factor above 25°C	P_D	120 2.67	mW mW/°C
Junction Temperature-Operating	T_J	100	°C
Storage Temperature Range	T_{stg}	-30 to +125	°C

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current $V_{CB} = 25$ V, $I_E = 0$ $V_{CB} = 25$ V, $I_E = 0$, $T_A = 100°C$	I_{CBO}	– –	0.5 15	μA μA
Emitter Cutoff Current $V_{EB} = 5$ V	I_{EBO}	–	0.5	μA
Small Signal Current Gain (f = 1 kHz) $V_{CE} = 10$ V, $I_C = 2$ mA MPS2923 MPS2924 MPS2925	h_{fe}	90 150 235	180 300 470	–
Collector Capacitance $V_{CB} = 10$ V, $I_E = 0$, f = 1 MHz	C_{ob}	–	12	pF

MPS2926 (SILICON)
MPS3721



CASE 29(1)
(TO-92)

NPN silicon epitaxial plastic encapsulated transistors designed for general-purpose applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	18	Vdc
Collector-Base Voltage	V_{CB}	18	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	100	mAdc
Total Device Dissipation @ 25°C Ambient Temperature	P_D	310	mW
Total Device Dissipation @ 60°C Ambient Temperature	P_D	210	mW
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW
Junction Temperature, Operating	T_J	135	°C
Storage Temperature Range	T_{stg}	-55 to +135	°C

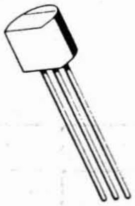
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Typ	Max	Unit
Collector Cutoff Current (V_{CB} = 18 Vdc, I_E = 0) (V_{CB} = 18 Vdc, I_E = 0, T_A = 100°C)	I_{CBO}	— —	— —	0.5 15	μA
Emitter Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)	I_{EBO}	—	—	0.5	μA
Current Gain — Bandwidth Product (I_C = 4 mA, V_{CE} = 5 V) MPS2926	f_T	—	300	—	MHz
Output Capacitance (V_{CB} = 10 V, I_E = 0, f = 1 MHz)	C_{ob}	—	—	3.5	pF
Small Signal Current Gain (V_{CE} = 10 V, I_C = 2 mA, f = 1 kHz) MPS2926 MPS3721	h_{fe}	35 60	— —	470 660	—

Each unit will be branded with the MPS2926 type and also by color code to identify the different A-C beta categories. A-C beta is broken down into five groups, and typical values of DC beta are listed for guidance.

MPS2926 Color Code	h_{fe} (V_{CE} = 10 V, I_C = 2 mA, f = 1 KHz)		h_{FE} (V_{CE} = 4.5 V, I_C = 2 mA)
	Min	Max	Typ
Brown	35	70	36
Red	55	110	62
Orange	90	180	115
Yellow	150	300	155
Green	235	470	215

MPS3392 thru MPS3395 (SILICON)



CASE 29(1)
TO-92

NPN silicon annular plastic encapsulated transistors designed for small-signal, low power audio applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	100	mAdc
Total Device Dissipation @ $T_A = 25^oC$	P_D	310	mW
Total Device Dissipation @ $T_C = 60^oC$	P_D	210	mW
Operating Junction Temperature	T_J	135	^oC
Storage Temperature Range	T_{stg}	-55 to +135	^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Rating	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

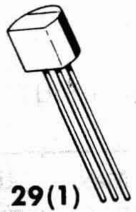
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)		BV_{CEO}	25	-	Vdc
Collector Cutoff Current (V_{CB} = 18 Vdc, I_E = 0)		I_{CBO}	-	0.1	μAdc
Emitter Cutoff Current (V_{EB} = 5 Vdc, I_C = 0)		I_{EBO}	-	0.1	μAdc
DC Current Gain (V_{CE} = 4.5 Vdc, I_C = 2 mAdc)	MPS3392	h_{FE}	150	300	-
	MPS3393		90	180	
	MPS3394		55	110	
	MPS3395		150	500	
Output Capacitance (V_{CB} = 10 V, I_E = 0, f = 1 MHz)		C_{ob}	-	3.5	pF
Small Signal Current Gain (V_{CE} = 4.5 V, I_C = 2 mA, f = 1 kHz)	MPS3392	h_{fe}	150	500	-
	MPS3393		90	400	
	MPS3394		55	300	
	MPS3395		150	800	

MPS3563

For Specifications, See MPS918 Data.

MPS3638 (SILICON)
MPS3638A



CASE 29(1)
(TO-92)

PNP silicon epitaxial transistor designed for high-current digital applications. Features one-piece, injection-molded plastic package for high reliability.

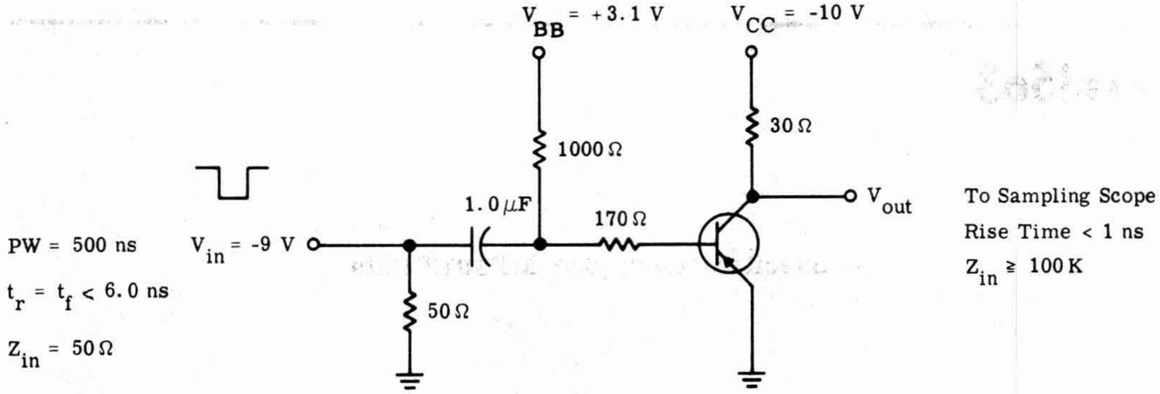
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Emitter Voltage	V_{CES}	25	Vdc
Collector-Base Voltage	V_{CB}	25	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current	I_C	500	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

FIGURE 1

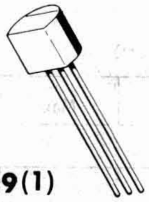

V_{BB} = +3.1 V
V_{CC} = -10 V
1000 Ω
30 Ω
1.0 μF
170 Ω
V_{out}
To Sampling Scope
Rise Time < 1 ns
Z_{in} ≥ 100 K
PW = 500 ns
V_{in} = -9 V
$t_r = t_f$ < 6.0 ns
Z_{in} = 50 Ω
50 Ω

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	25	-	Vdc
Collector-Emitter Breakdown Voltage (I_C = 100 μAdc, V_{BE} = 0)	BV_{CES}	25	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	25	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4.0	-	Vdc
Collector Reverse Current (V_{CE} = 15 Vdc, V_{BE} = 0) (V_{CE} = 15 Vdc, V_{BE} = 0, T_A = +65°C)	I_{CES}	- -	0.035 2.0	μAdc
Base Current (V_{CE} = 15 Vdc, V_{BE} = 0)	I_B	-	0.035	μAdc
ON CHARACTERISTICS				
DC Current Gain* (I_C = 1 mAdc, V_{CE} = 10 Vdc) MPS3638A (I_C = 10 mAdc, V_{CE} = 10 Vdc) MPS3638 MPS3638A (I_C = 50 mAdc, V_{CE} = 1 Vdc) MPS3638 MPS3638A (I_C = 300 mAdc, V_{CE} = 2 Vdc) MPS3638 MPS3638A	h_{FE}*	80 20 100 30 100 20 20	- - - - - - -	-
Collector-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 2.5 mAdc) (I_C = 300 mAdc, I_B = 30 mAdc)	$V_{CE(sat)}$*	- -	0.25 1.0	Vdc
Base-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 2.5 mAdc) (I_C = 300 mAdc, I_B = 30 mAdc)	$V_{BE(sat)}$*	- 0.80	1.1 2.0	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (V_{CE} = 3 Vdc, I_C = 50 mAdc, f = 100 MHz) MPS3638 MPS3638A	f_T	100 150	- -	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 140 kHz) MPS3638 MPS3638A	C_{ob}	- -	20 10	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz) MPS3638 MPS3638A	C_{ib}	- -	65 25	pF
Small-Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) MPS3638 MPS3638A	h_{fe}	25 100	180 -	-
Output Conductance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	-	1.2	mmhos
Input Resistance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) MPS3638 MPS3638A	h_{ie}	- -	1500 2000	Ohms
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz) MPS3638 MPS3638A	h_{re}	- -	26 15	$X10^{-4}$
SWITCHING CHARACTERISTICS				
Delay Time V_{CC} = 10 Vdc, I_C = 300 mAdc, I_{B1} = 30 mAdc, $V_{BE(off)}$ = 3.1 Vdc	t_d	-	20	ns
Rise Time	t_r	-	70	ns
Storage Time V_{CC} = 10 Vdc, I_C = 300 mAdc, I_{B1} = 30 mAdc, I_{B2} = 30 mAdc	t_s	-	140	ns
Fall Time	t_f	-	70	ns
Turn-On Time I_C = 300 mAdc, I_{B1} = 30 mAdc	t_{on}	-	75	ns
Turn-Off Time I_C = 300 mAdc, I_{B1} = 30 mAdc, I_{B2} = 30 mAdc	t_{off}	-	170	ns

*Pulse Test: Pulse Width = 300 μs; Duty Cycle = 1%.

MPS3639 (SILICON)



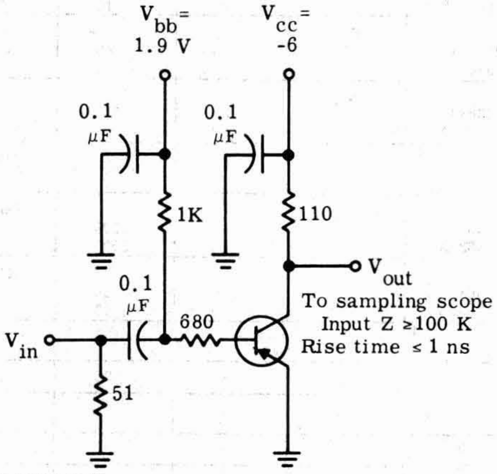
CASE 29(1)
(TO-92)

PNP silicon annular, plastic encapsulated transistor for low-cost, low-level, high-speed switching applications.

MAXIMUM RATINGS

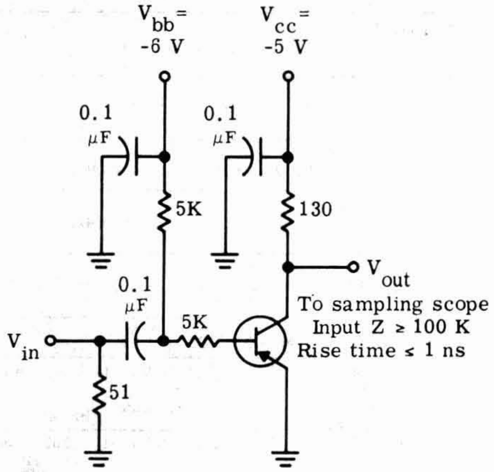
Rating	Symbol	Value	Unit
Collector Current	I_C	80	mAdc
Collector-Base Voltage	V_{CB}	6.0	Vdc
Collector-Emitter Voltage	V_{CEO}	6.0	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Total Device Dissipation @ 25° Ambient Temperature Derate above 25° C	P_D	0.2 2.0	Watts mW/°C
Total Device Dissipation @ 25° C Case Temperature Derate above 25° C	P_D	0.5 5.0	Watts mW/°C
Operating Junction Temperature	T_J	125	°C
Storage Temperature Range	T_{stg}	-55 to +125	°C

SWITCHING TIME TEST CIRCUITS


V_{bb} = 1.9 V
V_{cc} = -6
0.1 µF
0.1 µF
1K
110
V_{out}
To sampling scope
Input Z ≥100 K
Rise time ≤ 1 ns
0.1 µF
680
V_{in}
51

PULSE SOURCE
Rise time ≤ 1 ns
PW ≥100 ns
Z_{in} = 50Ω
Fall time ≤1 ns

NOTES: (1) Collector Current = 50 mA
(2) Turn-On and Turn-Off Base Currents = 5 mA


V_{bb} = -6 V
V_{cc} = -5 V
0.1 µF
0.1 µF
5K
130
V_{out}
0.1 µF
5K
To sampling scope
Input Z ≥ 100 K
Rise time ≤ 1 ns
V_{in}
51

PULSE SOURCE
Rise time ≤ 1 ns
PW ≥ 200 ns
Z_{in} = 50Ω
Fall time ≤1 s

NOTES: (1) Collector Current = 10 mA
(2) Turn-On and Turn-Off Base Currents = 0.5 mA

ELECTRICAL CHARACTERISTICS (Tc = 25°C unless otherwise noted)

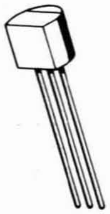
Characteristic	Symbol	Min	Max	Unit
Collector Cutoff Current $V_{CE} = 3$ V, $V_{EB} = 0$ $V_{CE} = 3$ V, $V_{EB} = 0$, $T_A = +65°C$	I_{CES}	– –	0.01 1.0	μA
Base Current $V_{CE} = 3$ V, $V_{EB} = 0$	I_B	–	10	nA
Collector-Emitter Breakdown Voltage $I_C = 100$ μA, $V_{BE} = 0$	BV_{CES}	6.0	–	V
Collector-Base Breakdown Voltage $I_C = 100$ μA, $I_E = 0$	BV_{CBO}	6.0	–	V
Emitter-Base Breakdown Voltage $I_E = 100$ μA, $I_C = 0$	BV_{EBO}	4.0	–	V
Collector-Emitter Sustaining Voltage * $I_B = 0$, $I_C = 10$ mA	$V_{CEO(sus)}$*	6.0	–	V
Collector-Emitter Saturation Voltage * $I_C = 10$ mA, $I_B = 1$ mA $I_C = 50$ mA, $I_B = 5$ mA $I_C = 10$ mA, $I_B = 1$ mA, $T_A = +65°C$	$V_{CE(sat)}$*	– – –	0.16 0.5 0.23	V
Base-Emitter Saturation Voltage * $I_C = 10$ mA, $I_B = 0.5$ mA $I_C = 10$ mA, $I_B = 1$ mA $I_C = 50$ mA, $I_B = 5$ mA	$V_{BE(sat)}$*	0.75 0.8 –	0.95 1.0 1.5	V
Forward Current Transfer Ratio * $V_{CE} = 0.3$ V, $I_C = 10$ mA $V_{CE} = 1.0$ V, $I_C = 50$ mA	h_{FE} *	30 20	120 –	–

*Pulse Test: Pulse Width = 300 μs, Duty Cycle ≤ 1.0%.

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Max	Unit
Small-Signal Current Transfer Ratio	h_{fe}			–
V_{CE} = 5 V, I_C = 10 mA, f = 100 MHz		5.0	–	
V_{CB} = 0, I_C = 10 mA, f = 100 MHz		3.0	–	
Output Capacitance I_E = 0, V_{CB} = 5 V, f = 140 kHz	C_{ob}	–	3.5	pF
Input Capacitance V_{BE} = 0.5 V, I_C = 0, f = 140 kHz	C_{ib}	–	3.5	pF
Delay Time V_{CC} = 6 V, I_C = 50 mA, I_{B1} = 5 mA $V_{BE(off)}$ = 1.9 V	t_d	–	10	ns
Rise Time V_{CC} = 6 V, I_C = 50 mA, I_{B1} = 5 mA, $V_{BE(off)}$ = 1.9 V	t_r	–	30	ns
Storage Time V_{CC} = 6 V, I_C = 50 mA, I_{B1} = I_{B2} = 5 mA	t_s	–	20	ns
Fall Time V_{CC} = 6 V, I_C = 50 mA, I_{B1} = I_{B2} = 5 mA	t_f	–	12	ns
Turn-On Time	t_{on}			ns
I_C = 50 mA, I_{B1} = 5 mA, V_{OB} = 1.9 V		–	25	
I_C = 10 mA, I_{B1} = 0.5 mA		–	60	
Turn-Off Time	t_{off}			ns
I_C = 50 mA, V_{OB} = 1.9 V, I_{B1} = I_{B2} = 5 mA		–	25	
I_C = 10 mA, I_{B1} = I_{B2} = 0.5 mA		–	60	

MPS 3640 (SILICON)



CASE 29(1)
(TO-92)

PNP silicon annular transistors designed for general-purpose low-level switching applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	12	Vdc
Collector-Base Voltage	V_{CB}	12	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current - Continuous	I_C	80	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Sustaining Voltage* ($I_C = 10$ mAdc, $I_B = 0$)	$BV_{CEO(sus)}$*	12	-	Vdc
Collector-Emitter Breakdown Voltage ($I_C = 100$ μAdc, $V_{BE} = 0$)	BV_{CES}	12	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 100$ μAdc, $I_E = 0$)	BV_{CBO}	12	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100$ μAdc, $I_C = 0$)	BV_{EBO}	4.0	-	Vdc
Collector Cutoff Current ($V_{CE} = 6.0$ Vdc, $V_{BE} = 0$) ($V_{CE} = 6.0$ Vdc, $V_{BE} = 0$, $T_A = 65°C$)	I_{CES}	 - -	 0.01 1.0	μAdc

ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted)

ON CHARACTERISTICS

Characteristic	Symbol	Min	Max	Unit
DC Current Gain* (I_C = 10 mAdc, V_{CE} = 0.3 Vdc) (I_C = 50 mAdc, V_{CE} = 1.0 Vdc)	h_{FE}*	 30 20	 120 -	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)* (I_C = 10 mAdc, I_B = 1.0 mAdc, T_A = 65°C)	$V_{CE(sat)}$	 - - -	 0.2 0.6 0.25	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc) (I_C = 10 mAdc, I_B = 1.0 mAdc) (I_C = 50 mAdc, I_B = 5.0 mAdc)*	$V_{BE(sat)}$	 0.75 0.8 -	 0.95 1.0 1.5	Vdc

DYNAMIC CHARACTERISTICS

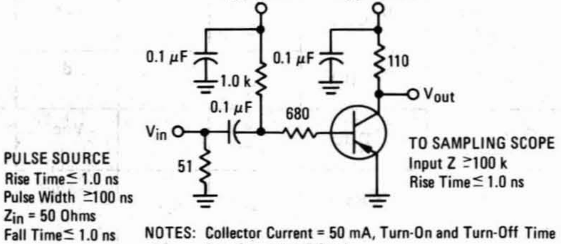
Characteristic	Symbol	Min	Max	Unit
Current-Gain–Bandwidth Product (I_C = 10 mAdc, V_{CE} = 5.0 Vdc, f = 100 MHz)	f_T	500	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 140 kHz)	C_{ob}	-	3.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 140 kHz)	C_{ib}	-	3.5	pF

SWITCHING CHARACTERISTICS

Characteristic		Symbol	Min	Max	Unit
Turn-On Time ($V_{BE(off)}$ = 1.9 Vdc, V_{CC} = 6.0 Vdc, I_C = 50 mAdc, I_{B1} = 5.0 mAdc)(See Figure 1) (I_C = 10 mAdc, V_{CC} = 1.5 Vdc, I_{B1} = 0.5 mAdc) (See Figure 2)		t_{on}	 - -	 25 60	ns
Delay Time	(V_{CC} = 6.0 Vdc, $V_{BE(off)}$ = 1.9 Vdc, I_C = 50 mAdc, I_{B1} = 5.0 mAdc) (See Figure 1)	t_d	-	10	ns
Rise Time		t_r	-	30	ns
Turn-Off Time ($V_{BE(off)}$=1.9Vdc, V_{CC}=6.0Vdc, I_C=50mAdc, I_{B1}=I_{B2}=5.0mAdc)(See Figure 1) (I_C = 10 mAdc, V_{CC} = 1.5 Vdc, I_{B1} = I_{B2} = 0.5 mAdc) (See Figure 2)		t_{off}	 - -	 35 75	ns
Storage Time	(V_{CC} = 6.0 Vdc, I_C = 50 mAdc, I_{B1} = I_{B2} = 5.0 mAdc) (See Figure 1)	t_s	-	20	ns
Fall Time		t_f	-	12	ns

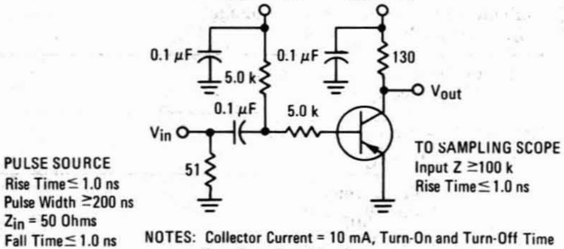
*Pulse Test: Pulse Width = 300 μs, Duty Cycle = 1.0%.

FIGURE 1 – SWITCHING TIME TEST CIRCUIT


VBB = +1.9 V
VCC = -6.0 V
0.1 μF
1.0 k
0.1 μF
110
Vout
0.1 μF
680
Vin
51
TO SAMPLING SCOPE
Input Z ≥100 k
Rise Time ≤ 1.0 ns
PULSE SOURCE
Rise Time ≤ 1.0 ns
Pulse Width ≥100 ns
Zin = 50 Ohms
Fall Time ≤ 1.0 ns

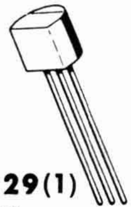
NOTES: Collector Current = 50 mA, Turn-On and Turn-Off Time Base Currents = 5.0 mA.

FIGURE 2 – SWITCHING TIME TEST CIRCUIT


VBB = -6.0 V
VCC = 1.5 V
0.1 μF
5.0 k
0.1 μF
130
Vout
0.1 μF
5.0 k
Vin
51
TO SAMPLING SCOPE
Input Z ≥100 k
Rise Time ≤ 1.0 ns
PULSE SOURCE
Rise Time ≤ 1.0 ns
Pulse Width ≥200 ns
Zin = 50 Ohms
Fall Time ≤ 1.0 ns

NOTES: Collector Current = 10 mA, Turn-On and Turn-Off Time Base Currents = 0.5 mA.

MPS3646 (SILICON)



CASE 29(1)
(TO-92)

NPN silicon annular transistor designed for high-speed saturated switching applications. Features one-piece, injection-molded plastic package for high reliability.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	40	Vdc
Collector-Emitter Voltage	V_{CES}	40	Vdc
Collector-Emitter Voltage Applicable 0.01-200 mA	V_{CEO}	15	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current	I_C	200	mA
Collector Current (10 μs pulse)	I_C	500	mA
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	200 2.0	mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	500 5.0	mW mW/°C
Operating Junction Temperature	T_J	125	°C
Storage Temperature Range	T_{stg}	-55 to +125	°C

FIGURE 1 — t_{on} and t_{off} TEST CIRCUIT

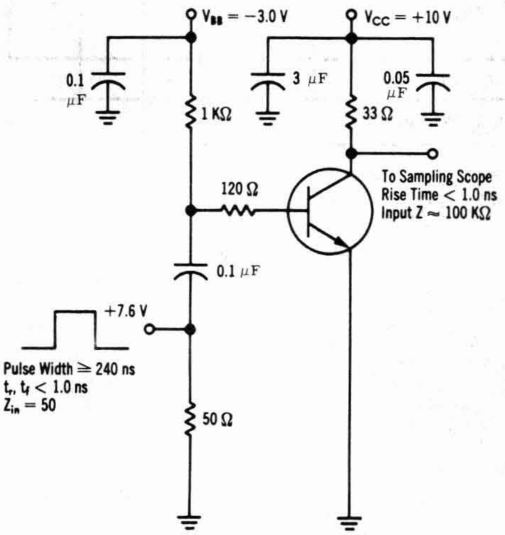
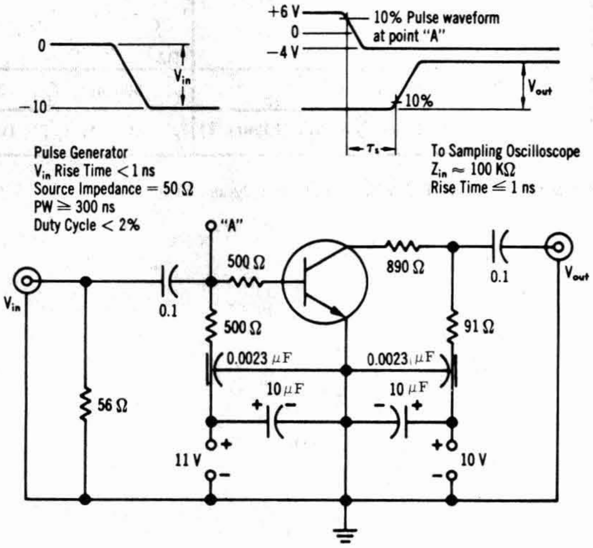

$V_{BB} = -3.0$ V
$V_{CC} = +10$ V
0.1 μF
1 KΩ
3 μF
0.05 μF
33 Ω
120 Ω
To Sampling Scope
Rise Time < 1.0 ns
Input Z ≈ 100 KΩ
0.1 μF
+7.6 V
Pulse Width ≥ 240 ns
t_r, t_f < 1.0 ns
Z_{in} = 50
50 Ω

FIGURE 2 — CHARGE STORAGE TIME MEASUREMENT CIRCUIT


0
V_{in}
−10
+6 V
0
−4 V
10% Pulse waveform at point "A"
V_{out}
10%
T_s
Pulse Generator
V_{in} Rise Time < 1 ns
Source Impedance = 50 Ω
PW ≥ 300 ns
Duty Cycle < 2%
To Sampling Oscilloscope
Z_{in} ≈ 100 KΩ
Rise Time ≤ 1 ns
"A"
500 Ω
890 Ω
0.1
V_{out}
V_{in}
0.1
500 Ω
91 Ω
0.0023 μF
0.0023 μF
10 μF
10 μF
56 Ω
11 V
10 V

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise specified.)

Characteristic	Conditions	Symbol	Min	Max	Unit
Collector-Base Breakdown Voltage	$I_C = 100\ \mu Adc,\ I_E = 0$	BV_{CBO}	40	—	Vdc
Collector-Emitter Breakdown Voltage	$I_C = 100\ \mu Adc,\ V_{BE} = 0$	BV_{CES}	40	—	Vdc
Collector-Emitter Sustaining Voltage*	$I_C = 10$ mAdc	$V_{CEO(sus)}$*	15	—	Vdc
Emitter-Base Breakdown Voltage	$I_E = 100\ \mu Adc,\ I_C = 0$	BV_{EBO}	5.0	—	Vdc
Collector-Emitter Saturation Voltage*	$I_C = 30$ mAdc, $I_B = 3.0$ mAdc $I_C = 30$ mAdc, $I_B = 3.0$ mAdc, $T_A = +65$ C $I_C = 100$ mAdc, $I_B = 10$ mAdc $I_C = 300$ mAdc, $I_B = 30$ mAdc	$V_{CE(sat)}$*	— — — —	0.2 0.3 0.28 0.5	Vdc
Base-Emitter Saturation Voltage*	$I_C = 30$ mAdc, $I_B = 3.0$ mAdc $I_C = 100$ mAdc, $I_B = 10$ mAdc $I_C = 300$ mAdc, $I_B = 30$ mAdc	$V_{BE(sat)}$*	0.75 — —	0.95 1.2 1.7	Vdc
DC Current Gain*	$I_C = 30$ mAdc, $V_{CE} = 0.4$ Vdc $I_C = 100$ mAdc, $V_{CE} = 0.5$ Vdc $I_C = 300$ mAdc, $V_{CE} = 1.0$ Vdc	h_{FE}*	30 25 15	120 — —	—
Collector Reverse Current	$V_{CE} = 20$ Vdc, $V_{EB} = 0$ $V_{CE} = 20$ Vdc, $V_{EB} = 0$, $T_A = +65$ C	I_{CES}	— —	0.5 3.0	μAdc
Base Current	$V_{CE} = 20$ Vdc, $V_{EB} = 0$	I_B	—	0.5	μAdc
Output Capacitance	$V_{CB} = 5.0$ V, $I_E = 0$, f = 140 kHz	C_{ob}	—	5.0	pF
Input Capacitance	$V_{BE} = 0.5$ V, $I_C = 0$, f = 140 kHz	C_{ib}	—	8.0	pF
Small-Signal Current Gain	$I_C = 30$ mA, $V_{CE} = 10$ V, f = 100 MHz	$\|h_{fe}\|$	3.5	—	—
Turn-On Delay Time (Figure 1)	$V_{CC} = +10$ V, I_{CS} 300 mA, I_{B1} 30 mA, $V_{BE(off)} = -3.0$ V	t_d	—	10	ns
Rise Time (Figure 1)	$V_{CC} = +10$ V, I_{CS} 300 mA, I_{B1} 30 mA, $V_{BE(off)} = -3.0$ V	t_r	—	15	ns
Turn-On Time (Figure 1)	I_C 300 mA, I_{B1} 30 mA, $V_{BE(off)}$ -3.0 V	t_{on}	—	18	ns
Storage Time (Figure 1)	$V_{CC} = +10$ V, I_{CS} 300 mA, I_{B1} 30 mA, I_{B2} -30 mA	t_s	—	20	ns
Fall Time (Figure 1)	$V_{CC} = +10$ V, I_{CS} 300 mA, I_{B1} 30 mA, I_{B2} -30 mA	t_f	—	15	ns
Turn-Off Time (Figure 1)	I_C 300 mA, I_{B1} 30 mA, I_{B2} -30 mA	t_{off}	—	28	ns
Charge Storage Time Constant (Figure 2)	I_C 10 mA, I_{B1} 10 mA, I_{B2} -10 mA	τ_s	—	18	ns

*Pulse Conditions: PW ≦ 300 μs : Duty Cycle ≦1%

MPS3693 (SILICON)
MPS3694

CASE 29 (1)
(TO-92)

NPN silicon annular amplifier transistors designed for general purpose RF amplifier applications in frequency range to 50 MHz. These devices are particularly well suited for use in AM/FM receivers.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	45	Vdc
Collector-Base Voltage	V_{CB}	45	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

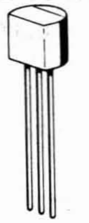
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Sustaining Voltage* (I_C = 10 mAdc, I_B = 0)	$BV_{CEO(sus)}$*	45	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	45	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 35 Vdc, I_E = 0) (V_{CB} = 35 Vdc, I_E = 0, T_A = 65°C)	I_{CBO}	- -	- -	50 5.0	nAdc μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc) MPS3693 MPS3694	h_{FE}	40 100	- -	160 400	-
DYNAMIC CHARACTERISTICS					
Current-Gain – Bandwidth Product (I_C = 10 mAdc, V_{CE} = 15 Vdc, f = 100 MHz)	f_T	200	-	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	-	3.5	pF
Collector-Base Time Constant (I_E = 10 mAdc, V_{CB} = 15 Vdc, f = 31.8 MHz)	r'_bC_c	-	-	55	ps
Noise Figure (I_C = 3.0 mAdc, V_{CE} = 10 Vdc, R_S = 300 ohms, f = 1.0 MHz)	NF	-	4.0	-	dB

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 1.0%.

MPS3702 (SILICON)
MPS3703

PNP silicon annular plastic encapsulated transistors designed for low-power, large-signal audio applications.



CASE 29 (1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	MPS3702	MPS3703	Unit
Collector-Emitter Voltage	V_{CEO}	25	30	Vdc
Collector-Base Voltage	V_{CB}	40	50	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current - Continuous	I_C	200		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	MPS3702 MPS3703	BV_{CEO}*	25 30	- -	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	MPS3702 MPS3703	BV_{CBO}	40 50	- -	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)		I_{CBO}	-	100	nAdc
Emitter Cutoff Current (V_{BE} = 3 Vdc, I_C = 0)		I_{EBO}	-	100	nAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 50 mAdc, V_{CE} = 5 Vdc)	MPS3702 MPS3703	h_{FE}*	60 30	300 150	-
Collector-Emitter Saturation Voltage* (I_C = 50 mAdc, I_B = 5 mAdc)		$V_{CE(sat)}$*	-	0.25	Vdc
Base-Emitter On Voltage* (I_C = 50 mAdc, V_{CE} = 5 Vdc)		$V_{BE(on)}$*	0.6	1.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 5 Vdc, f = 20 MHz)		f_T	100	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, f = 1 MHz)		C_{ob}	-	12	pF

*Pulse Test: Pulse Width = 300 μs; Duty Cycle = 2%

MPS3704 (SILICON)
MPS3705
MPS3706

NPN silicon annular plastic encapsulated transistors designed for low-power, large-signal audio applications.

CASE 29(1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	MPS3704 MPS3705	MPS3706	Unit
Collector-Emitter Voltage	V_{CEO}	30	20	Vdc
Collector-Base Voltage	V_{CB}	50	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current - Continuous	I_C	600		mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81		mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

THERMAL CHARACTERISTICS

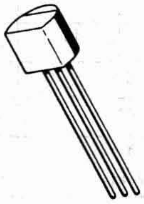
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_E = 0)	MPS3704 MPS3705 MPS3706	BV_{CEO}*	30 30 20	- - -	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	MPS3704 MPS3705 MPS3706	BV_{CBO}	50 50 40	- - -	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)		I_{CBO}	-	100	nAdc
Emitter Cutoff Current (V_{BE} = 3 Vdc, I_C = 0)		I_{EBO}	-	100	nAdc
ON CHARACTERISTICS					
DC Current Gain* (I_C = 50 mAdc, V_{CE} = 2 Vdc)	MPS3704 MPS3705 MPS3706	h_{FE}*	100 50 30	300 150 600	-
Collector-Emitter Saturation Voltage* (I_C = 100 mAdc, I_B = 5 mAdc)	MPS3704 MPS3705 MPS3706	$V_{CE(sat)}$*	- - -	0.6 0.8 1.0	Vdc
Base-Emitter On Voltage* (I_C = 100 mAdc, V_{CE} = 2 Vdc)		$V_{BE(on)}$*	0.5	1.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 50 mAdc, V_{CE} = 2 Vdc, f = 20 MHz)		f_T	100	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz)		C_{ob}	-	12	pF

*Pulse Test: Pulse Width = 300 μs; Duty Cycle = 2%

MPS3707 (SILICON)
MPS3708
MPS3709
MPS3710
MPS3711



CASE 29(1)
(TO-92)

NPN silicon epitaxial plastic encapsulated transistors designed for general-purpose, low-level amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	6.0	Vdc
Collector Current	I_C	30	mAdc
Total Device Dissipation @ $T_A = 25^oC$	P_D	310	mW
Total Device Dissipation @ $T_C = 60^oC$	P_D	210	mW
Operating Junction Temperature	T_J	135	^oC
Storage Temperature Range	T_{stg}	-55 to +135	^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Rating	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	$^oC/W$

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

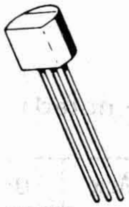
Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)		BV_{CEO}	30	-	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)		I_{CBO}	-	100	nAdc
Emitter Cutoff Current (V_{EB} = 6 Vdc, I_C = 0)		I_{EBO}	-	100	nAdc
DC Current Gain (I_C = 100 μAdc, V_{CE} = 5 Vdc)	MPS3707	h_{FE}	100	400	-
(I_C = 1 mAdc, V_{CE} = 5 Vdc)	MPS3708		45	660	
	MPS3709		45	165	
	MPS3710		90	330	
	MPS3711		180	660	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 0.5 mAdc)		$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter Voltage (I_C = 1 mAdc, V_{CE} = 5 Vdc)		V_{BE}	0.5	1.0	Vdc
Small Signal Current Gain (I_C = 100 μAdc, V_{CE} = 5 Vdc, f = 1 kHz)	MPS3707	h_{FE}	100	550	-
(I_C = 1 mAdc, V_{CE} = 5 Vdc, f = 1 kHz)	MPS3708		45	800	
	MPS3709		45	250	
	MPS3710		90	450	
	MPS3711		180	800	
Noise Figure (V_{CE} = 5 V, I_C = 100 μA, R_G = 5 kΩ, Noise Bandwidth = 15.7 kHz) Note 1	MPS3707	NF	-	5.0	dB

Note 1 Average Noise Figure is measured in an amplifier with low frequency response down 3 dB at 10 Hz.

MPS3721 (SILICON)

For Specifications, See MPS2926 Data.

MPS6507 (SILICON)



CASE 29(1)
(TO-92)

NPN silicon transistor designed as a VHF mixer in TV applications.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	30	Volts
Collector-Emitter Voltage	V_{CEO}	20	Volts
Emitter-Base Voltage	V_{EB}	3.0	Volts
Collector Current	I_C	100	mA
Total Device Dissipation @ T_A = 60°C @ T_A = 25°C	P_D	210 310	mW
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW
Junction Temperature	T_J	135	°C

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)	BV_{CEO}	20	—	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, V_{EB} = 0)	BV_{CES}*	30	—	—	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 60 °C)	I_{CBO}	— —	— —	0.05 1.0	μAdc
DC Current Gain (I_C = 2 mAdc, V_{CE} = 10 Vdc)	h_{FE}	25	—	—	—
High Frequency Current Gain (I_C = 2 mAdc, V_{CE} = 10 Vdc, f = 44 MHz)	$\lvert h_{fe} \rvert$	20	—	—	dB
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	—	2.5	pF
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc)	f_T	700	—	—	MHz
Conversion Gain (See Figures 7, 8, 9) (I_C = 3 mAdc, V_{CE} = 10 Vdc, 213 to 44 MHz)		—	23	—	dB

* Pulse Test: Pulse Width ≤ 300 μs , Duty Cycle ≤ 2%

MPS6507 (continued)

FIGURE 1 — COLLECTOR CURRENT versus COLLECTOR-EMITTER VOLTAGE

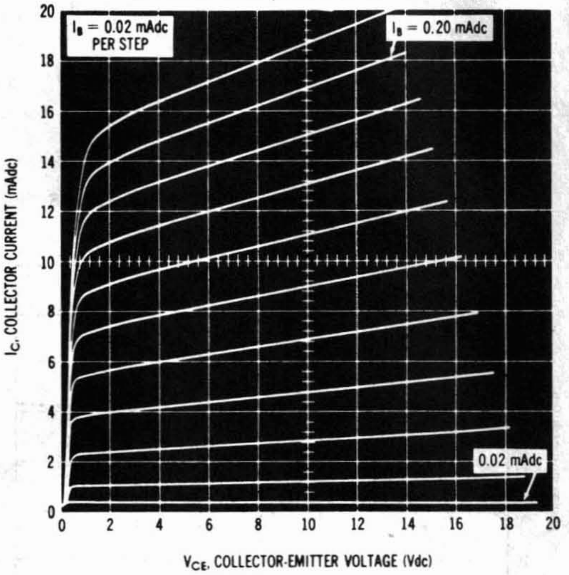
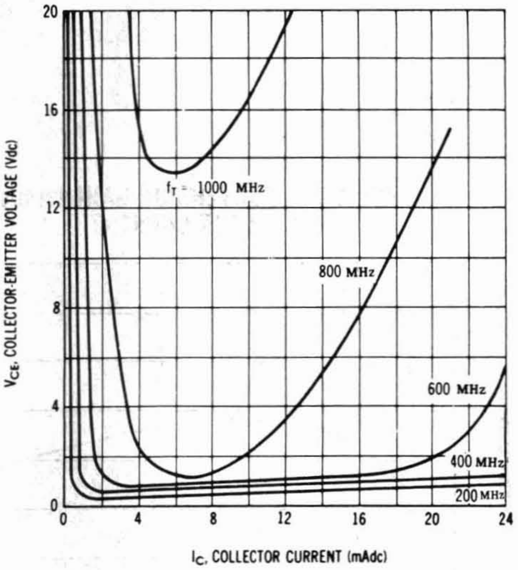


FIGURE 2 — CONTOURS OF CONSTANT GAIN-BANDWIDTH PRODUCT



y PARAMETER VARIATIONS

(V_{CE} = 10 Vdc, I_C = 3 mAdc, T_A = 25°C)

FIGURE 3 — y_{ie}, INPUT ADMITTANCE versus FREQUENCY

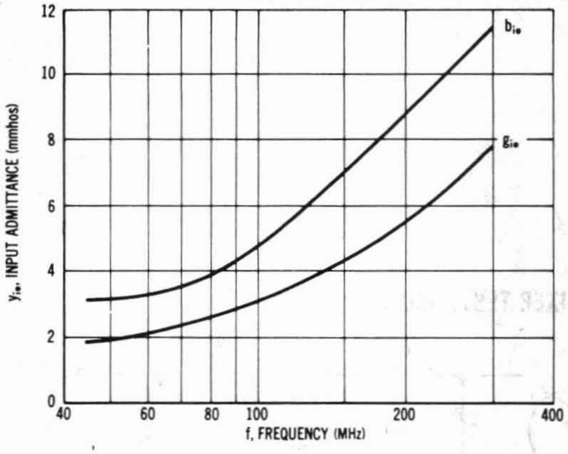


FIGURE 4 — y_{re}, REVERSE TRANSFER ADMITTANCE versus FREQUENCY

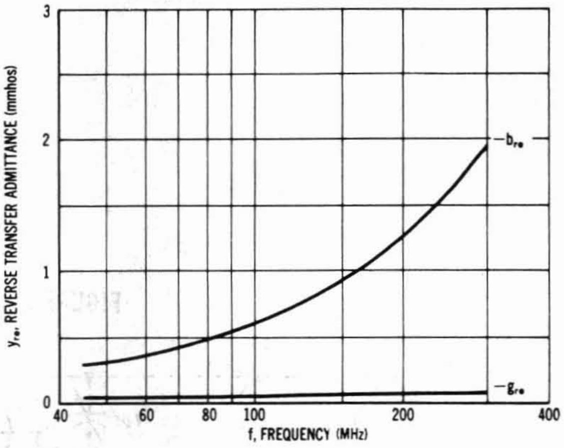


FIGURE 5 — y_{fe}, FORWARD TRANSFER ADMITTANCE versus FREQUENCY

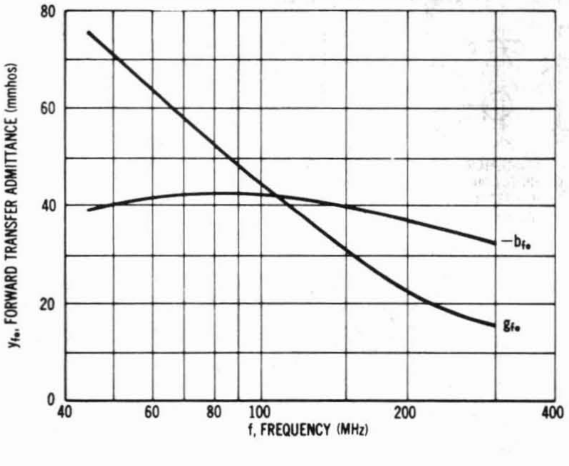


FIGURE 6 — y_{oe}, OUTPUT ADMITTANCE versus FREQUENCY

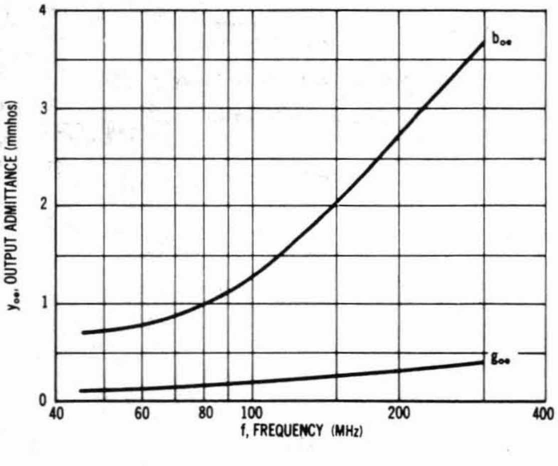


FIGURE 7 — CONVERSION GAIN versus COLLECTOR CURRENT

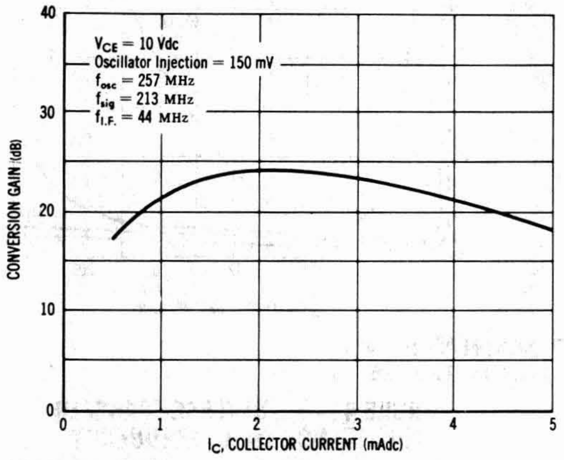


FIGURE 8 — CONVERSION GAIN versus OSCILLATOR INJECTION

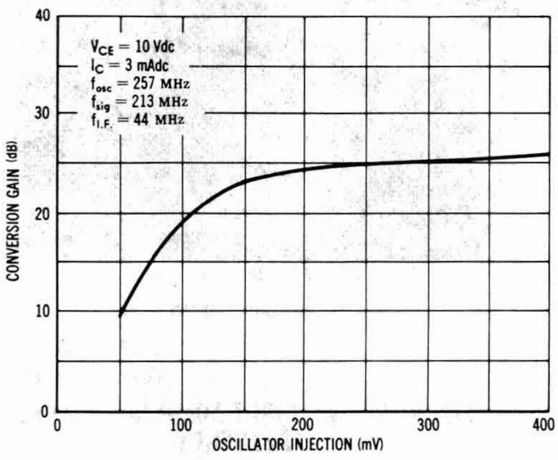
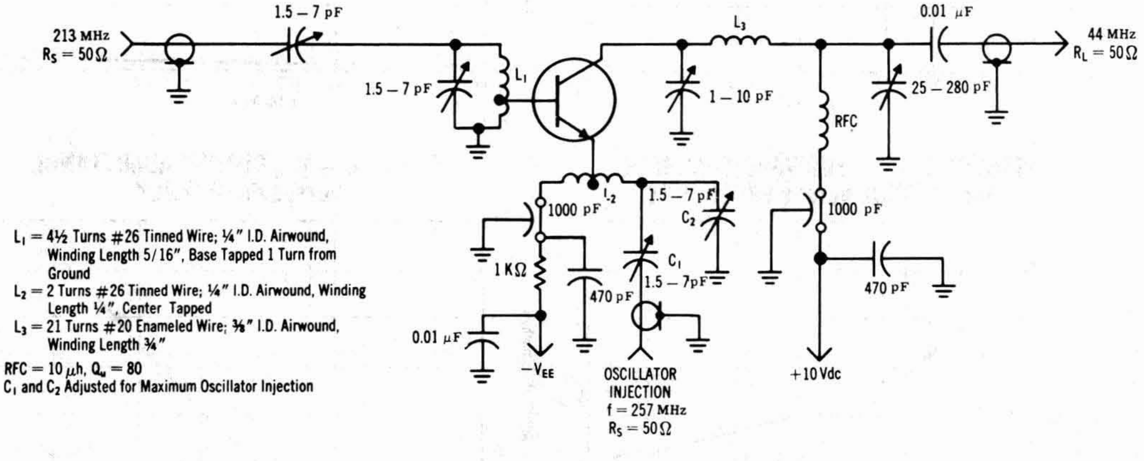
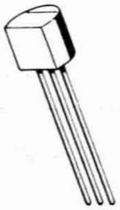


FIGURE 9 — MIXER TEST CIRCUIT


213 MHz
R_S = 50Ω
1.5 – 7 pF
1.5 – 7 pF
L_1
L_2
L_3
1 – 10 pF
RFC
0.01 μF
25 – 280 pF
44 MHz
R_L = 50Ω
1000 pF
1.5 – 7 pF
C_2
C_1
1.5 – 7pF
1 KΩ
470 pF
0.01 μF
$-V_{EE}$
OSCILLATOR INJECTION
f = 257 MHz
R_S = 50Ω
1000 pF
470 pF
+10 Vdc

L_1 = 4½ Turns #26 Tinned Wire; ¼" I.D. Airwound, Winding Length 5/16", Base Tapped 1 Turn from Ground
L_2 = 2 Turns #26 Tinned Wire; ¼" I.D. Airwound, Winding Length ¼", Center Tapped
L_3 = 21 Turns #20 Enameled Wire; ⅜" I.D. Airwound, Winding Length ¾"
RFC = 10 μh, Q_u = 80
C_1 and C_2 Adjusted for Maximum Oscillator Injection

MPS6511 (SILICON)



CASE 29(1)
(TO-92)

NPN silicon transistor designed for use in non-AGC IF applications.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Base Voltage	V_{CB}	30	Volts
Collector-Emitter Voltage	V_{CES}	30	Volts
Collector-Emitter Voltage	V_{CEO}	20	Volts
Emitter-Base Voltage	V_{EB}	3.0	Volts
Collector Current	I_C	100	mAdc
Total Device Dissipation @ $T_A = 60°C$ @ $T_A = 25°C$	P_D	210 310	mW
Junction Temperature	T_J	135	°C

THERMAL RESISTANCE

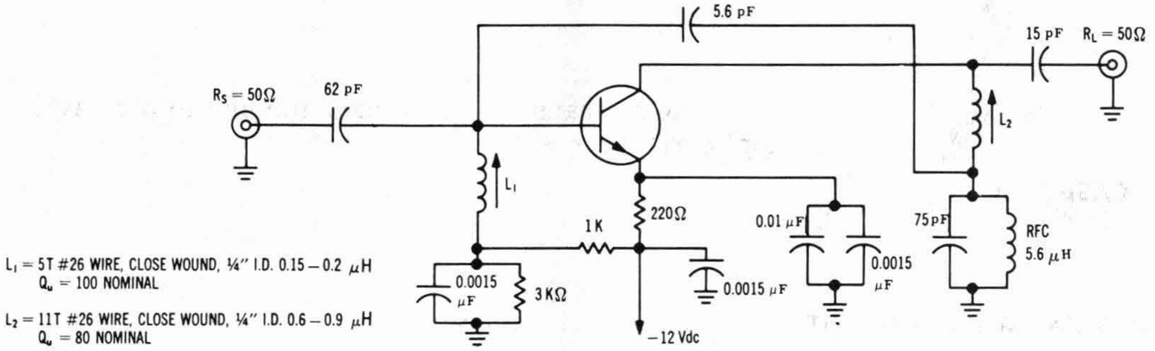
$\theta_{JA(air)} = 0.357$°C/mW

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min	Max	Unit
Collector-Emitter Breakdown Voltage*	BV_{CES}*	I_C = 10 mAdc, V_{EB} = 0	30	—	Vdc
Collector-Emitter Breakdown Voltage	BV_{CEO}	I_C = 0.5 mAdc, I_B = 0	20	—	Vdc
Collector Cutoff Current	I_{CBO}	V_{CB} = 15 Vdc, I_E = 0 V_{CB} = 15 Vdc, I_E = 0, T_A = 60°C	— —	0.05 1.0	μAdc
Current Gain	h_{FE}	V_{CE} = 10 Vdc, I_C = 10 mAdc	25	—	—
Output Capacitance	C_{ob}	V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz	—	2.5	pF
Power Gain	G_{pe}	V_{CC} = 12 Vdc, I_C = 10 mAdc, f = 45 MHz (Figure 1)	30	—	dB

*Pulse Test: PW ≤ 300 μs, duty cycle ≤ 2%.

FIGURE 1 – 45 MHz POWER GAIN TEST CIRCUIT


5.6 pF
15 pF
$R_L = 50\Omega$
$R_S = 50\Omega$
62 pF
L_2
L_1
1 K
220Ω
0.01 μF
75 pF
RFC
5.6 μH
0.0015 μF
3 KΩ
0.0015 μF
0.0015 μF
−12 Vdc

L_1 = 5T #26 WIRE, CLOSE WOUND, ¼" I.D. 0.15 – 0.2 μH
Q_u = 100 NOMINAL

L_2 = 11T #26 WIRE, CLOSE WOUND, ¼" I.D. 0.6 – 0.9 μH
Q_u = 80 NOMINAL

FIGURE 2 — CONTOURS OF CONSTANT GAIN — BANDWIDTH PRODUCT

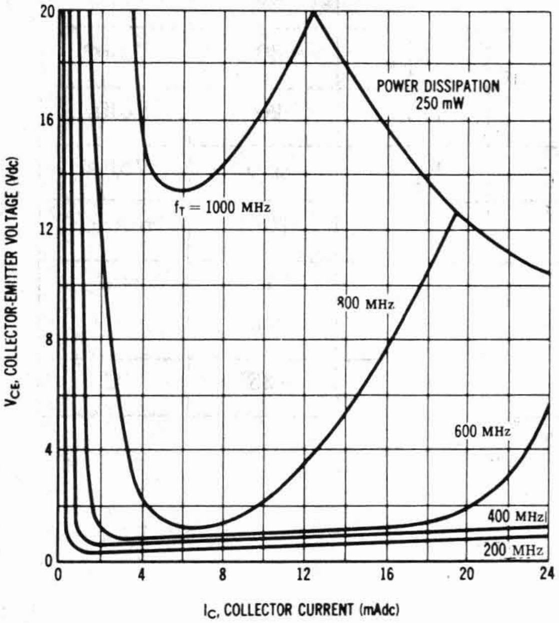


FIGURE 3 — COLLECTOR CURRENT versus COLLECTOR-EMITTER VOLTAGE

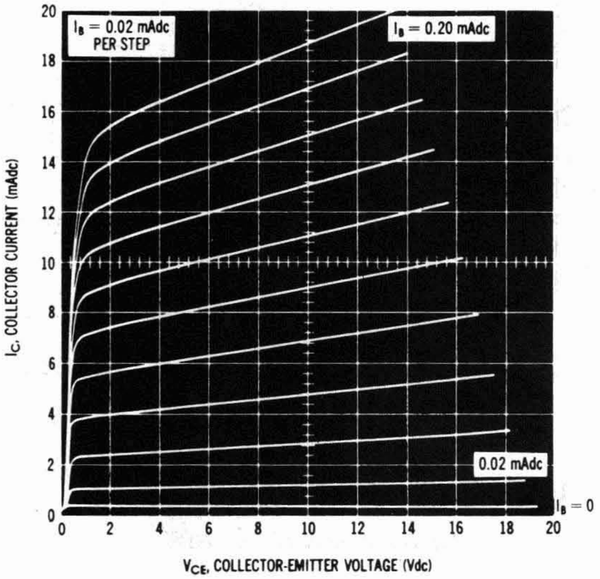


FIGURE 4 — INPUT ADMITTANCE versus COLLECTOR CURRENT

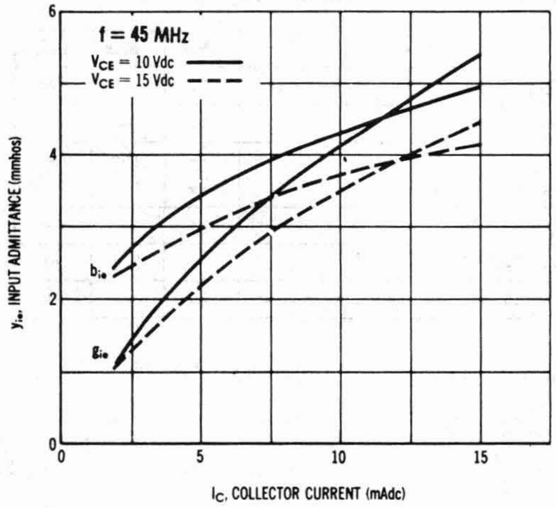


FIGURE 5 — REVERSE TRANSFER ADMITTANCE versus COLLECTOR CURRENT

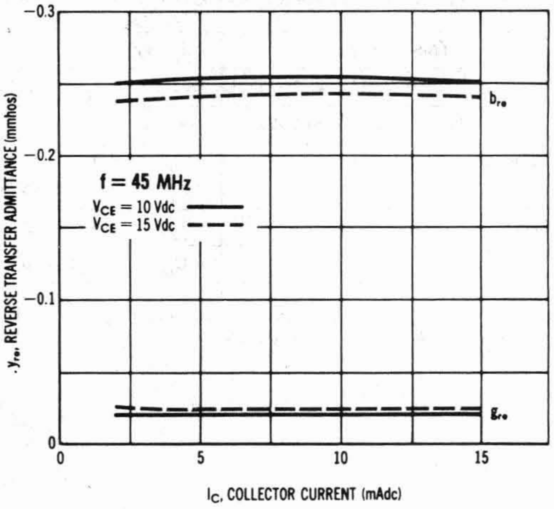


FIGURE 6 — FORWARD TRANSFER ADMITTANCE versus COLLECTOR CURRENT

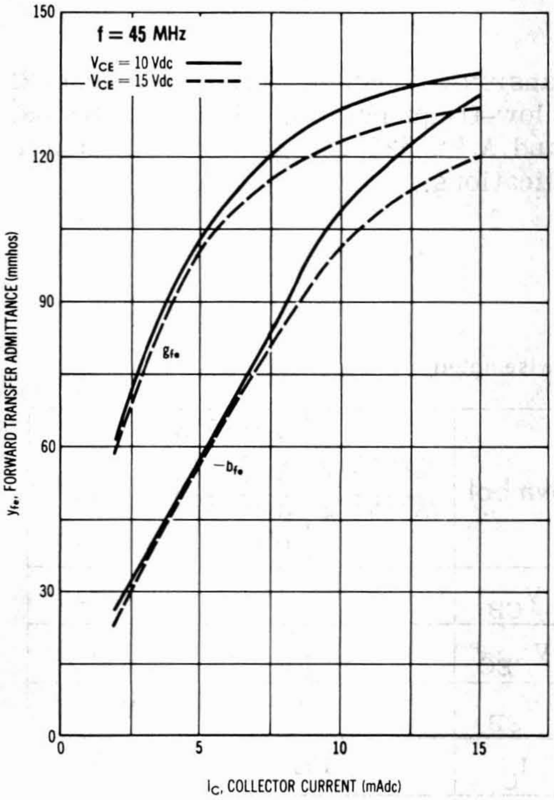


FIGURE 7 — OUTPUT ADMITTANCE versus COLLECTOR CURRENT

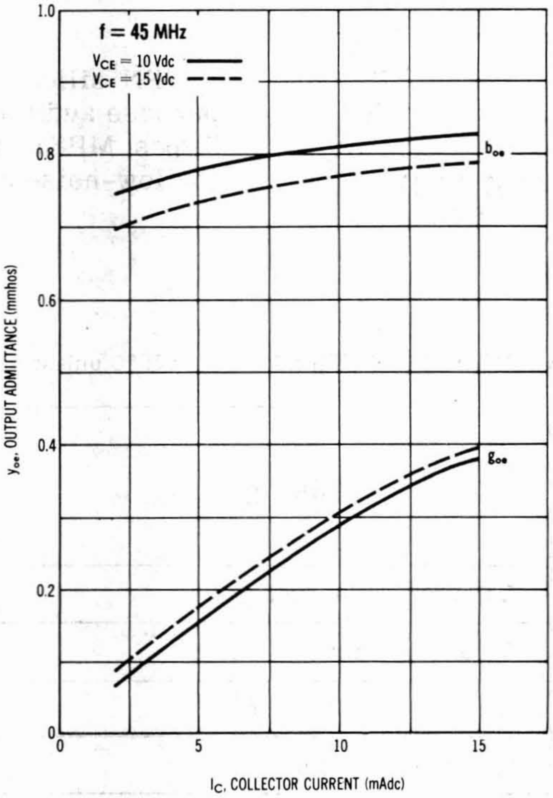
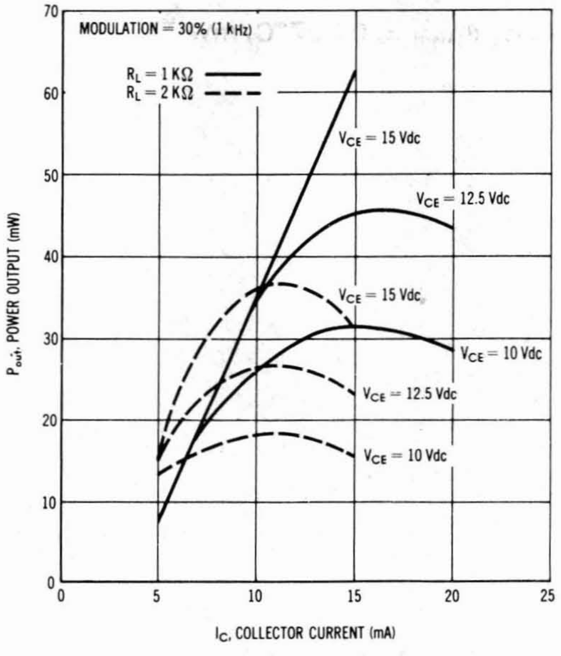
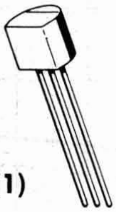


FIGURE 8 — POWER OUTPUT versus COLLECTOR CURRENT

(FOR 3% ENVELOPE DISTORTION)



MPS6512 thru MPS6515 (SILICON)
MPS6520
MPS6521



CASE 29(1)
(TO-92)

NPN silicon transistors designed for use in general-purpose audio and low-frequency amplifier applications. Types MPS6520 and MPS6521 are particularly suited for low-noise applications.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	MPS6512 MPS6513	MPS6514 MPS6515 MPS6520 MPS6521	Unit
Collector-Base Voltage	V_{CB}	40	40	Volts
Collector-Emitter Voltage	V_{CEO}	30	25	Volts
Emitter-Base Voltage	V_{EB}	4.0		Volts
Collector Current	I_C	100		mA
Total Device Dissipation @ T_A = 60°C @ T_A = 25°C	P_D	210 310		mW
Junction Temperature	T_J	135		°C

THERMAL RESISTANCE $\theta_{JA(air)} = 0.357$°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 0.5 mAdc, I_B = 0)	MPS6512, MPS6513	BV_{CEO}	30	—	—	Vdc
	MPS6514, MPS6515		25	—	—	
	MPS6520, MPS6521		25	—	—	
Emitter-Base Breakdown Voltage (I_B = 10 μAdc, I_C = 0)		BV_{EBO}	4.0	—	—	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)		I_{CBO}	—	—	0.05	μAdc
(V_{CB} = 30 Vdc, I_E = 0, T_A = 60°C)			—	—	1.0	
DC Current Gain (I_C = 100 μAdc, V_{CE} = 10 Vdc)	MPS6520	h_{FE}	100	—	—	—
	MPS6521		150	—	—	
(I_C = 2 mAdc, V_{CE} = 10 Vdc)	MPS6512		50	—	100	
	MPS6513		90	—	180	
	MPS6514		150	—	300	
	MPS6515		250	—	500	
	MPS6520		200	—	400	
	MPS6521		300	—	600	
(I_C = 100 mAdc, V_{CE} = 10 Vdc)*	MPS6512		30	—	—	
	MPS6513		60	—	—	
	MPS6514		90	—	—	
	MPS6515		150	—	—	
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 5 mAdc)		$V_{CE(sat)}$	—	—	0.5	Vdc
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	—	—	3.5	pF
Current Gain - Bandwidth Product (I_C = 2 mAdc, V_{CE} = 10 Vdc)	MPS6512, MPS6513	f_T	—	250	—	MHz
	MPS6514, MPS6515		—	390	—	
	MPS6520, MPS6521		—	390	—	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	MPS6512, MPS6513		—	330	—	
	MPS6514, MPS6515		—	480	—	
	MPS6520, MPS6521		—	480	—	
Wideband Noise Figure (V_{CE} = 5 Vdc, I_C = 10 μAdc, R_G = 10 k ohms, Power Bandwidth = 15.7 kHz, 3 dB points @ 10 Hz and 10kHz)	MPS6520, MPS6521	NF	—	1.8	3.0	dB

*Pulse Test: PW ≤ 30 μs, duty cycle ≤ 2%

WIDEBAND NOISE FIGURE versus SOURCE IMPEDANCE

FIGURE 1 — MPS6512 thru MPS6515

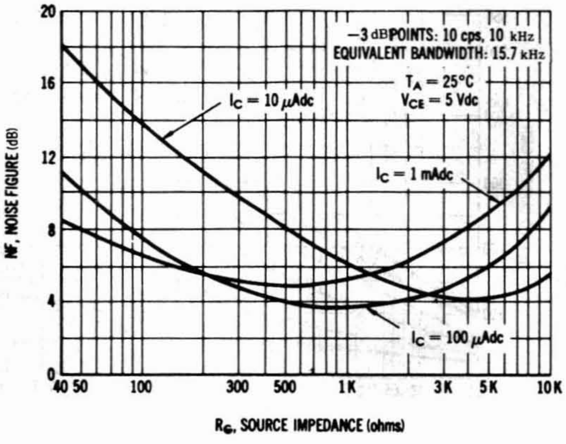
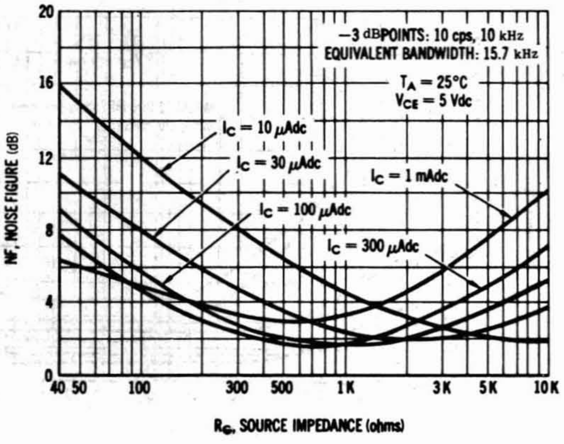


FIGURE 2 — MPS6520, MPS6521



COLLECTOR CHARACTERISTICS — COMMON EMITTER

FIGURE 3 — MPS6512

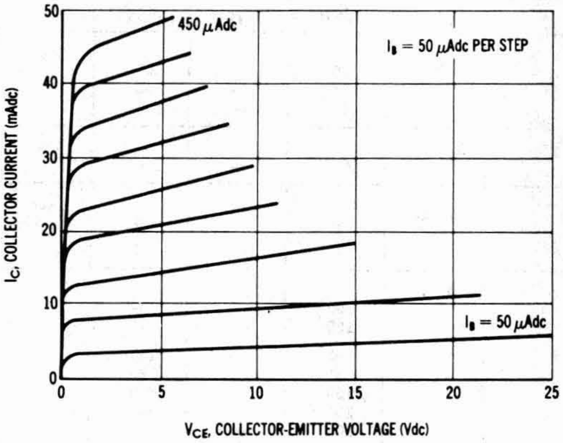


FIGURE 4 — MPS6513

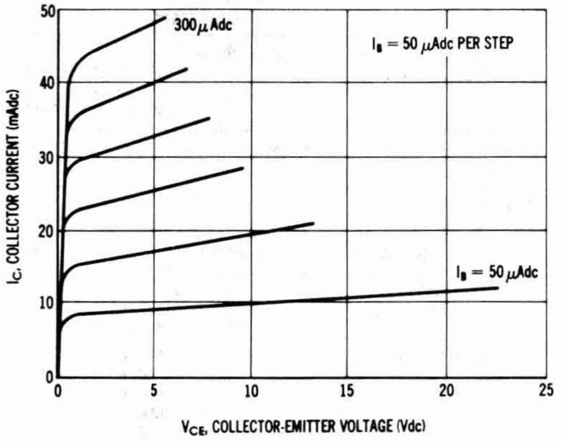


FIGURE 5 — MPS6514, MPS6520

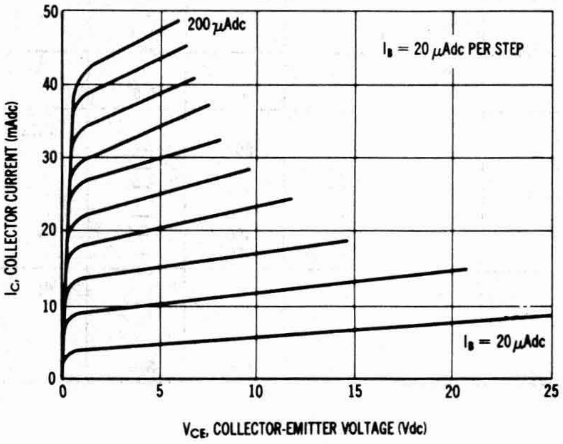


FIGURE 6 — MPS6515, MPS6521

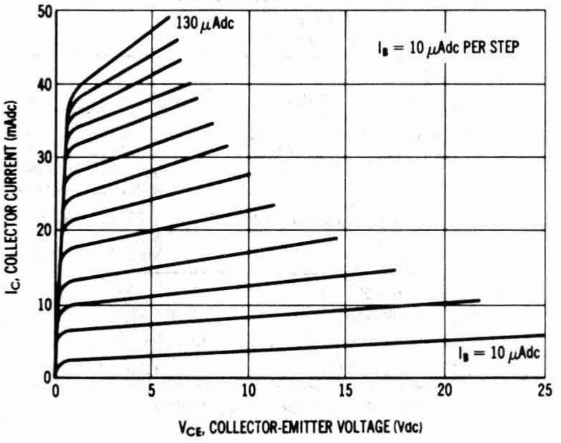


FIGURE 7 — SPOT NOISE FIGURE versus FREQUENCY

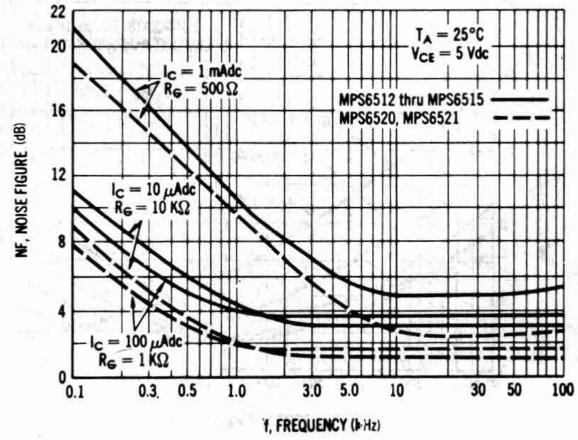
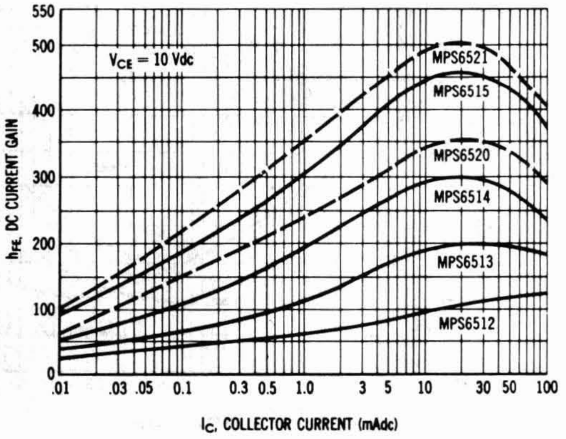


FIGURE 8 — DC CURRENT GAIN versus COLLECTOR CURRENT



h PARAMETER VARIATIONS
($f = 1$ MHz, $T_A = 25°C$)

FIGURE 9 — INPUT IMPEDANCE versus COLLECTOR CURRENT

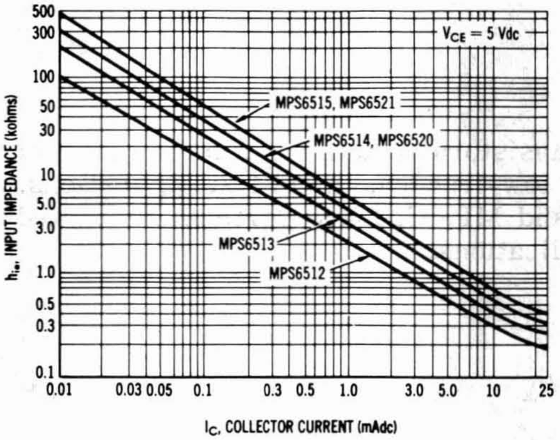


FIGURE 10 — REVERSE VOLTAGE TRANSFER RATIO versus COLLECTOR CURRENT

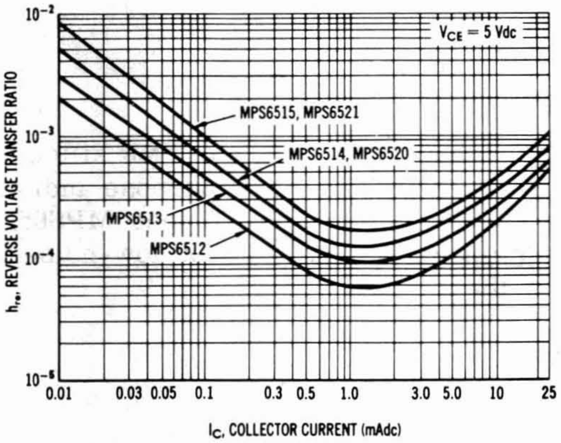


FIGURE 11 — SMALL SIGNAL CURRENT GAIN versus COLLECTOR CURRENT

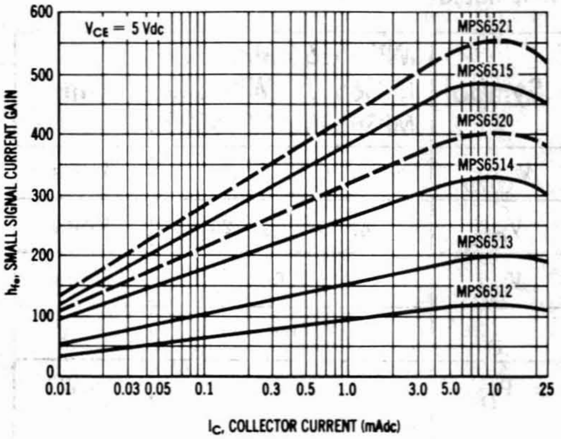


FIGURE 12 — OUTPUT ADMITTANCE versus COLLECTOR CURRENT

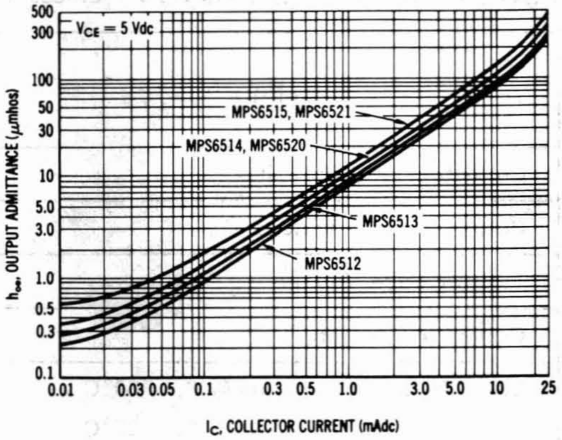


FIGURE 13 — GAIN — BANDWIDTH PRODUCT versus COLLECTOR CURRENT

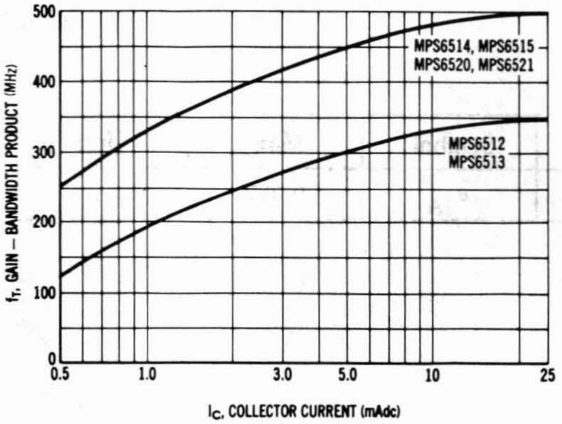
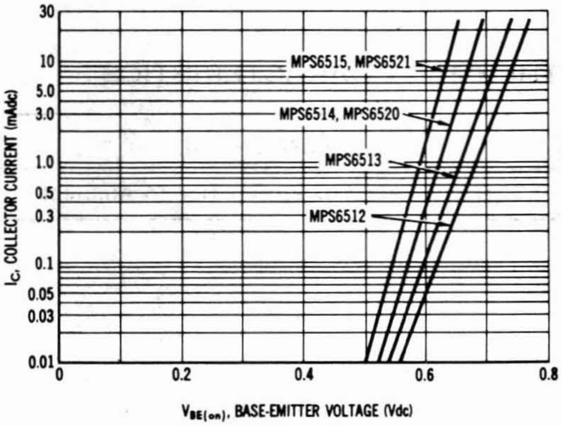
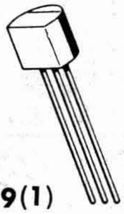


FIGURE 14 — COLLECTOR CURRENT versus BASE-EMITTER TURN-ON VOLTAGE



MPS6516 thru MPS6519 (SILICON)
MPS6522
MPS6523



CASE 29(1)
(TO-92)

PNP silicon transistors designed for use in general purpose audio and low-frequency amplifier applications. Types MPS6522 and MPS6523 are particularly suited for low-noise applications.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	MPS6516 MPS6517 MPS6518	MPS6519 MPS6522 MPS6523	Unit
Collector-Emitter Voltage	V_{CEO}	40	25	Volts
Collector-Base Voltage	V_{CB}	40	25	Volts
Emitter Base Voltage	V_{EB}	4.0		Volts
Collector Current	I_C	100		mA
Total Device Dissipation @ T_A = 60°C @ T_A = 25°C	P_D	210 310		mW
Junction Temperature	T_J	135		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

MPS6516 thru MPS6519, MPS6522, MPS6523 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 0.5 mAdc, I_B = 0)	MPS6516 thru MPS6518 MPS6519, MPS6522, MPS6523	BV_{CEO}	40 25	— —	— —	Vdc
Emitter-Base Breakdown Voltage (I_B = 10 μAdc, I_C = 0)		BV_{EBO}	4.0	—	—	Vdc
Collector Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 30 Vdc, I_E = 0)	MPS6516 thur MPS6518		—	—	0.05	
(V_{CB} = 20 Vdc, I_E = 0)	MPS6519, MPS6522, MPS6523		—	—	0.05	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 60°C)	MPS6516 thru MPS 6518		—	—	1.0	
(V_{CB} = 20 Vdc, I_E = 0, T_A = 60°C)	MPS6519, MPS6522, MPS6523		—	—	1.0	
DC Current Gain		h_{FE}				—
(I_C = 100 μAdc, V_{CE} = 10 Vdc)	MPS6522 MPS6523		100 150	— —	— —	
(I_C = 2 mAdc, V_{CE} = 10 Vdc)	MPS6516 MPS6517 MPS6518 MPS6519 MPS6522 MPS6523		50 90 150 250 200 300	— — — — — —	100 180 300 500 400 600	
(I_C = 100 mAdc, V_{CE} = 10 Vdc)	MPS6516 MPS6517 MPS6518 MPS6519		30 60 90 150	— — — —	— — — —	
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 5 mAdc)		$V_{CE(sat)}$	—	—	0.5	Vdc
Current Gain — Bandwidth Product		f_T				MHz
(I_C = 2 mAdc, V_{CE} = 10 Vdc)	MPS6516, MPS6517 MPS6518, MPS6519 MPS6522, MPS6523		— — —	200 340 340	— — —	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	MPS6516, MPS6517 MPS6518, MPS6519 MPS6522, MPS6523		— — —	270 420 420	— — —	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	MPS6516 thru MPS6519 MPS6522, MPS6523	C_{ob}	— —	— —	4.0 4.0	pF
Wideband Noise Figure (V_{CE} = 5 Vdc, I_C = 10 μAdc, R_S = 10 kohms, Power Bandwidth = 15.7 kHz, 3 dB points @ 10 Hz and 10 kHz)	MPS6522, MPS6523	NF	—	1.8	3.0	dB

*Pulse Test: Pulse Width < 30 μs, duty cycle ≤ 2%

WIDEBAND NOISE FIGURE versus SOURCE IMPEDANCE

FIGURE 1 — MPS6516 thru MPS6519

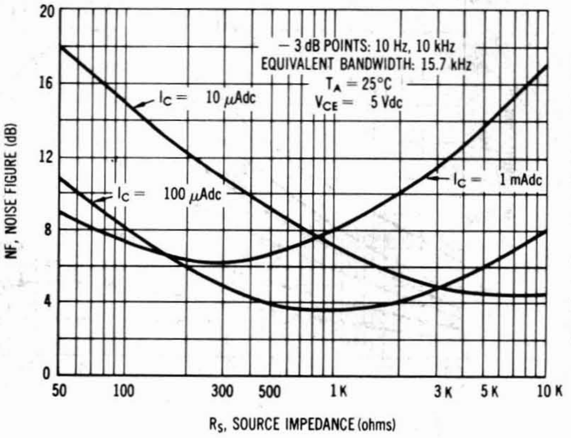
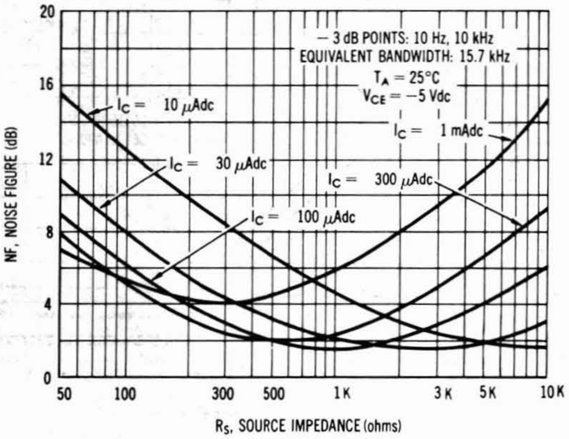


FIGURE 2 — MPS6522, MPS6523



COLLECTOR CHARACTERISTICS — COMMON EMITTER

FIGURE 3 — MPS6516

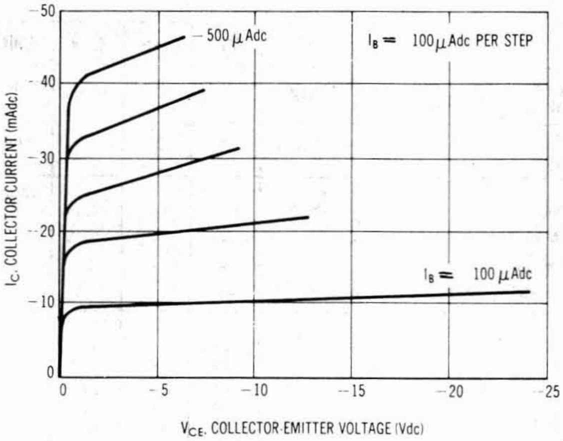


FIGURE 4 — MPS6517

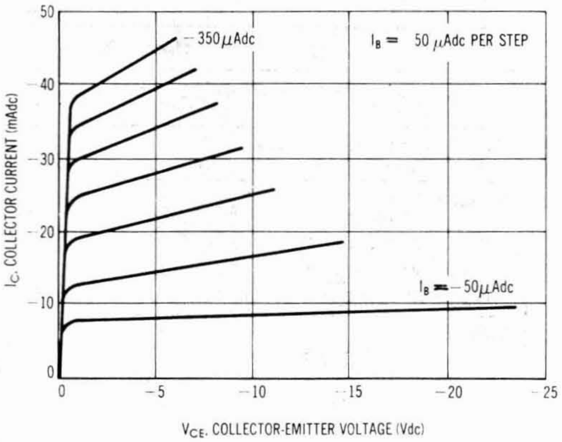


FIGURE 5 — MPS6518, MPS6522

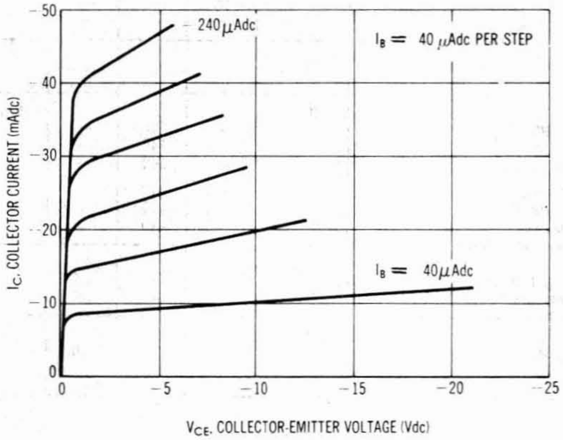


FIGURE 6 — MPS6519, MPS6523

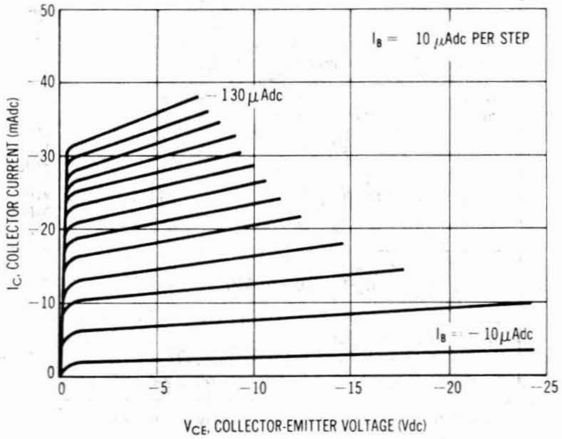


FIGURE 7 — SPOT NOISE FIGURE versus FREQUENCY

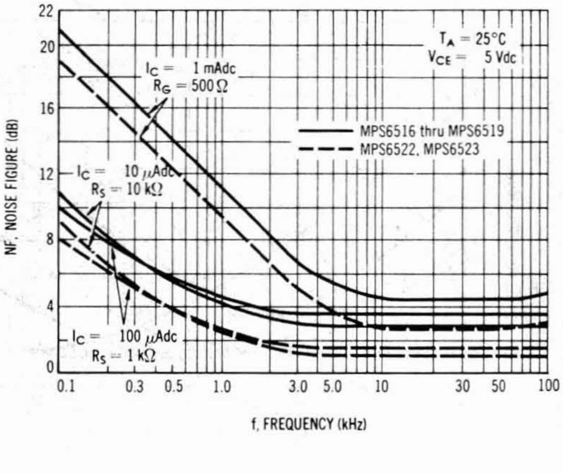
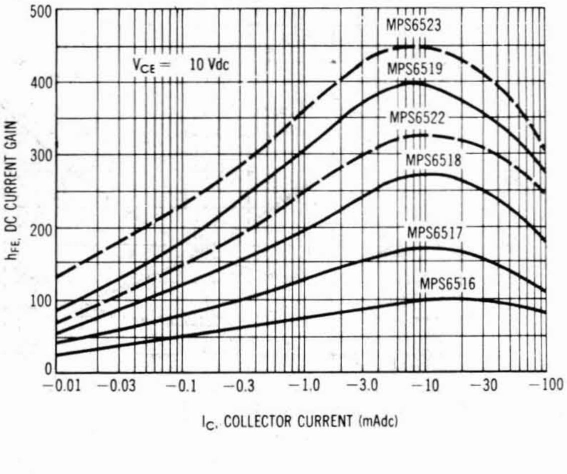


FIGURE 8 — DC CURRENT GAIN versus COLLECTOR CURRENT



h PARAMETER VARIATIONS
($f = 1$ kHz, $T_A = 25°C$)

FIGURE 9 — INPUT IMPEDANCE versus COLLECTOR CURRENT

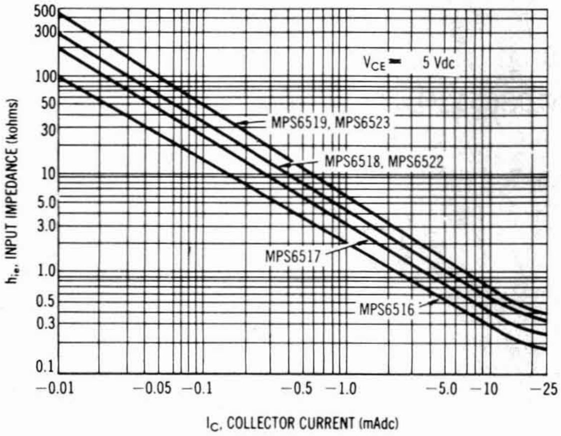


FIGURE 10 — REVERSE VOLTAGE TRANSFER RATIO versus COLLECTOR CURRENT

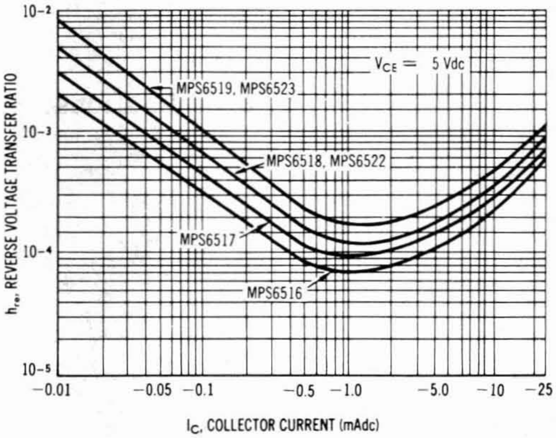


FIGURE 11 — SMALL-SIGNAL CURRENT GAIN versus COLLECTOR CURRENT

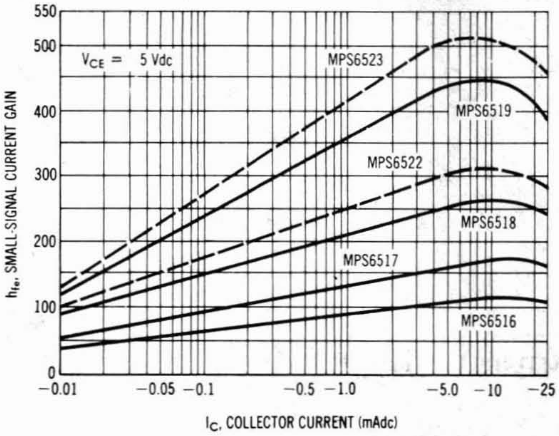


FIGURE 12 — OUTPUT ADMITTANCE versus COLLECTOR CURRENT

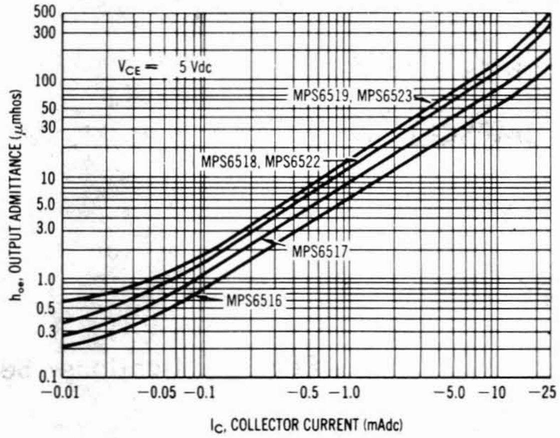


FIGURE 13 — GAIN — BANDWIDTH PRODUCT versus COLLECTOR CURRENT

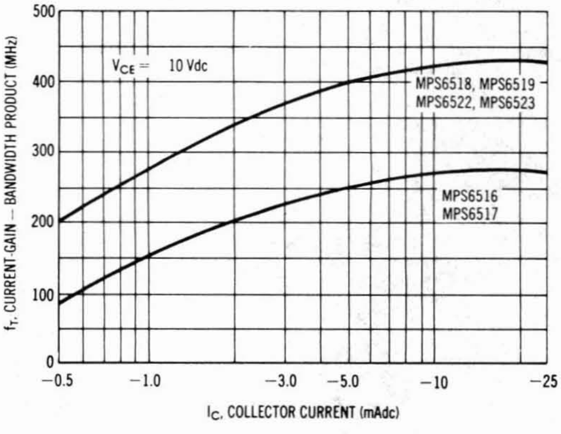
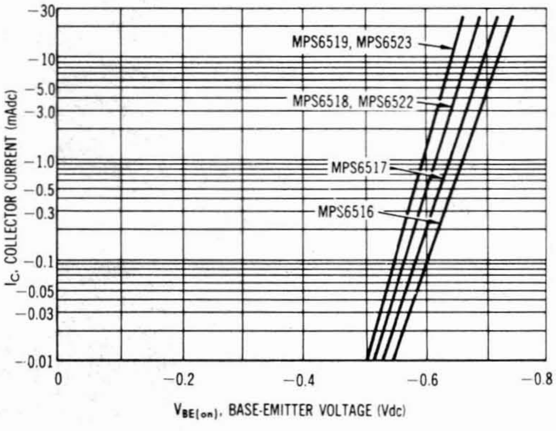


FIGURE 14 — COLLECTOR CURRENT versus BASE-EMITTER TURN-ON VOLTAGE



MPS6520
MPS6521

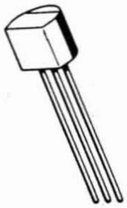
For Specifications, See MPS6512 Data.

MPS6522
MPS6523

For Specifications, See MPS6516 Data.

MPS6530
MPS6531 } **NPN (SILICON)**
MPS6532

MPS6533
MPS6534 } **PNP**
MPS6535



CASE 29(1)
(TO-92)

Silicon annular transistors designed for use in complementary amplifier circuits.

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	NPN	PNP	Unit
Collector-Base Voltage	V_{CB}			Vdc
MPS6530, MPS6531		60		
MPS6532		50		
MPS6533, MPS6534			40	
MPS6535			30	
Collector-Emitter Voltage	V_{CEO}			Vdc
MPS6530, MPS6531		40		
MPS6532		30		
MPS6533, MPS6534			40	
MPS6535			30	
Emitter-Base Voltage	V_{EB}	5.0	4.0	Vdc
Collector Current	I_C	600	600	mAdc
Total Device Dissipation @ T_A = 60°C	P_D	210	210	mW
@ T_A = 25°C		310	310	
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	0.357	°C/mW
Junction Temperature	T_J	135	135	°C

MPS6530 thru MPS6532 (NPN)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	MPS6530, MPS6531	BV_{CBO}	60	-	-	Vdc
(I_C = 10 μAdc, I_E = 0)	MPS6532		50	-	-	
Collector-Emitter Breakdown Voltage	MPS6530, MPS6531	BV_{CEO}	40	-	-	Vdc
(I_C = 10 mAdc, I_B = 0)	MPS6532		30	-	-	
Emitter-Base Breakdown Voltage (I_B = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	-	-	Vdc
Collector Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 40 Vdc, I_E = 0)	MPS6530, MPS6531		-	-	0.05	
(V_{CB} = 30 Vdc, I_E = 0)	MPS6532		-	-	0.1	
(V_{CB} = 40 Vdc, I_E = 0, T_A = 60°C)	MPS6530, MPS6531		-	-	2.0	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 60°C)	MPS6532		-	-	5.0	
DC Current Gain		h_{FE}				-
(I_C = 10 mAdc, V_{CE} = 1 Vdc)	MPS6530		30	75	-	
	MPS6531		60	120	-	
(I_C = 100 mAdc, V_{CE} = 1 Vdc)	MPS6530		40	85	120	
	MPS6531		90	150	270	
	MPS6532		30	-	-	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)	MPS6530		25	60	-	
	MPS6531		50	80	-	
Collector-Emitter Saturation Voltage	MPS6530, MPS6532	$V_{CE(sat)}$	-	0.2	0.5	Vdc
(I_C = 100 mAdc, I_B = 10 mAdc)	MPS6531		-	0.13	0.3	
Base-Emitter Saturation Voltage	MPS6530, MPS6531	$V_{BE(sat)}$	-	0.82	1.0	Vdc
(I_C = 100 mAdc, I_B = 10 mAdc)	MPS6532		-	0.85	1.2	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	3.5	5.0	pF
Current-Gain–Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc)		f_T	-	390	-	MHz

MPS6533 thru MPS6535 (PNP)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Collector-Base Breakdown Voltage	MPS6533, MPS6534	BV_{CBO}	40	-	-	Vdc
(I_C = 10 μAdc, I_E = 0)	MPS6535		30	-	-	
Collector-Emitter Breakdown Voltage	MPS6533, MPS6534	BV_{CEO}	40	-	-	Vdc
(I_C = 10 mAdc, I_B = 0)	MPS6535		30	-	-	
Emitter-Base Breakdown Voltage (I_B = 10 μAdc, I_C = 0)		BV_{EBO}	4.0	-	-	Vdc
Collector Cutoff Current		I_{CBO}				μAdc
(V_{CB} = 30 Vdc, I_E = 0)	MPS6533, MPS6534		-	-	0.05	
(V_{CB} = 20 Vdc, I_E = 0)	MPS6535		-	-	0.1	
(V_{CB} = 30 Vdc, I_E = 0, T_A = 60°C)	MPS6533, MPS6534		-	-	2.0	
(V_{CB} = 20 Vdc, I_E = 0, T_A = 60°C)	MPS6535		-	-	5.0	
DC Current Gain		h_{FE}				-
(I_C = 10 mAdc, V_{CE} = 1 Vdc)	MPS6533		30	70	-	
	MPS6534		60	110	-	
(I_C = 100 mAdc, V_{CE} = 1 Vdc)	MPS6533		40	85	120	
	MPS6534		90	140	270	
	MPS6535		30	-	-	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)	MPS6533		25	55	-	
	MPS6534		50	70	-	
Collector-Emitter Saturation Voltage	MPS6533, MPS6535	$V_{CE(sat)}$	-	0.2	0.5	Vdc
(I_C = 100 mAdc, I_B = 10 mAdc)	MPS6534		-	0.13	0.3	
Base-Emitter Saturation Voltage	MPS6533, MPS6534	$V_{BE(sat)}$	-	0.84	1.0	Vdc
(I_C = 100 mAdc, I_B = 10 mAdc)	MPS6535		-	0.87	1.2	
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	4.8	6.0	pF
Current-Gain–Bandwidth Product (I_C = 50 mAdc, V_{CE} = 10 Vdc)		f_T	-	260	-	MHz

MPS6539 (SILICON)

NPN silicon epitaxial transistor designed for RF applications in FM receivers.

CASE 29(2)
TO-92

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	20	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

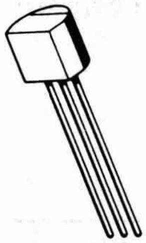
Characteristics	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristics	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 500 μAdc, I_B = 0)	BV_{CEO}	20	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	20	-	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0)	I_{CBO}	-	50	nAdc
Emitter Cutoff Current ($V_{EB(off)}$ = 3.0 Vdc, I_C = 0)	I_{EBO}	-	100	nAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 4.0 mAdc, V_{CE} = 10 Vdc)	h_{FE}	20	-	-
Base-Emitter On Voltage (I_C = 4.0 mAdc, V_{CE} = 10 Vdc)	$V_{BE(on)}$	-	0.85	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 4.0 mAdc, V_{CE} = 10 Vdc, f = 100 mHz)	f_T	500	-	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{cb}	-	0.7	pF
Collector-Base Time Constant (I_E = 4.0 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)	$r_b'C_c$	-	9.0	ps
Noise Figure (I_C = 4.0 mAdc, V_{CE} = 10 Vdc, R_S = 75 ohms, f = 100 MHz)	NF	-	4.5	dB

MPS6540 (SILICON)

NPN silicon annular amplifier transistor designed for IF applications in FM radio receivers.



CASE 29(2)
TO-92

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)	BV_{CEO}	30	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	30	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 25 Vdc, I_E = 0)	I_{CBO}	-	-	100	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 2.0 mAdc, V_{CE} = 10 Vdc)	h_{FE}	25	-	-	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	-	-	0.5	Vdc
Base-Emitter On Voltage (I_C = 10 mAdc, V_{CE} = 5.0 Vdc)	$V_{BE(on)}$	-	-	0.95	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	350	-	-	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{cb}	-	-	0.65	pF
Real Part of Output Impedance (I_C = 2.0 mAdc, V_{CE} = 10 Vdc, f = 10.7 MHz)	R_{oep}	80	-	-	k ohms
Collector-Base Time Constant (I_E = 4.0 mAdc, V_{CB} = 10 Vdc, f = 31.8 MHz)	$r_b'C_c$	-	4.5	-	ps
FUNCTIONAL TESTS					
Maximum Available Gain (f = 10.7 MHz)	MAG	-	48	-	dB

COMMON-EMITTER y PARAMETERS

(V_{CE} = 10 Vdc, f = 10.7 MHz, T_A = 25°C)

FIGURE 1 — INPUT ADMITTANCE

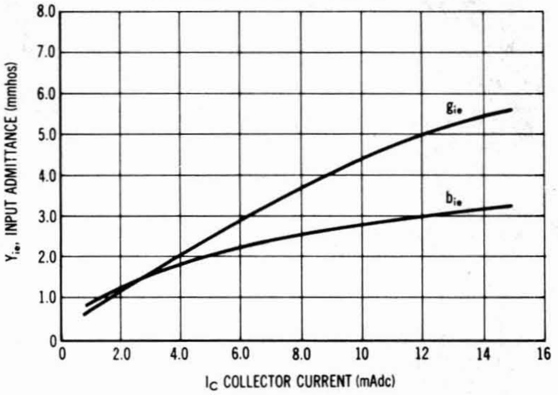


FIGURE 2 — REVERSE TRANSFER ADMITTANCE

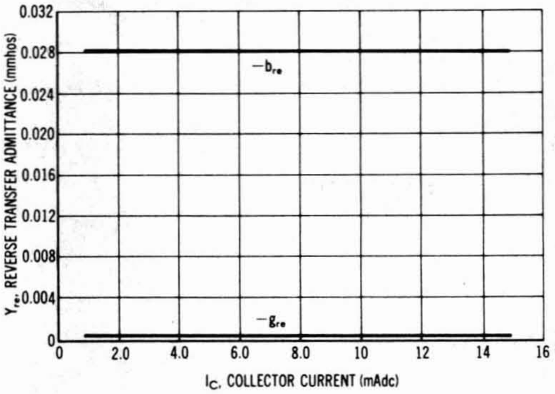


FIGURE 3 — FORWARD TRANSFER ADMITTANCE

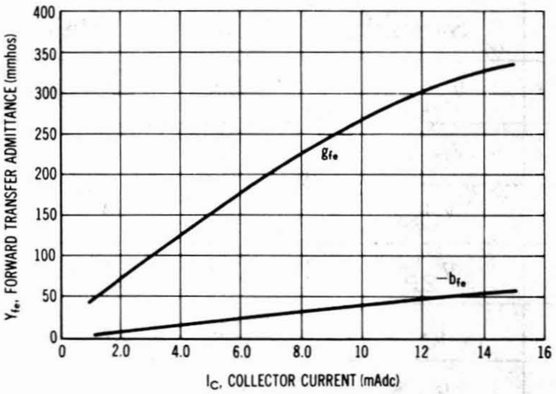


FIGURE 4 — OUTPUT ADMITTANCE

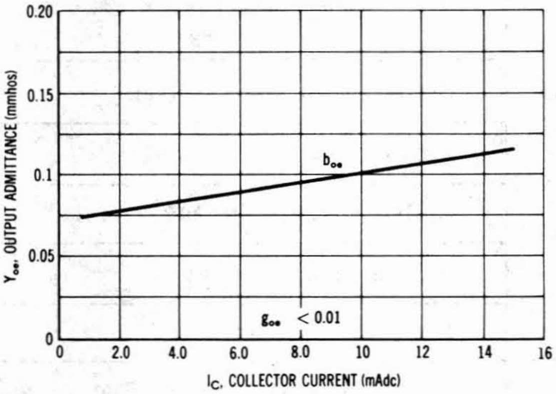


FIGURE 5 — CAPACITANCES

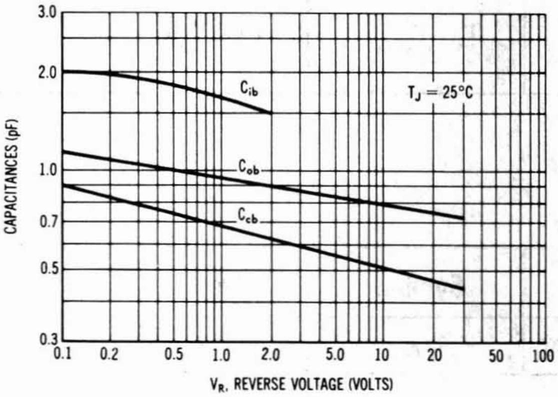
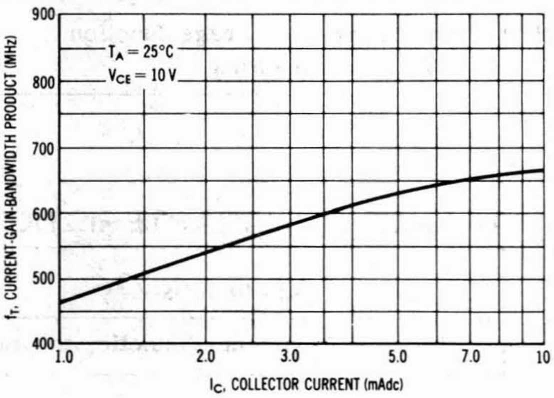
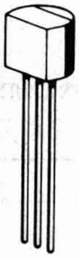


FIGURE 6 — CURRENT-GAIN—BANDWIDTH PRODUCT



MPS6542 (SILICON)



CASE 29(2)
TO-92

NPN silicon epitaxial transistor designed for VHF mixer applications in TV receivers.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Emitter Voltage	V_{CES}	30	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current	I_C	100	mAdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	310 2.81	mW mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	^oC/mW

MPS6542 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)	BV_{CEO}	20	—	—	Vdc
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, V_{BE} = 0)	BV_{CES}*	30	—	—	Vdc
Collector Cutoff Current (V_{CB} = 15 Vdc, I_E = 0) (V_{CB} = 15 Vdc, I_E = 0, T_A = 60°C)	I_{CBO}	— —	— —	0.05 1.0	μAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 2 mAdc, V_{CE} = 10 Vdc)	h_{FE}	25	—	—	—
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	700	—	—	MHz
Common-Emitter Reverse Transfer Capacitance (V_{CB} = 10 Vdc)	C_{re}	—	0.33	—	pF
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	—	1.5	pF
High-Frequency Current Gain (I_C = 2 mAdc, V_{CE} = 10 Vdc, f = 44 MHz)	h_{fe}	10	—	—	—
Conversion Gain (213 to 44 MHz) (I_C = 2.5 mAdc, V_{CE} = 10 Vdc, See Figures 1, 2, & 9)	—	20	23	—	dB

*Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2%

CONVERSION GAIN CHARACTERISTICS

(TEST CIRCUIT FIGURE 9)

FIGURE 1 — VARIATION WITH COLLECTOR CURRENT

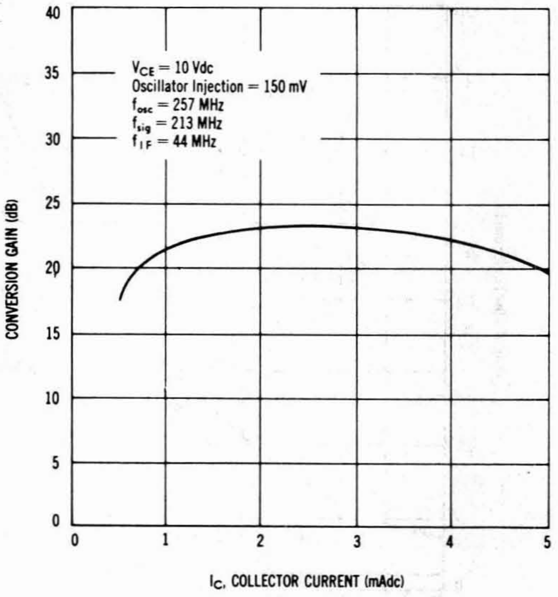
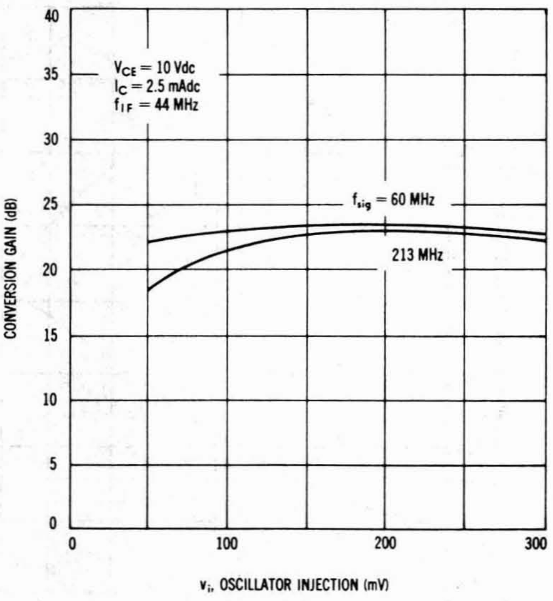


FIGURE 2 — VARIATION WITH INJECTION LEVEL



COMMON-EMITTER y PARAMETERS

$I_C = 2.5$ mAdc, $V_{CE} = 10$ Vdc, $T_A = 25°C$

FIGURE 3 — INPUT ADMITTANCE

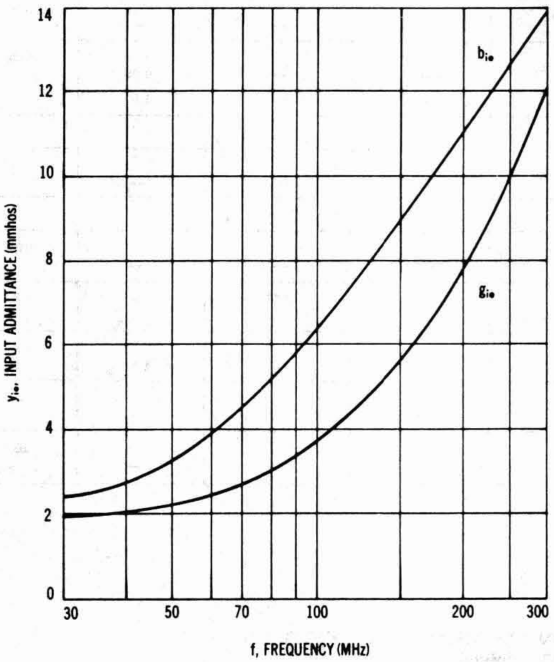


FIGURE 4 — REVERSE TRANSFER ADMITTANCE

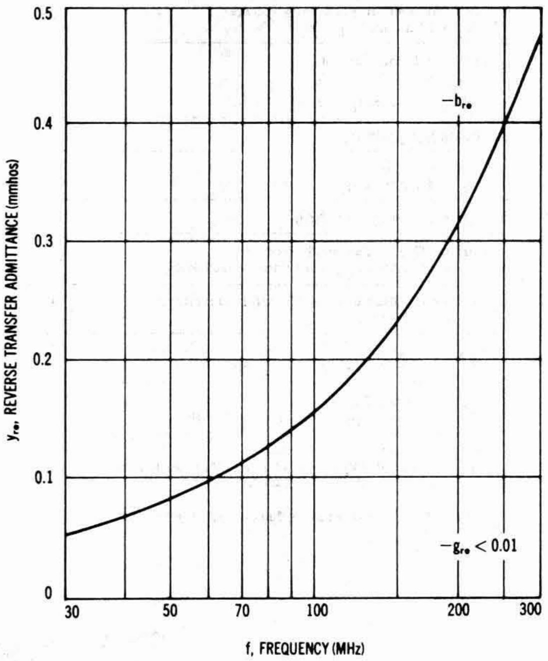


FIGURE 5 — FORWARD TRANSFER ADMITTANCE

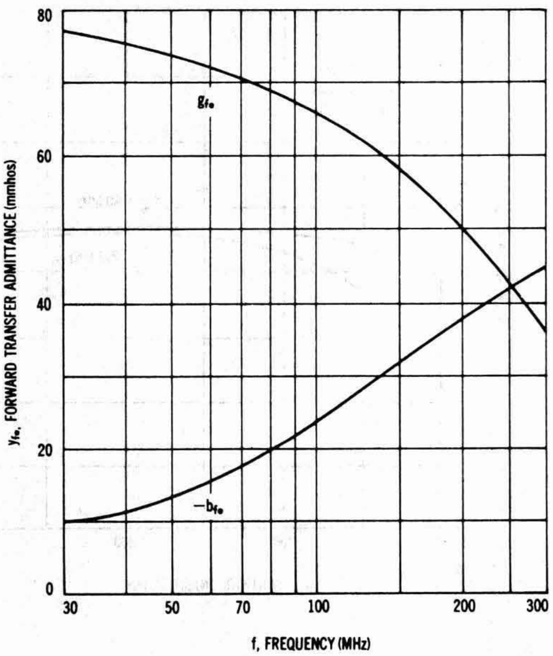


FIGURE 6 — OUTPUT ADMITTANCE

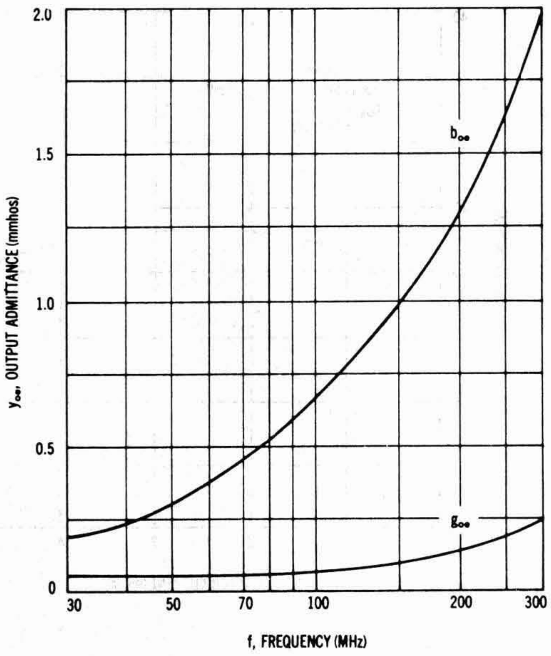


FIGURE 7 — DC CURRENT GAIN

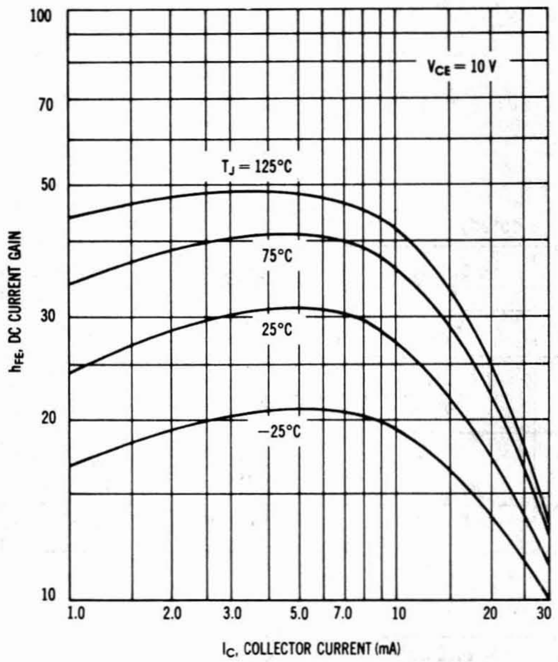


FIGURE 8 — CAPACITANCES

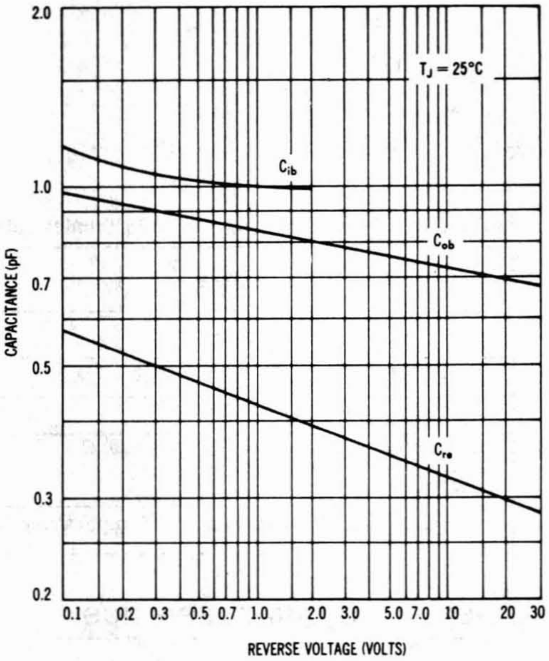
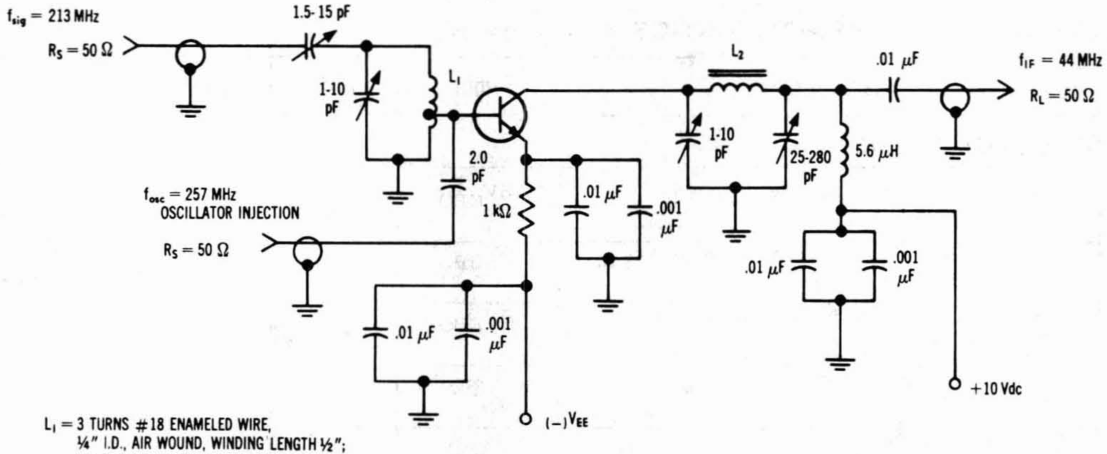


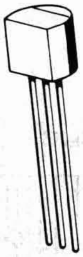
FIGURE 9 — MIXER TEST CIRCUIT


f_{sig} = 213 MHz
R_S = 50 Ω
1.5-15 pF
1-10 pF
L_1
2.0 pF
f_{osc} = 257 MHz
OSCILLATOR INJECTION
R_S = 50 Ω
1 kΩ
.01 µF
.001 µF
.01 µF
.001 µF
(−)V_{EE}
L_2
1-10 pF
25-280 pF
5.6 µH
.01 µF
.01 µF
.001 µF
f_{IF} = 44 MHz
R_L = 50 Ω
+10 Vdc

L_1 = 3 TURNS #18 ENAMELED WIRE,
¼″ I.D., AIR WOUND, WINDING LENGTH ½″;
BASE TAPPED 1 TURN FROM GROUND.

L_2 = 10 TURNS #26 INSULATED WIRE,
WOUND ON ¼″ I.D. COIL FORM,
ARNOLD PART NO. A1-10 IRON POWDER CORE.

MPS6543 (SILICON)



CASE 29 (2)
(TO-92)

NPN silicon epitaxial transistor designed for use in UHF oscillator applications.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Base Voltage	V_{CB}	35	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	310 2.81	mW mW/^oC
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	^oC

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	^oC/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)	BV_{CEO}	25	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	35	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3.0	—	Vdc
Collector Cutoff Current (V_{CB} = 25 Vdc, I_E = 0)	I_{CBO}	—	0.1	μAdc
Emitter Cutoff Current (V_{BE} = 2 Vdc, I_C = 0)	I_{EBO}	—	1.0	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 4 mAdc, V_{CE} = 10 Vdc)	h_{FE}	25	—	—
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$	—	0.35	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{BE(sat)}$	—	0.95	Vdc

MPS6543 (Continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product (I_C = 4 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	f_T	750	—	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	1.0	pF
Collector-Base Time Constant (I_E = 4 mAdc, V_{CE} = 10 Vdc, f = 31.8 MHz)	$r_b'C_c$	—	9.5	ps

COMMON-BASE y PARAMETERS

V_{CB} = 10 Vdc, f = 930 MHz, T_A = 25°C

FIGURE 1—INPUT ADMITTANCE

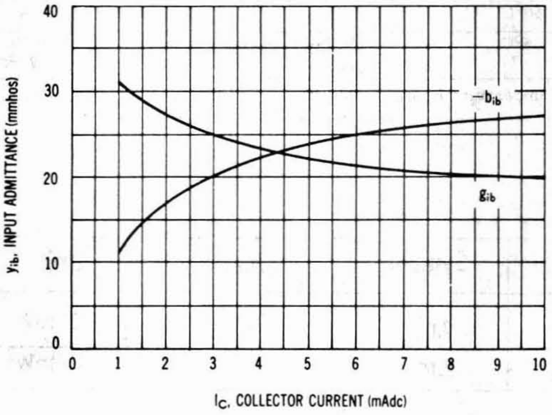


FIGURE 2—REVERSE TRANSFER ADMITTANCE

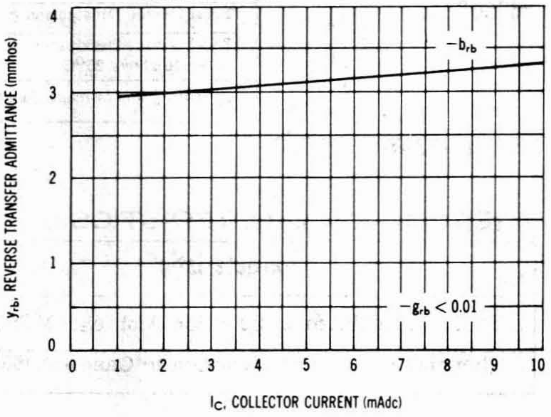


FIGURE 3—FORWARD TRANSFER ADMITTANCE

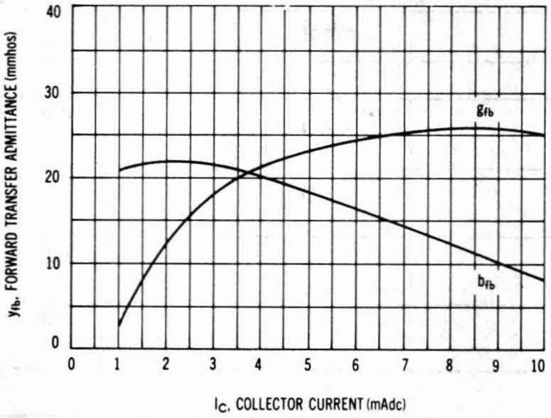


FIGURE 4—OUTPUT ADMITTANCE

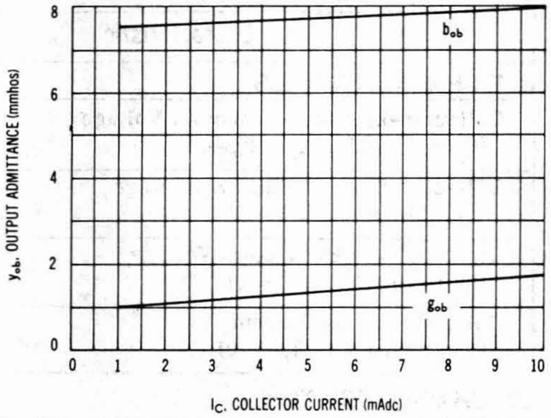


FIGURE 5—CAPACITANCES

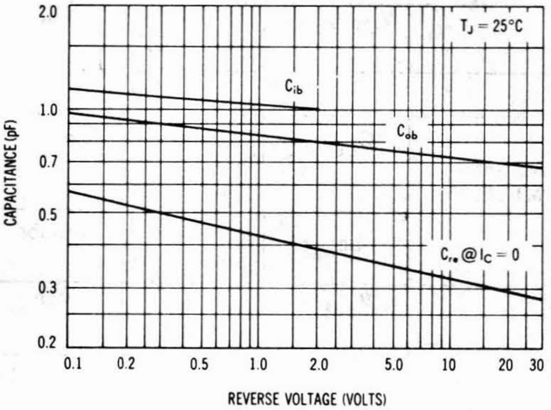
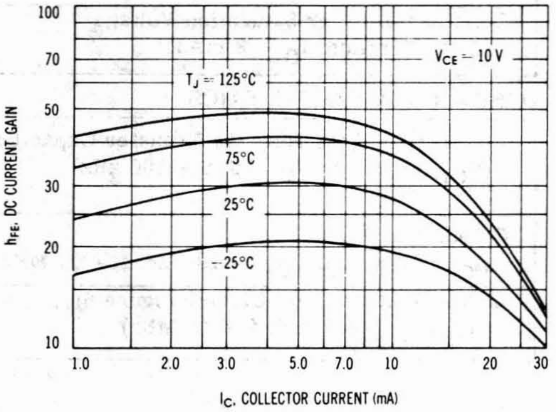
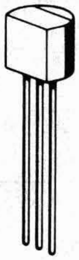


FIGURE 6—DC CURRENT GAIN



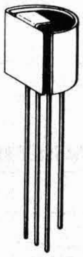
MPS6544 (SILICON)
MPS6545

CASE 29 (2)
TO-92



MPS6544

CASE 29A



MPS6545
TO-92 WITH SHIELD

NPN silicon annular amplifier transistors designed for third-stage video IF applications in television receivers.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	45	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Total Device Dissipation @ T_A = 60°C	P_D	210	mW
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction Ambient - MPS6544	θ_{JA}	0.357	°C/mW
Thermal Resistance, Junction to Case - MPS6545	θ_{JC}	0.150	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_E = 0)	BV_{CEO}	45	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	4.0	—	Vdc
Collector Cutoff Current (V_{CB} = 35 Vdc, I_E = 0)	I_{CBO}	—	0.5	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 30 mAdc, V_{CE} = 10 Vdc)	h_{FE}	20	—	—
Collector-Emitter Saturation Voltage (I_C = 30 mAdc, I_B = 3 mAdc)	$V_{CE(sat)}$	—	0.5	Vdc
DYNAMIC CHARACTERISTICS				
Common-Emitter Reverse Transfer Capacitance (V_{CB} = 10 Vdc, I_C = 0, f = 100 kHz) MPS6544 MPS6545	C_{re}	— —	0.65 0.58	pF
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 45 MHz)	y_{oe}	—	0.10	mmhos
Output Voltage (Test Circuit Figure 6) ($V_{in(RMS)}$ =12 mV, f = 45 MHz)	V_{out}	1.0	—	Vdc

COMMON-EMITTER y PARAMETERS

V_{CE} = 20 Vdc, f = 45 MHz, T_A = 25°C

FIGURE 1 — INPUT ADMITTANCE

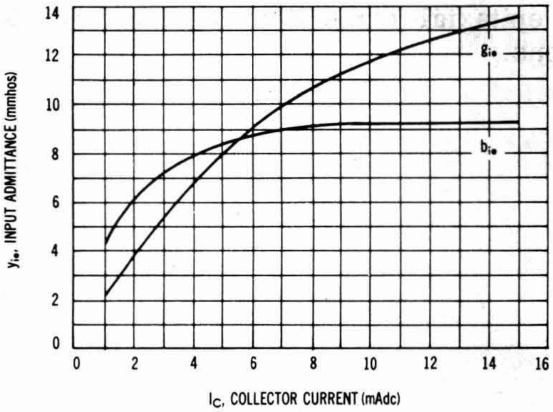


FIGURE 2 — REVERSE TRANSFER ADMITTANCE

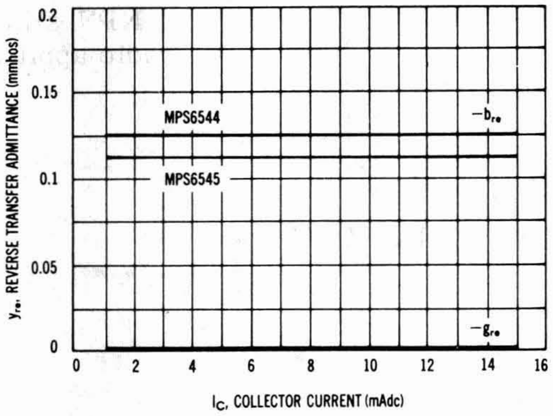


FIGURE 3 — FORWARD TRANSFER ADMITTANCE

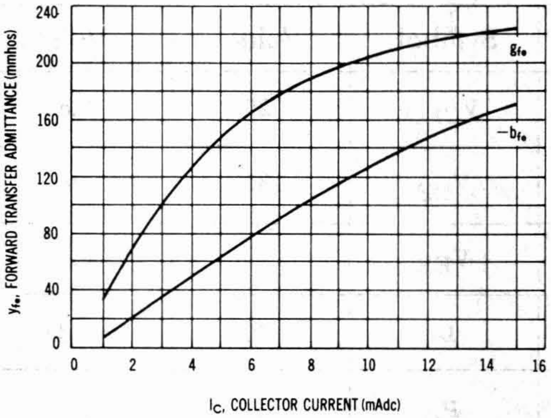


FIGURE 4 — OUTPUT ADMITTANCE

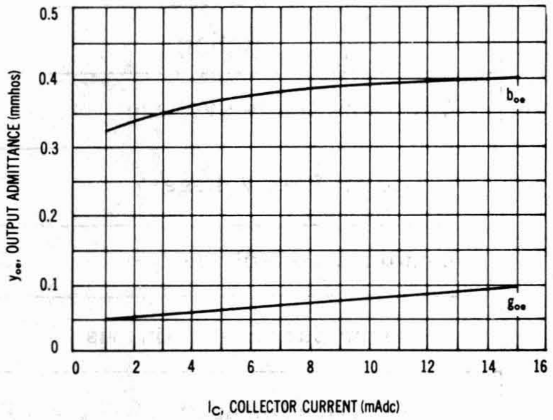


FIGURE 5 — CAPACITANCES

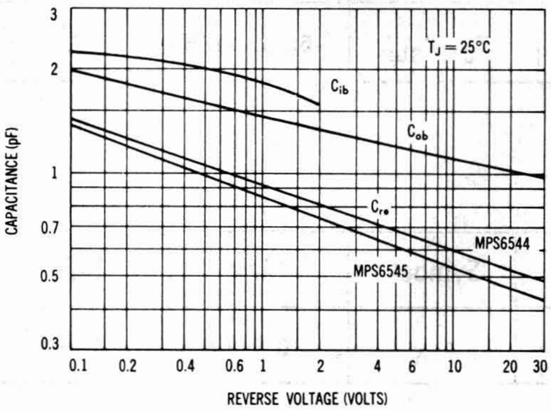
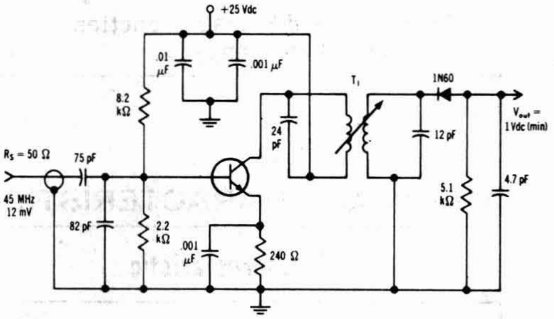


FIGURE 6 — 45 MHz TEST CIRCUIT


+25 Vdc
.01 μF
.001 μF
8.2 kΩ
T_1
1N60
V_{out} = 1 Vdc (min)
24 pF
12 pF
R_S = 50 Ω
75 pF
45 MHz
12 mV
5.1 kΩ
4.7 pF
82 pF
2.2 kΩ
.001 μF
240 Ω

T_1 — PRIMARY: 7 TURNS #26 WIRE, ¼" I.D.
SECONDARY: 10 TURNS #26 WIRE, ¼" I.D.
CORE: ARNOLD IRON POWDER, PART NO. A1-10

FOR MPS6545 SHIELD IS CONNECTED TO GROUND

MPS6546 (SILICON)
MPS6547

Case 29(2)
TO-92

NPN silicon epitaxial transistors designed for FM radio applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Base Voltage	V_{CB}	35	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current-Continuous	I_C	50	mAdc
Total Device Dissipation @ $T_A = 25^{\circ}C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

MPS6546, MPS6547 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit

OFF CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)	BV_{CEO}	25	—	—	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	35	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	3.0	—	—	Vdc
Collector Cutoff Current (V_{CB} = 25 Vdc, I_E = 0)	I_{CBO}	—	—	0.1	μAdc
Emitter Cutoff Current (V_{BE} = 2 Vdc, I_C = 0)	I_{EBO}	—	—	1.0	μAdc

ON CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
DC Current Gain (I_C = 2 mAdc, V_{CE} = 10 Vdc)	h_{FE}	20	—	—	—
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$	—	—	0.35	Vdc

DYNAMIC CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Current-Gain — Bandwidth Product (I_C = 2 mAdc, V_{CE} = 10 Vdc, f = 100 mHz)	f_T	600	—	—	MHz
Common-Emitter Reverse Transfer Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz) MPS6547	C_{re}	—	—	0.35	pF
MPS6546		—	—	0.45	

FUNCTIONAL TEST

Characteristic	Symbol	Min	Typ	Max	Unit
Conversion Gain (108 MHz to 10.7 MHz) (I_C = 2.5 mAdc, V_{CE} = 10 Vdc, Test Circuit Figure 7) MPS6547	—	—	28	—	dB
Oscillator Power Output (V_{EE} = 12.5 Vdc, f = 118 MHz, Test Circuit Figure 13) MPS6546	P_{out}	10	18	—	mW

CONVERSION GAIN CHARACTERISTICS

(TEST CIRCUIT FIGURE 7)

FIGURE 1—VARIATION WITH COLLECTOR CURRENT

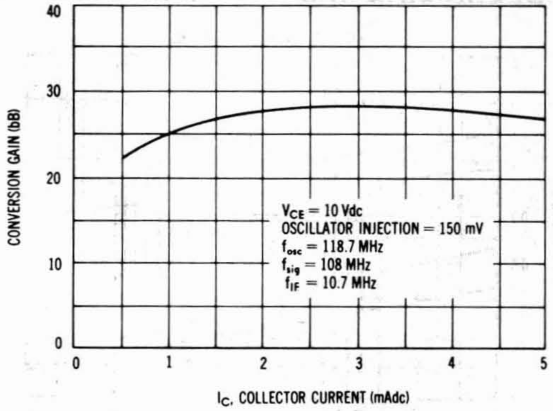
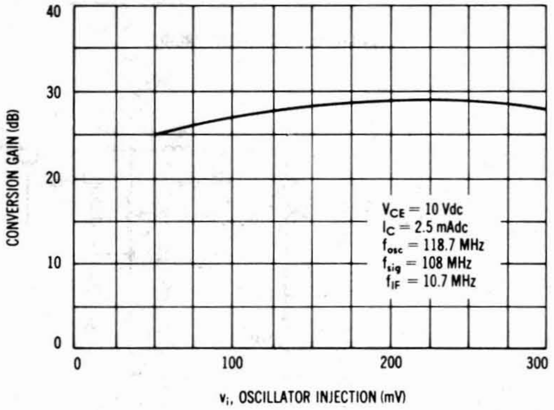


FIGURE 2—VARIATION WITH INJECTION LEVEL



COMMON-EMITTER y PARAMETERS

V_{CE} = 10 Vdc, f = 105 MHz, T_A = 25°C

FIGURE 3—INPUT ADMITTANCE

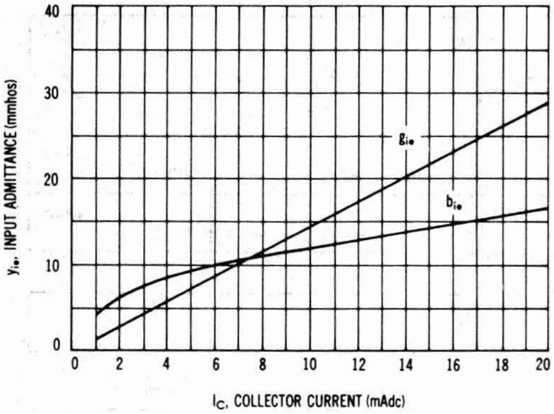


FIGURE 4—REVERSE TRANSFER ADMITTANCE

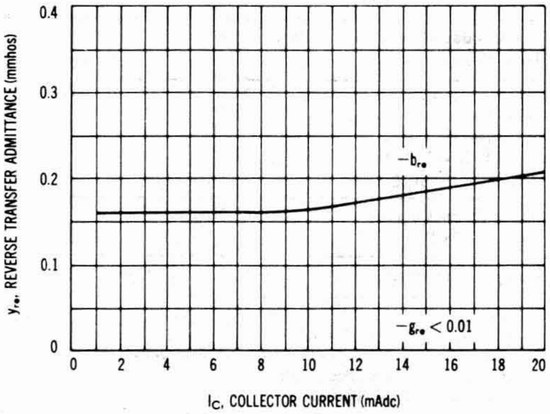


FIGURE 5—FORWARD TRANSFER ADMITTANCE

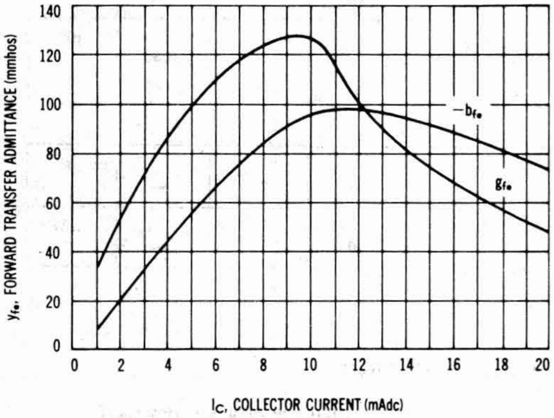


FIGURE 6—OUTPUT ADMITTANCE

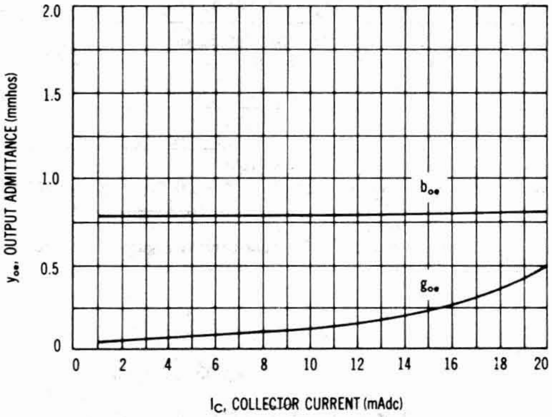
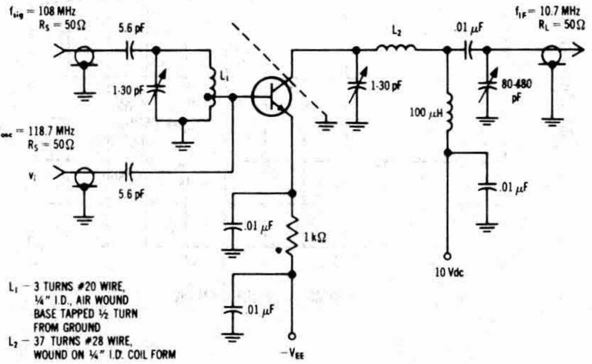
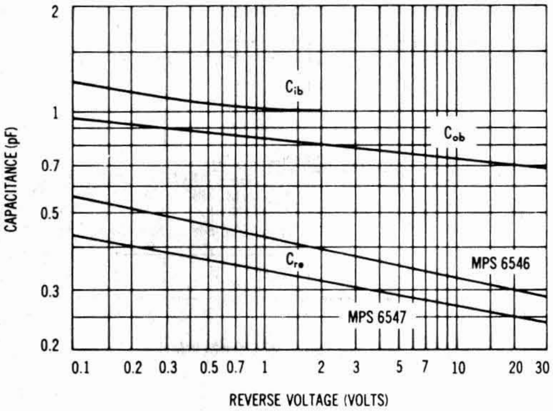


FIGURE 7—MIXER TEST CIRCUIT


f_{sig} = 108 MHz
R_S = 50Ω
5.6 pF
1-30 pF
L_1
f_{osc} = 118.7 MHz
R_S = 50Ω
v_i
5.6 pF
.01 μF
1 kΩ
.01 μF
$-V_{EE}$
L_2
.01 μF
f_{IF} = 10.7 MHz
R_L = 50Ω
1-30 pF
100 μH
80-480 pF
.01 μF
10 Vdc

L_1 — 3 TURNS #20 WIRE,
¼" I.D., AIR WOUND
BASE TAPPED ½ TURN
FROM GROUND
L_2 — 37 TURNS #28 WIRE,
WOUND ON ¼" I.D. COIL FORM

FIGURE 8—CAPACITANCES



COMMON-BASE y PARAMETERS

$V_{CB} = 10$ Vdc, $I_C = 2.5$ mAdc, $T_A = 25°C$

FIGURE 9—INPUT ADMITTANCE

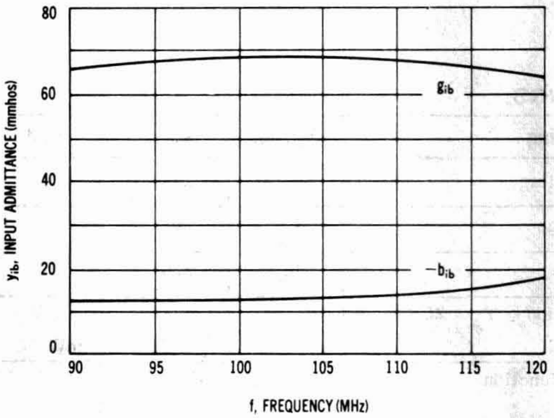


FIGURE 10—REVERSE TRANSFER ADMITTANCE

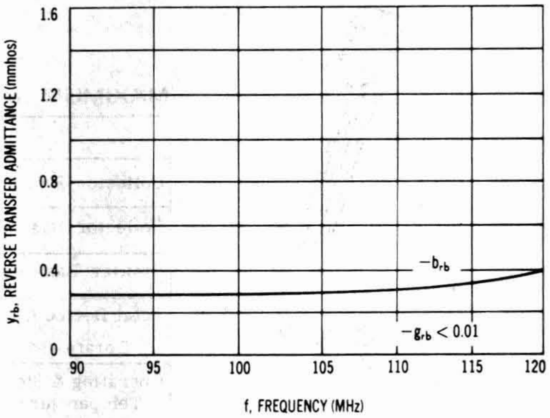


FIGURE 11—FORWARD TRANSFER ADMITTANCE

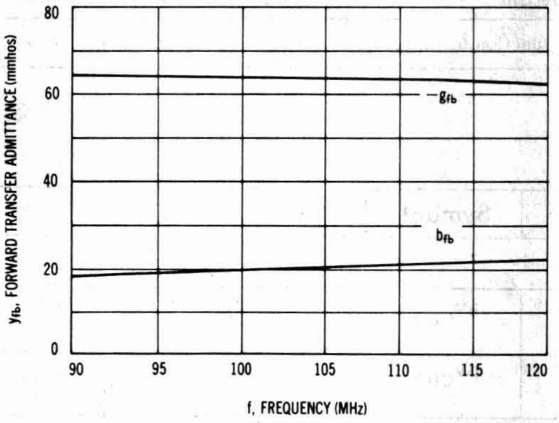
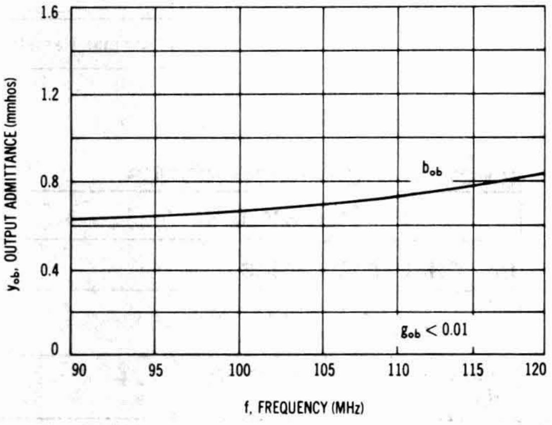
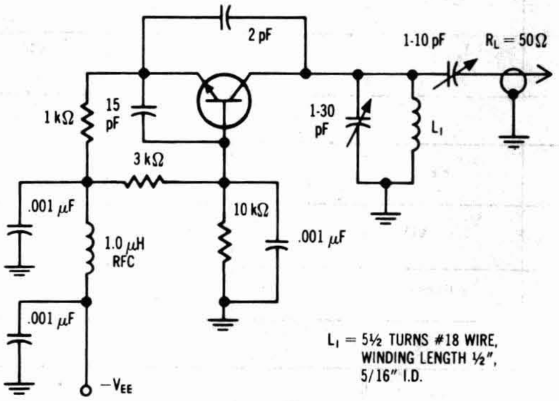


FIGURE 12—OUTPUT ADMITTANCE



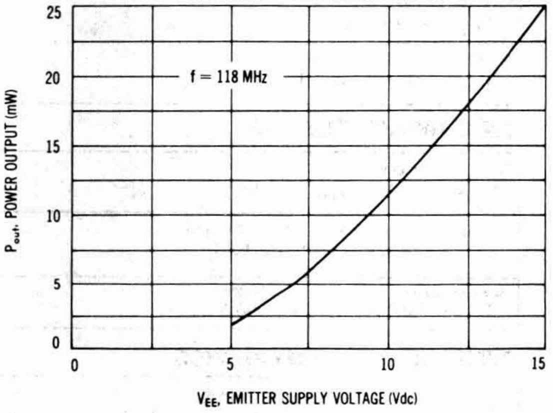
TYPICAL OSCILLATOR PERFORMANCE

FIGURE 13—TEST CIRCUIT


2 pF
1-10 pF
$R_L = 50\Omega$
1 kΩ
15 pF
1-30 pF
L_1
3 kΩ
.001 μF
10 kΩ
1.0 μH RFC
.001 μF
.001 μF
$-V_{EE}$

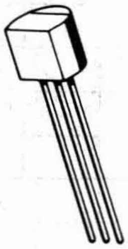
L_1 = 5½ TURNS #18 WIRE, WINDING LENGTH ½″, 5/16″ I.D.

FIGURE 14—POWER OUTPUT



MPS6548 (SILICON)

NPN silicon epitaxial transistor designed for use in UHF oscillator applications.



CASE 29 (2)
TO-92

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	25	Vdc
Collector-Base Voltage	V_{CB}	30	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS

Characteristics	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 1.0$ mAdc, $I_B = 0$)	BV_{CEO}	25	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 100$ μAdc, $I_E = 0$)	BV_{CBO}	30	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10$ μAdc, $I_C = 0$)	BV_{EBO}	3.0	-	Vdc
Collector Cutoff Current ($V_{CB} = 25$ Vdc, $I_E = 0$)	I_{CBO}	-	100	nAdc
Emitter Cutoff Current ($V_{BE} = 2.0$ Vdc, $I_C = 0$)	I_{EBO}	-	100	nAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 4.0$ mAdc, $V_{CE} = 10$ Vdc)	h_{FE}	25	-	-
Collector-Emitter Saturation Voltage ($I_C = 4.0$ mAdc, $I_B = 0.4$ mAdc)	$V_{CE(sat)}$	-	0.5	Vdc
Base-Emitter Saturation Voltage ($I_C = 4.0$ mAdc, $I_B = 0.4$ mAdc)	$V_{BE(sat)}$	-	0.95	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain — Bandwidth Product ($I_C = 4.0$ mAdc, $V_{CE} = 10$ Vdc, f = 100 MHz)	f_T	650	-	MHz
Collector-Base Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 100 kHz)	C_{cb}	-	0.7	pF
Collector-Base Time Constant ($I_E = 4.0$ mAdc, $V_{CB} = 10$ Vdc, f = 31.8 MHz)	$r_b'C_c$	-	9.0	ps

MPS 6560
MPS 6561

NPN (SILICON)

MPS 6562
MPS 6563

PNP

Silicon annular audio transistors designed for complementary symmetry audio output applications.

CASE 29(1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	MPS6560 MPS6562	MPS6561 MPS6563	Unit
Collector-Emitter Voltage	V_{CEO}	25	20	Vdc
Collector-Base Voltage	V_{CB}	25	20	Vdc
Emitter-Base Voltage	V_{EB}	4.0		Vdc
Collector Current-Continuous	I_C	600		mAdc
Total Device Dissipation @ $T_A = 25°C$	P_D	500		mW
Derate above 25°C		4.54		mW/°C
Total Device Dissipation @ $T_C = 25°C$	P_D	800		mW
Derate above 25°C		7.27		mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction To Ambient	θ_{JA}	0.220	°C/mW
Thermal Resistance, Junction To Case	θ_{JC}	0.137	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current		I_{CEO}			nAdc
(V_{CE} = 20 Vdc, I_B = 0)	MPS6561, MPS6563		-	100	
(V_{CE} = 25 Vdc, I_B = 0)	MPS6560, MPS6562		-	100	
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)		I_{CBO}	-	100	nAdc
Emitter Cutoff Current ($V_{EB(off)}$ = 4.0 Vdc, I_C = 0)		I_{EBO}	-	100	nAdc
ON CHARACTERISTICS					
DC Current Gain		h_{FE}			-
(I_C = 10 mAdc, V_{CE} = 1.0 Vdc)			35	-	
(I_C = 100 mAdc, V_{CE} = 1.0 Vdc)			50	-	
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)	MPS6560, MPS6562		50	200	
(I_C = 350 mAdc, V_{CE} = 1.0 Vdc)	MPS6561, MPS6563		50	200	
Collector-Emitter Saturation Voltage		$V_{CE(sat)}$			Vdc
(I_C = 500 mAdc, I_B = 50 mAdc)	MPS6560, MPS6562		-	0.5	
(I_C = 350 mAdc, I_B = 35 mAdc)	MPS6561, MPS6563		-	0.5	
Base-Emitter On Voltage		$V_{BE(on)}$			Vdc
(I_C = 500 mAdc, V_{CE} = 1.0 Vdc)	MPS6560, MPS6562		-	1.2	
(I_C = 350 mAdc, V_{CE} = 1.0 Vdc)	MPS6561, MPS6563		-	1.2	
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 30 MHz)		f_T	60	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	-	30	pF

TYPICAL CHARACTERISTICS

MPS6560
MPS6562

FIGURE 1 — DC CURRENT GAIN

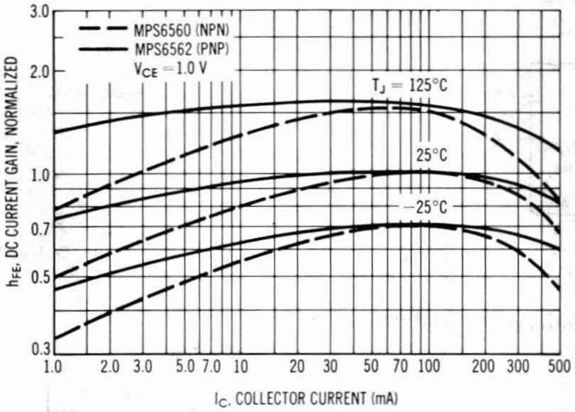


FIGURE 3 — COLLECTOR SATURATION REGION

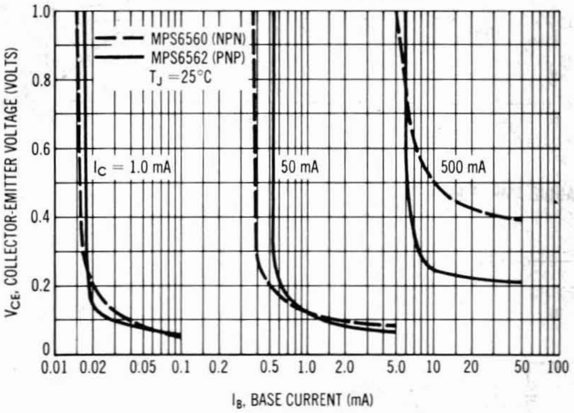
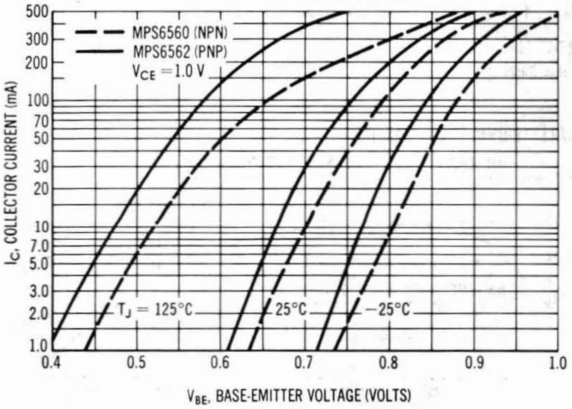


FIGURE 5 — TRANSCONDUCTANCE



MPS6561
MPS6563

FIGURE 2 — DC CURRENT GAIN

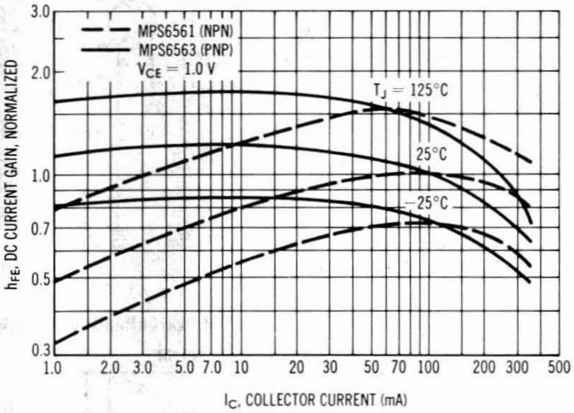


FIGURE 4 — COLLECTOR SATURATION REGION

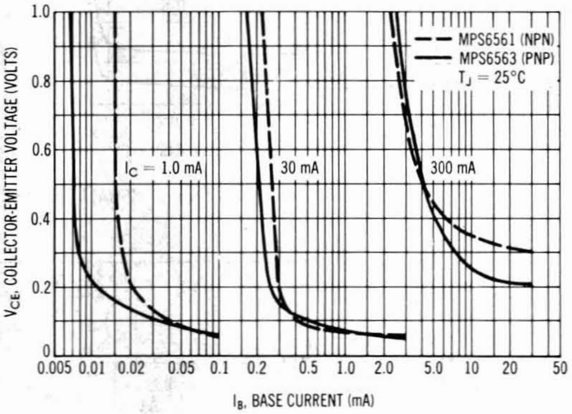
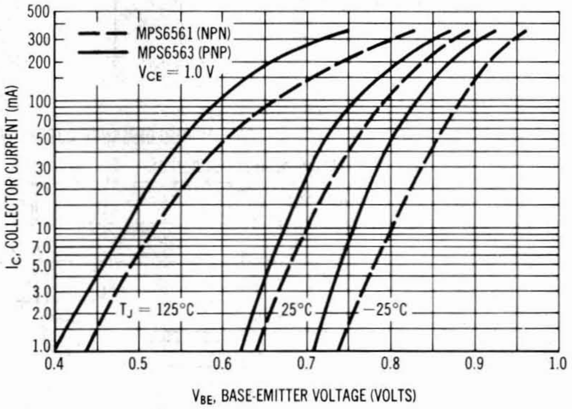


FIGURE 6 — TRANSCONDUCTANCE

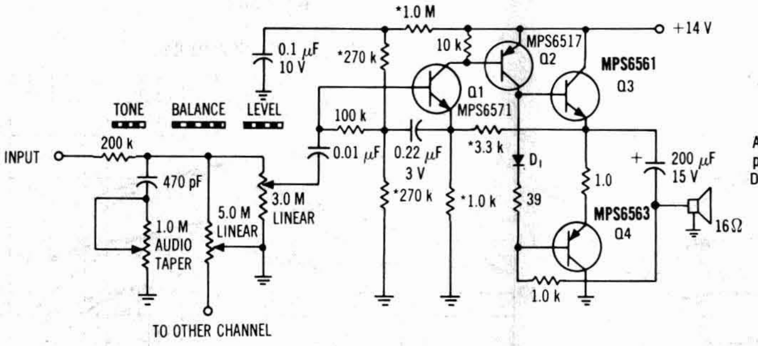


MPS6560, MPS6561, MPS6562, MPS6563 (continued)

TYPICAL AUDIO APPLICATIONS

1-WATT STEREOPHONIC AUDIO AMPLIFIER

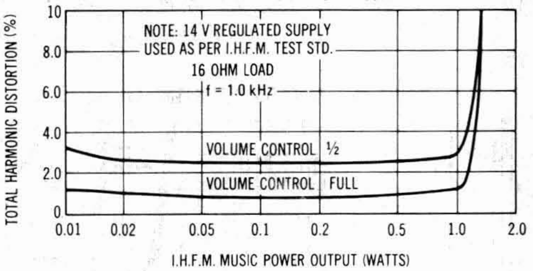
(ONE CHANNEL SHOWN)


*1.0 M
+14 V
0.1 μF
10 V
*270 k
10 k
MPS6517
Q2
MPS6561
Q3
Q1
MPS6571
TONE
BALANCE
LEVEL
100 k
INPUT
200 k
0.01 μF
0.22 μF
3 V
*3.3 k
D1
200 μF
15 V
470 pF
3.0 M
LINEAR
*270 k
*1.0 k
39
1.0
5.0 M
LINEAR
1.0 M
AUDIO
TAPER
MPS6563
Q4
16 Ω
1.0 k
TO OTHER CHANNEL

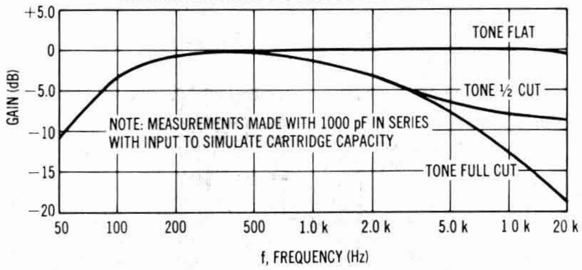
All resistors are ½ Watt, ±10% ratings, except for parts preceded by an asterisk (*) where ±5% types are recommended.
D_1 = MSS1000

TYPICAL PERFORMANCE CURVES FOR 1-WATT/16-OHM AUDIO AMPLIFIER

DISTORTION versus POWER OUTPUT

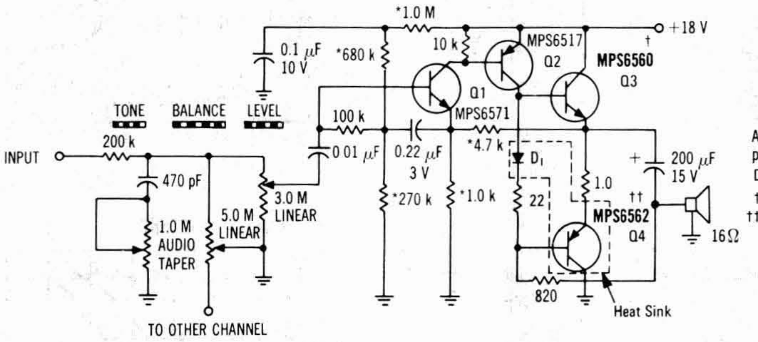


FREQUENCY RESPONSE AND TONE CONTROL ACTION



2-WATT STEREOPHONIC AUDIO AMPLIFIER

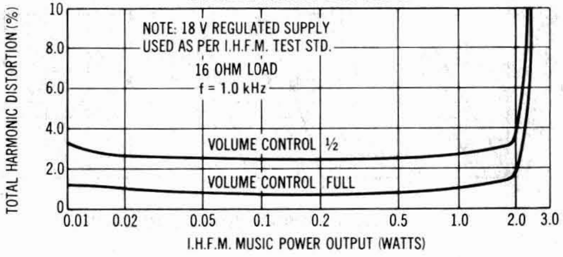
(ONE CHANNEL SHOWN)


*1.0 M
+18 V
0.1 μF
10 V
*680 k
10 k
MPS6517
Q2
†
MPS6560
Q3
Q1
MPS6571
TONE
BALANCE
LEVEL
100 k
INPUT
200 k
0.01 μF
0.22 μF
3 V
*4.7 k
D1
200 μF
15 V
470 pF
3.0 M
LINEAR
*270 k
*1.0 k
22
1.0
††
5.0 M
LINEAR
1.0 M
AUDIO
TAPER
MPS6562
Q4
16 Ω
820
Heat Sink
TO OTHER CHANNEL

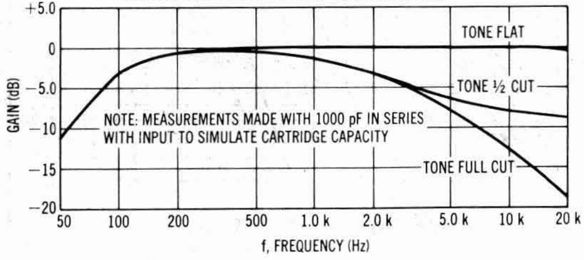
All resistors are ½ Watt, ±10% ratings, except for parts preceded by an asterisk (*) where ±5% types are recommended.
D_1 = MSS1000
†Requires Heat Sink. Use Staver F1-7A (or equivalent).
††Requires Heat Sink. Use Staver F1-8. This Heat Sink allows D_1 and Q4 to be thermally connected, thus enhancing high temperature operation.

TYPICAL PERFORMANCE CURVES FOR 2-WATT/16-OHM AUDIO AMPLIFIER

DISTORTION versus POWER OUTPUT



FREQUENCY RESPONSE AND TONE CONTROL ACTION



MPS6565 (SILICON)
MPS6566

NPN silicon annular transistors designed for general-purpose, low-level amplifier applications.

CASE 29 (1)
(TO-92)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	45	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current-Continuous	I_C	200	mAdc
Total Device Dissipation @ $T_A = 25^{\circ}C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25^{\circ}C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)	BV_{CEO}	45	—	—	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	60	—	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)	BV_{EBO}	4.0	—	—	Vdc
Collector Cutoff Current (V_{CB} = 30 Vdc, I_E = 0)	I_{CBO}	—	—	100	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc) MPS6565	h_{FE}	40	—	160	—
MPS6566		100	—	400	
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$	—	0.1	0.4	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	—	—	3.5	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	—	3.7	—	pF
Small Signal Current Gain (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	h_{fe}	2.0	—	—	—
Output Admittance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{oe}	—	60	—	μmhos
Input Impedance (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{ie}	—	500	—	ohms
Voltage Feedback Ratio (I_C = 10 mAdc, V_{CE} = 10 Vdc, f = 1 kHz)	h_{re}	—	2.5	—	$X\,10^{-4}$
Noise Figure (I_C = 100 μAdc, V_{CE} = 5 Vdc, R_S = 1000 ohms, f = 10 Hz to 15.7 kHz)	NF	—	4.0	—	dB

SMALL SIGNAL CHARACTERISTICS

NOISE FIGURE

V_{CE} = 5 Vdc, T_A = 25°C

FIGURE 1 — FREQUENCY EFFECTS

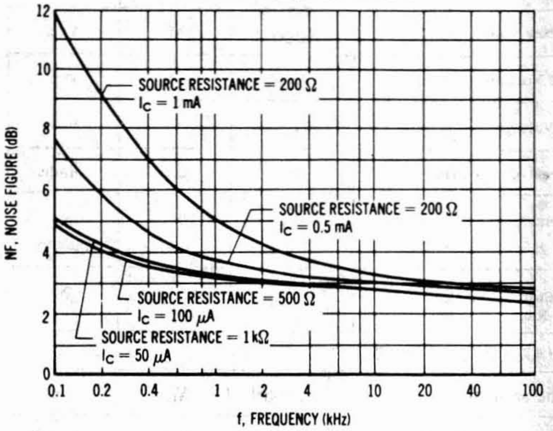
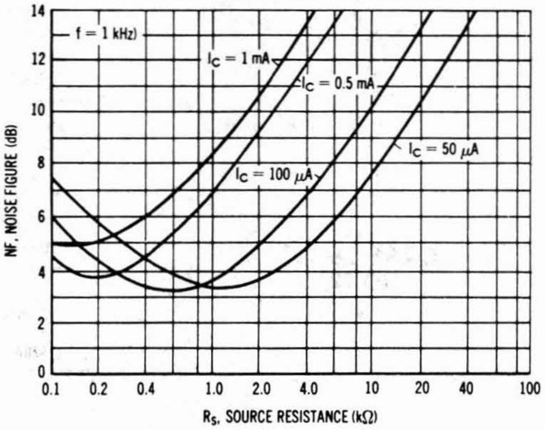


FIGURE 2 — SOURCE RESISTANCE EFFECTS



h PARAMETERS

V_{CE} = 10 V, f = 1 kHz, T_A = 25°C

FIGURE 3 — CURRENT GAIN

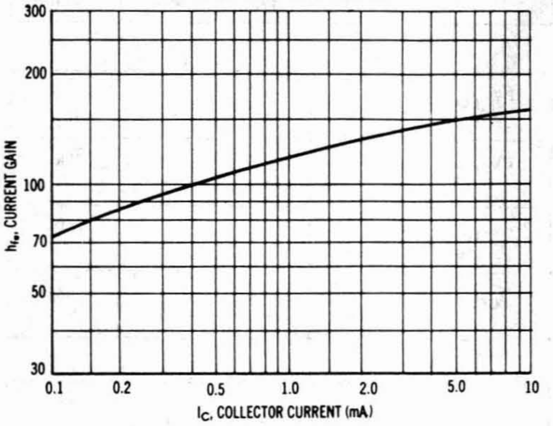


FIGURE 4 — OUTPUT ADMITTANCE

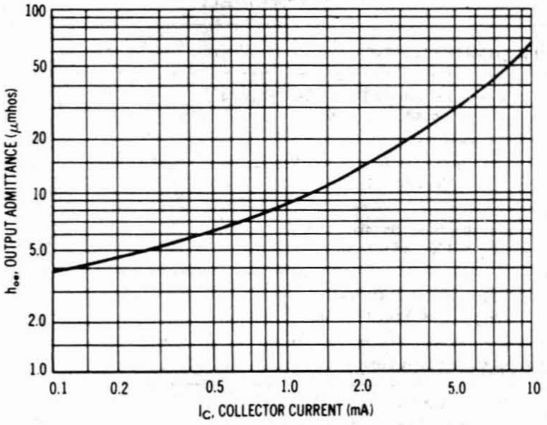


FIGURE 5 — INPUT IMPEDANCE

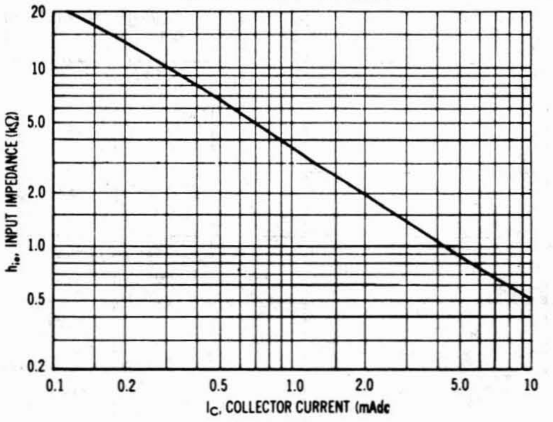
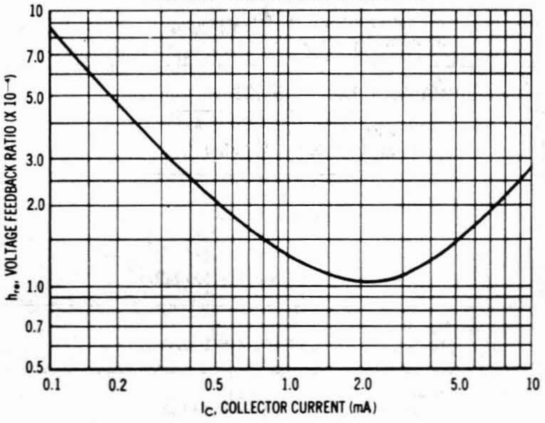


FIGURE 6 — VOLTAGE FEEDBACK RATIO



STATIC CHARACTERISTICS

FIGURE 7 — NORMALIZED CURRENT GAIN

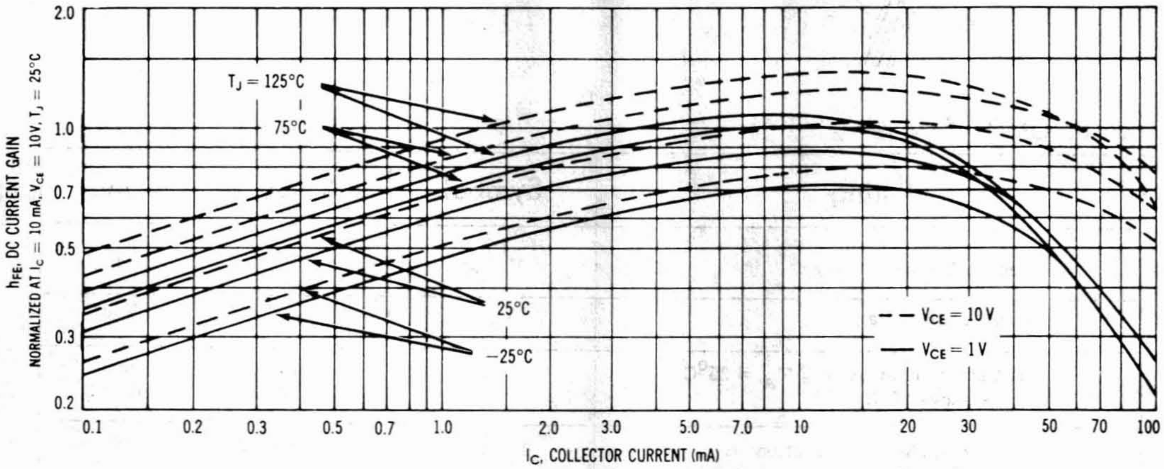


FIGURE 8 — COLLECTOR SATURATION REGION

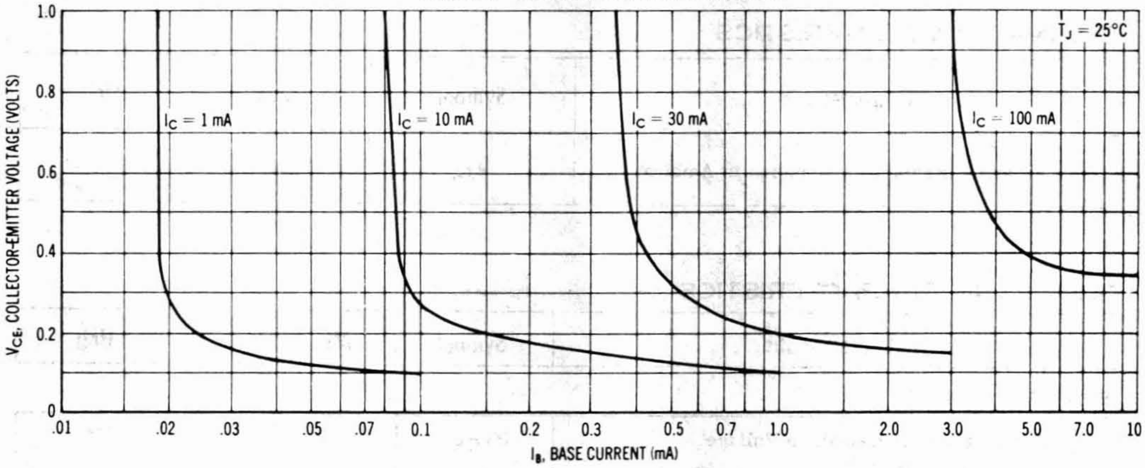


FIGURE 9 — TRANSCONDUCTANCE

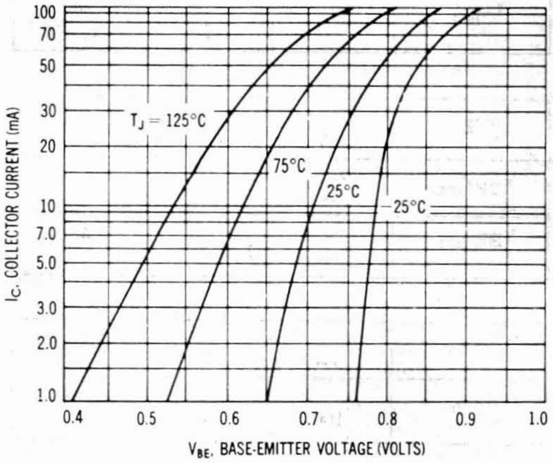
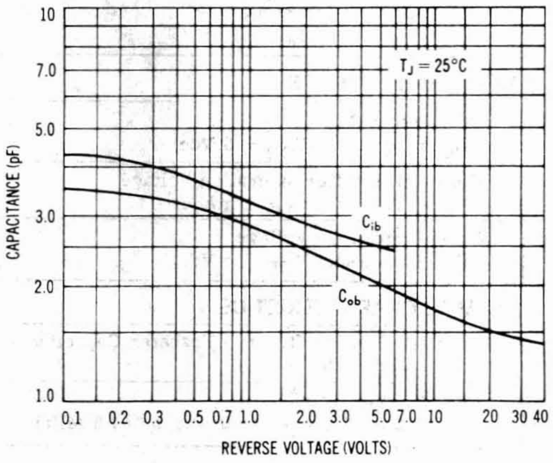
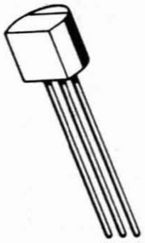


FIGURE 10 — CAPACITANCES



MPS6567 (SILICON)



CASE 29(2)
TO-92

NPN silicon annular transistor designed for 4.5 MHz sound IF applications in TV receivers.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Total Device Dissipation @ $T_A = 25^oC$ Derate above 25^oC	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_E = 0)	BV_{CEO}	40	—	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	—	Vdc
Collector Cutoff Current (V_{CB} = 35 Vdc, I_E = 0)	I_{CBO}	—	0.5	μAdc
ON CHARACTERISTICS				
DC Current Gain (I_C = 10 mAdc, V_{CE} = 5 Vdc)	h_{FE}	25	—	—
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1 mAdc)	$V_{CE(sat)}$	—	0.5	Vdc
Base-Emitter On Voltage (I_C = 10 mAdc, V_{CE} = 5 Vdc)	$V_{BE(on)}$	—	0.8	Vdc
DYNAMIC CHARACTERISTICS				
Common-Emitter Reverse Transfer Capacitance (V_{CB} = 10 Vdc, I_E = 0)	C_{re}	—	0.7	pF
Output Resistance (I_C = 2 mAdc, V_{CE} = 10 Vdc, f = 4.5 MHz)	R_{oep}	100	—	kohms

COMMON-EMITTER y PARAMETERS

f = 4.5 MHz, T_A = 25°C

FIGURE 1 — INPUT ADMITTANCE

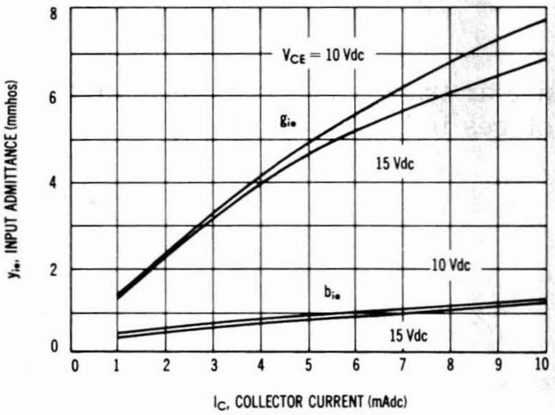


FIGURE 2 — REVERSE TRANSFER ADMITTANCE

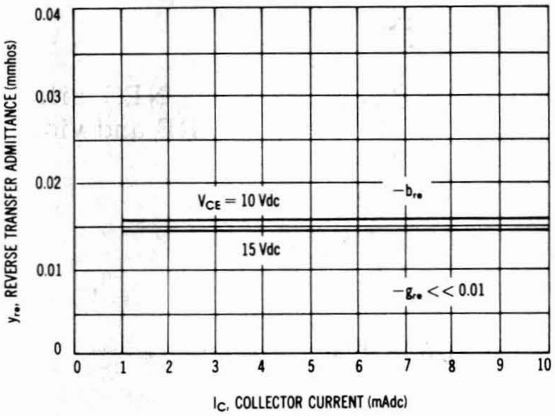


FIGURE 3 — FORWARD TRANSFER ADMITTANCE

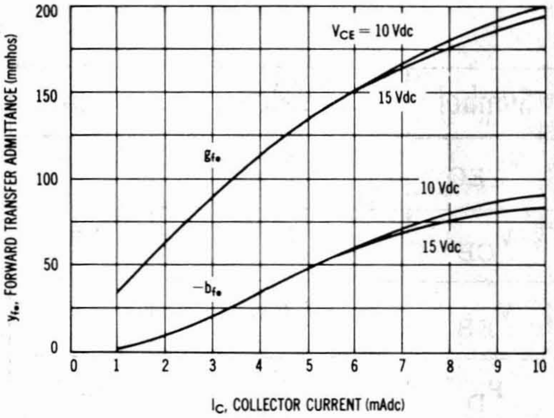


FIGURE 4 — OUTPUT ADMITTANCE

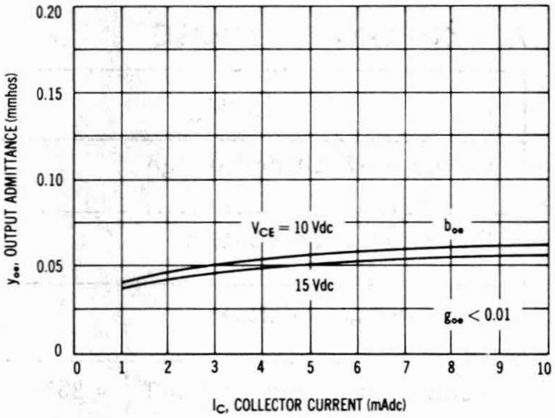


FIGURE 5 — CAPACITANCES

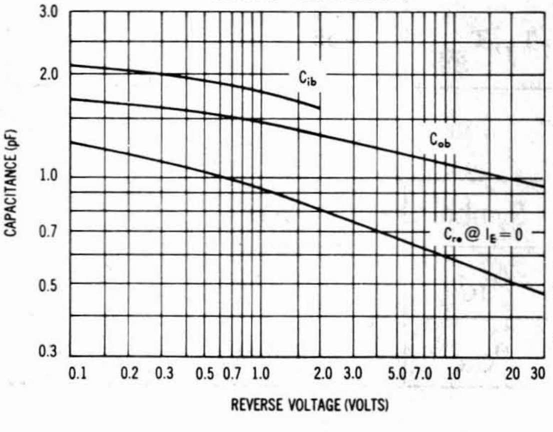
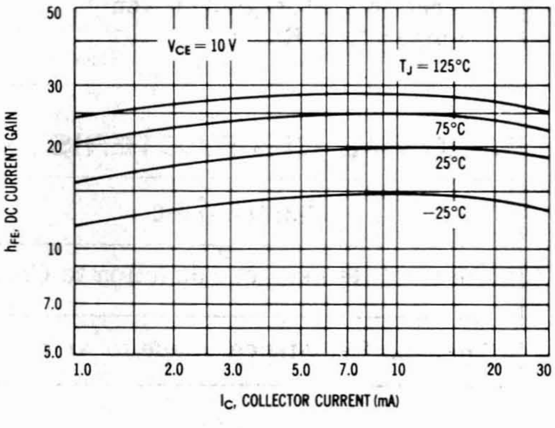
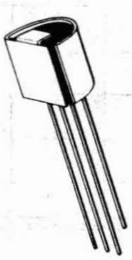


FIGURE 6 — DC CURRENT GAIN



MPS6568 (SILICON)
MPS6569
MPS6570



CASE 29A

NPN silicon annular transistors designed for VHF-RF and video IF stages in TV receivers.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	20	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Total Device Dissipation $T_A = 25°C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating & Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.137	°C/mW
Thermal Resistance, Case to Ambient	θ_{CA}	0.220	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
Collector-Emitter Breakdown Voltage (I_C = 1 mAdc, I_B = 0)		BV_{CEO}	20	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)		BV_{CBO}	20	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 100 μAdc, I_C = 0)		BV_{EBO}	3.0	-	Vdc
Collector Cutoff Current (V_{CB} = 10 Vdc, I_E = 0)		I_{CBO}	-	50	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 4 mAdc, V_{CE} = 5 Vdc)		h_{FE}	20	200	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 5 mAdc)		$V_{CE(sat)}$	0.1	3.0	Vdc
Base-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 5 mAdc)		$V_{BE(sat)}$	-	0.96	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 4 mAdc, V_{CE} = 10 Vdc, f = 100 MHz)	MPS6568 MPS6569, MPS6570	f_T	375 300	800 800	MHz
Collector-Base Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 1 MHz, emitter guarded, with shield)		C_{cb}	0.25	0.5	pF
Noise Figure (V_{AGC} = 1.4 Vdc, R_S = 50 ohms, f = 200 MHz, Figure 9) (V_{AGC} = 2.75 Vdc, R_S = 50 ohms, f = 45 MHz, Figure 10)	MPS6568 MPS6569, MPS6570	NF	- -	3.3 6.0	dB
FUNCTIONAL TEST					
Power Gain (V_{AGC} = 1.4 Vdc, R_S = 50 ohms, f = 200 MHz, Figure 9) (V_{AGC} = 2.75 Vdc, R_S = 50 ohms, f = 45 MHz, Figure 10)	MPS6568 MPS6569, MPS6570	G_{pe}	20 22.5	27 28.5	dB
Forward AGC Voltage (Gain Reduction = 30 dB, R_S = 50 ohms, f = 200 MHz, Figure 9) (Gain Reduction = 30 dB, R_S = 50 ohms, f = 45 MHz, Figure 10)	MPS6568 MPS6569 MPS6570	V_{AGC}	4.0 4.4 5.2	5.0 5.4 6.2	Vdc

AGC CHARACTERISTICS

V_{CC} = 12 Vdc, R_S = 50 OHMS, SEE FIGURES 9 AND 10

—— f = 45 MHz – – – f = 200 MHz

FIGURE 1 — POWER GAIN

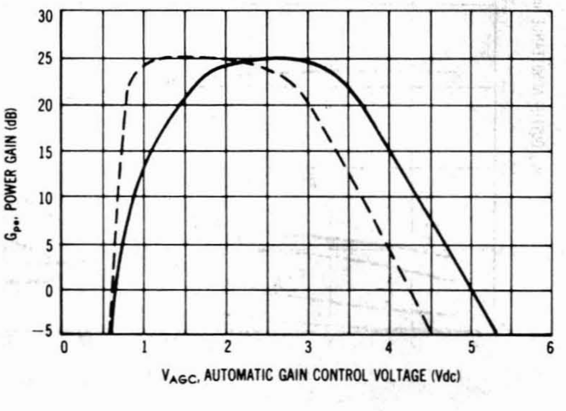
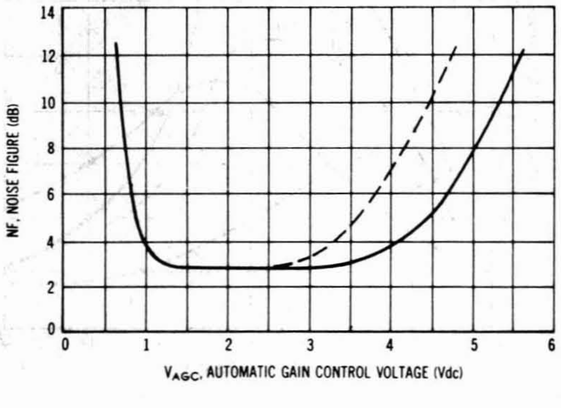


FIGURE 2 — NOISE FIGURE



COMMON-EMITTER y PARAMETERS

V_{CE} = 12 Vdc, T_A = 25°C

— f = 45 MHz   - - f = 200 MHz

FIGURE 3 — INPUT ADMITTANCE

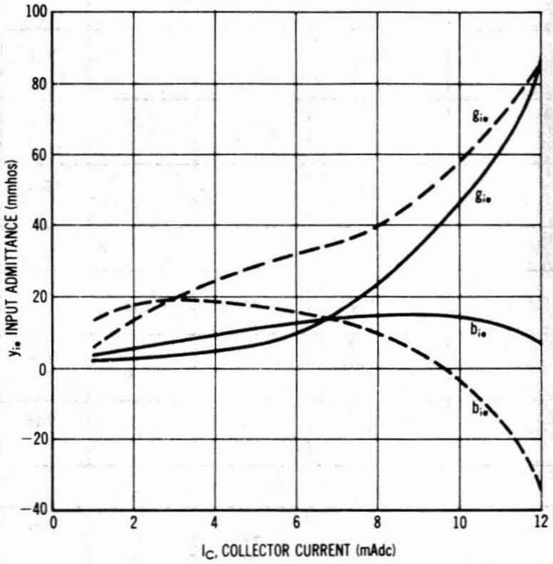


FIGURE 4 — REVERSE TRANSFER ADMITTANCE

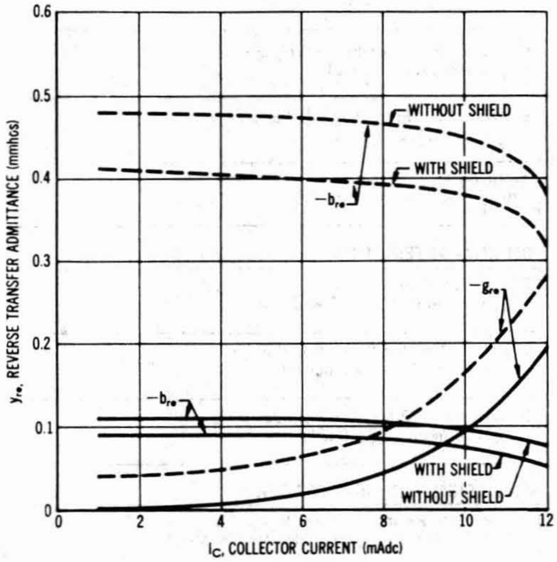


FIGURE 5 — FORWARD TRANSFER ADMITTANCE

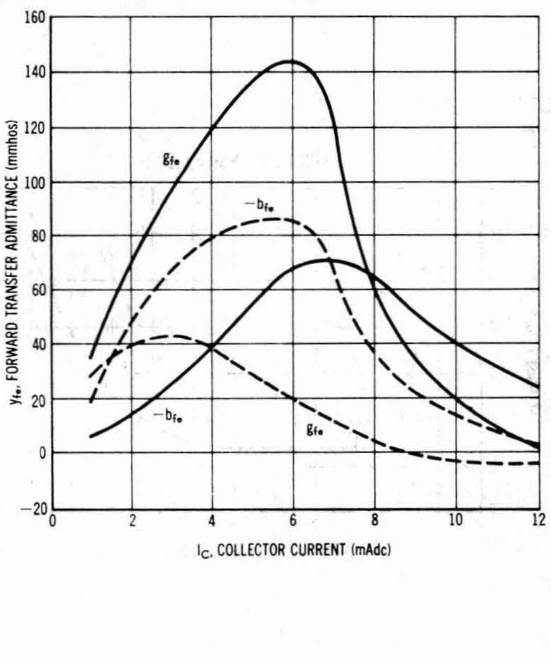


FIGURE 6 — OUTPUT ADMITTANCE

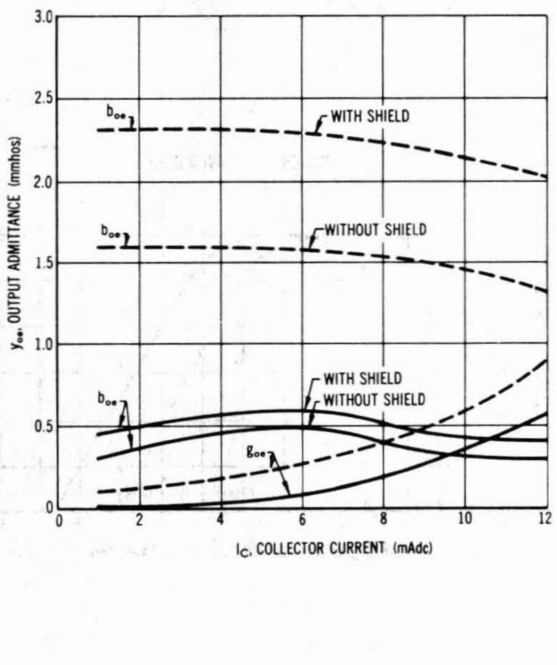


FIGURE 7 — DC CURRENT GAIN

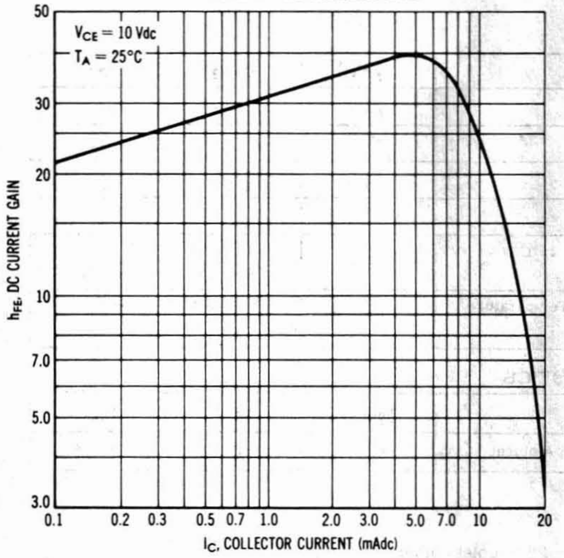


FIGURE 8 — COLLECTOR-BASE CAPACITANCE

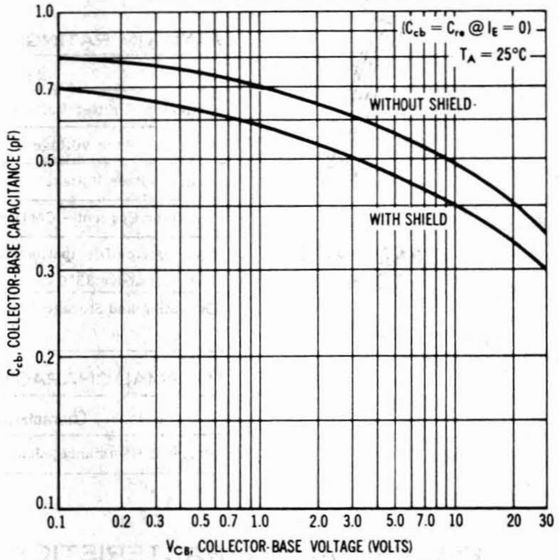
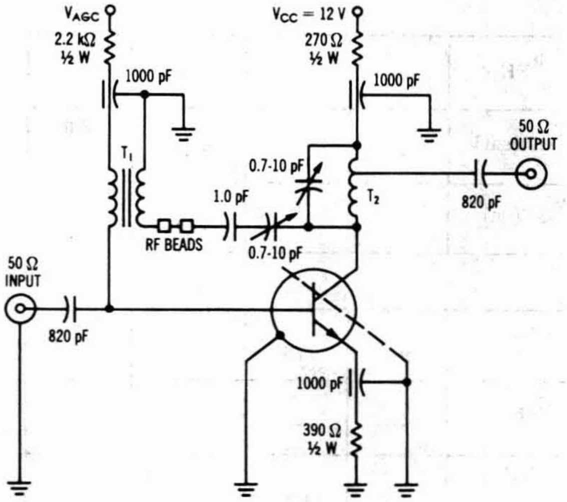


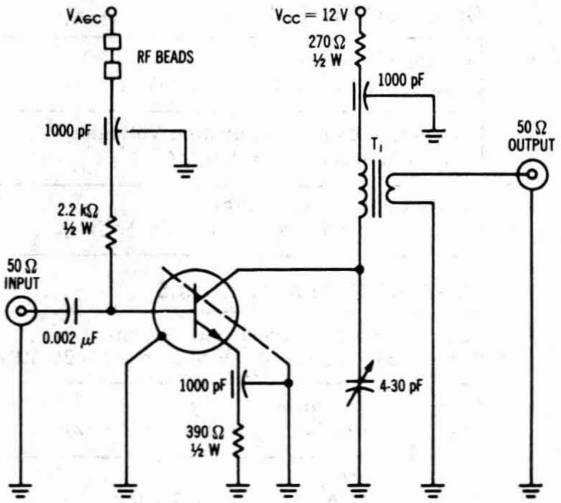
FIGURE 9 — 200 MHz FUNCTIONAL TEST CIRCUIT
(NEUTRALIZED)



V_{AGC}
2.2 kΩ
½ W
1000 pF
T_1
RF BEADS
1.0 pF
0.7-10 pF
0.7-10 pF
V_{CC} = 12 V
270 Ω
½ W
1000 pF
T_2
50 Ω
OUTPUT
820 pF
50 Ω
INPUT
820 pF
1000 pF
390 Ω
½ W

T_1 = FERRITE CORE INDIANA GEN. CORP. F-684
T_2 = 6 TURNS #16 BUSS WIRE, ID = ¼″, L = ¾″.

FIGURE 10 — 45 MHz FUNCTIONAL TEST CIRCUIT
(UNNEUTRALIZED)

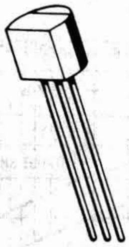


V_{AGC}
RF BEADS
1000 pF
2.2 kΩ
½ W
50 Ω
INPUT
0.002 μF
V_{CC} = 12 V
270 Ω
½ W
1000 pF
T_1
50 Ω
OUTPUT
1000 pF
390 Ω
½ W
4-30 pF

T_1 = TOROID 4:1 RATIO
8T-PRI 2T-SEC } #22 WIRE

MPS6571 (SILICON)

NPN silicon annular amplifier transistor designed for audio pre-amplifier applications in audio amplifiers.



CASE 29(1)
TO-92

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Collector-Base Voltage	V_{CB}	20	Vdc
Emitter-Base Voltage	V_{EB}	3.0	Vdc
Collector Current - Continuous	I_C	50	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)	BV_{CEO}	20	-	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	25	-	-	Vdc
Collector Cutoff Current (V_{CB} = 20 Vdc, I_E = 0)	I_{CBO}	-	-	50	nAdc
Emitter Cutoff Current ($V_{EB(off)}$ = 3.0 Vdc, I_C = 0)	I_{EBO}	-	-	50	nAdc
ON CHARACTERISTICS					
DC Current Gain (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	h_{FE}	250	-	1000	-
Collector-Emitter Saturation Voltage (I_C = 10 mAdc, I_B = 1.0 mAdc)	$V_{CE(sat)}$	-	-	0.5	Vdc
Base-Emitter On, Voltage (I_C = 10 mAdc, V_{CE} = 5.0 Vdc)	$V_{BE(on)}$	-	-	0.8	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain — Bandwidth Product (I_C = 500 μAdc, V_{CE} = 5.0 Vdc, f = 20 MHz)	f_T	50	175	-	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	-	4.5	pF
Noise Figure (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, R_s = 10 kohms, f = 100 Hz)	NF	-	1.2	-	dB

FIGURE 1 — DC CURRENT GAIN

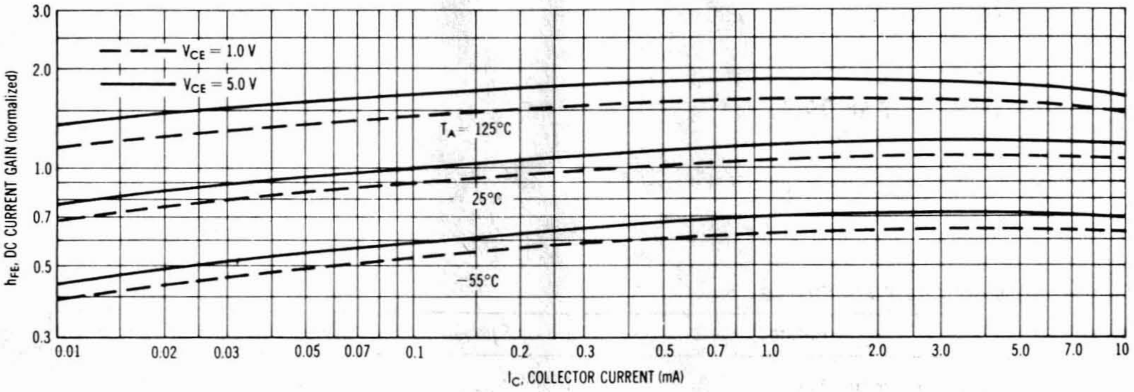


FIGURE 2 — CURRENT GAIN

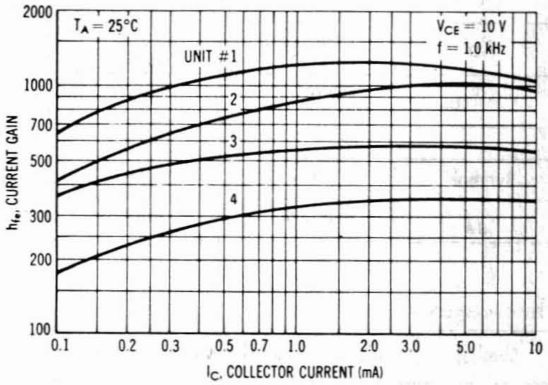
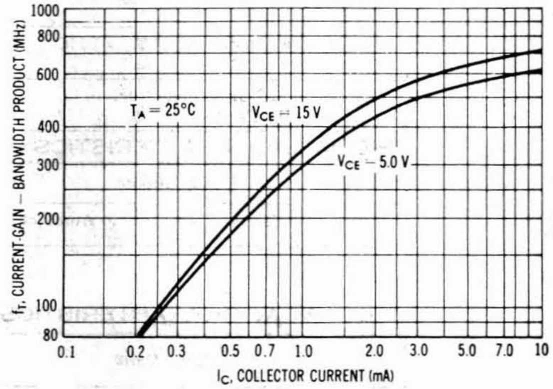


FIGURE 3 — CURRENT GAIN — BANDWIDTH PRODUCT



NOISE FIGURE

V_{CE} = 5.0 Vdc, T_A = 25°C

FIGURE 4 — FREQUENCY EFFECTS

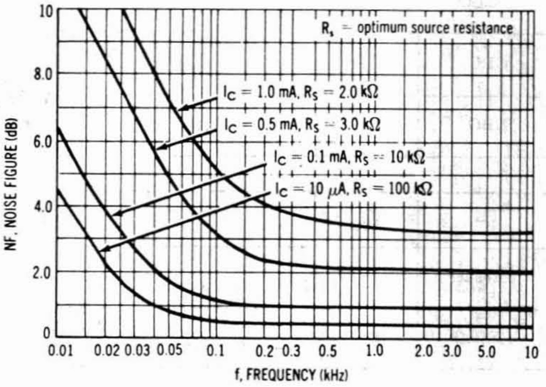
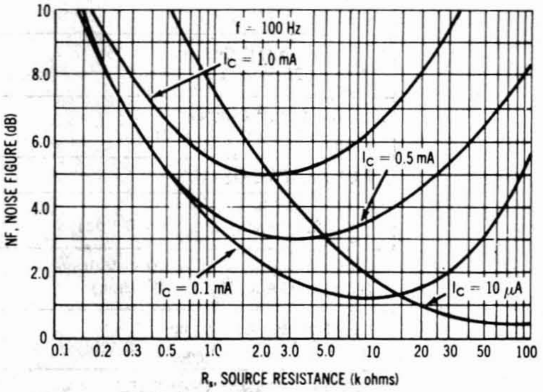


FIGURE 5 — SOURCE RESISTANCE EFFECTS



MPS-A09 (SILICON)

CASE 29(1)
(TO-92)

NPN silicon annular amplifier transistors designed for pre-amplifier applications in audio amplifiers.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Vdc
Collector-Base Voltage	V_{CB}	50	Vdc
Collector Current - Continuous Peak	I_C	50 100	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage ($I_C = 1.0$ mAdc, $I_B = 0$)	BV_{CEO}	50	-	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 0.1$ mAdc, $I_E = 0$)	BV_{CBO}	50	-	-	Vdc
Collector Cutoff Current ($V_{CB} = 25$ Vdc, $I_E = 0$)	I_{CBO}	-	-	100	nAdc
Emitter Cutoff Current ($V_{BE} = 3.0$ Vdc, $I_C = 0$)	I_{EBO}	-	-	100	nAdc
ON CHARACTERISTICS					
DC Current Gain ($I_C = 0.1$ mAdc, $V_{CE} = 5.0$ Vdc)	h_{FE}	100	-	600	-
Collector-Emitter Saturation Voltage ($I_C = 10$ mAdc, $I_B = 1.0$ mAdc)	$V_{CE(sat)}$	-	-	0.9	Vdc
Base-Emitter On Voltage ($I_C = 1.0$ mAdc, $V_{CE} = 5.0$ Vdc)	$V_{BE(on)}$	-	-	1.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain–Bandwidth Product ($I_C = 0.5$ mAdc, $V_{CE} = 5.0$ Vdc, f = 20 MHz)	f_T	30	80	-	MHz
Output Capacitance ($V_{CB} = 5.0$ Vdc, $I_E = 0$, f = 100 kHz)	C_{ob}	-	-	5.0	pF
Noise Figure ($I_C = 0.1$ mAdc, $V_{CE} = 5.0$ Vdc, $R_S = 6.8$ k ohms, f = 1.0 kHz)	NF	-	1.4	-	dB

FIGURE 1 – DC CURRENT GAIN

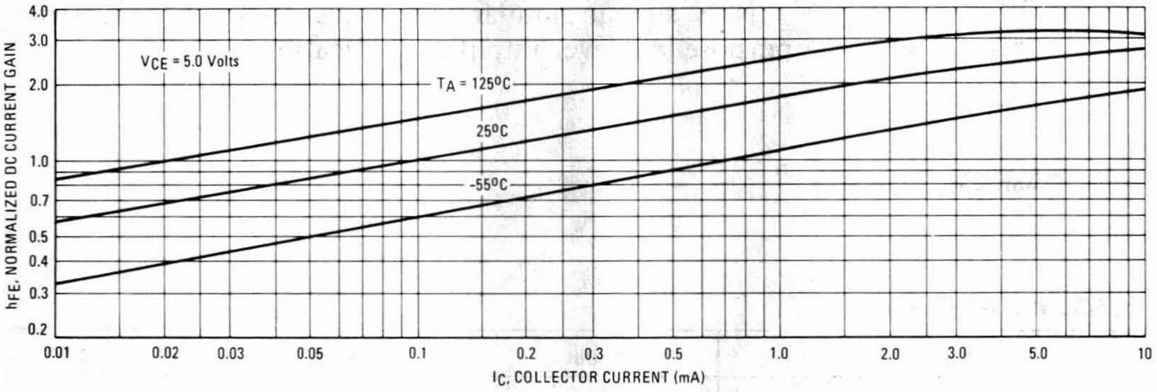


FIGURE 2 – COLLECTOR SATURATION REGION

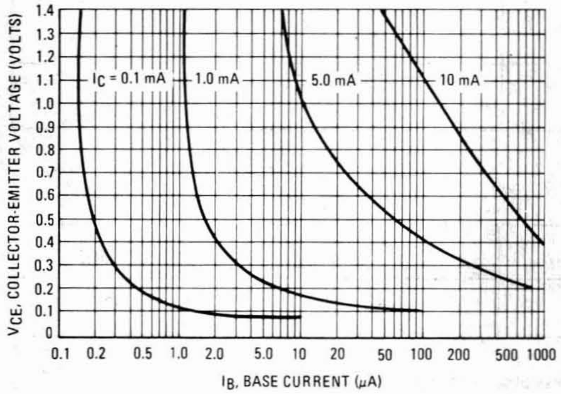
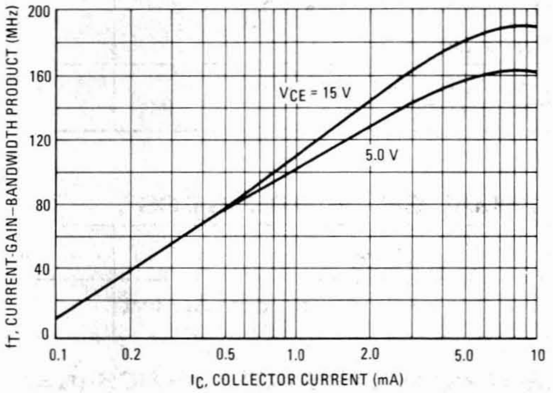


FIGURE 3 – CURRENT GAIN–BANDWIDTH PRODUCT



NOISE FIGURE

(V_{CE} = 5.0 Vdc, T_A = 25°C)

FIGURE 4 – FREQUENCY EFFECTS

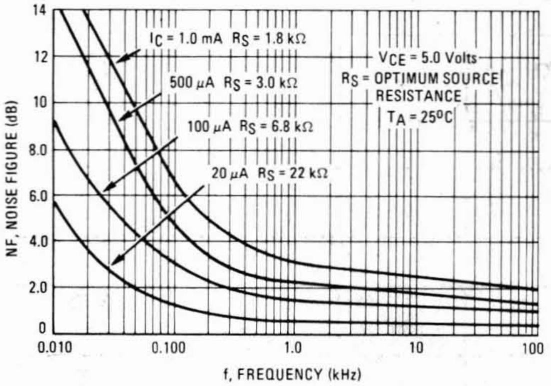
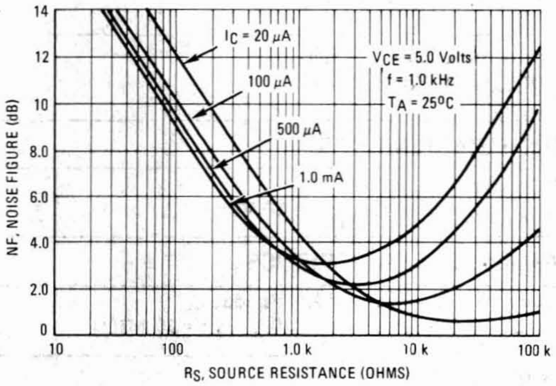
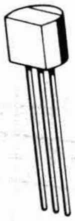


FIGURE 5 - SOURCE RESISTANCE EFFECT



MPS-A10 (SILICON)



CASE 29(1)
(TO-92)

NPN silicon annular transistors designed for general-purpose low-level amplifier applications.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Emitter-Base Voltage	V_{EB}	4.0	Vdc
Collector Current – Continuous	I_C	100	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	210 1.91	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.524	°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 1.0$ mAdc, $I_B = 0$)	BV_{CEO}	40	-	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100$ µAdc, $I_C = 0$)	BV_{EBO}	4.0	-	Vdc
Collector Cutoff Current ($V_{CB} = 30$ Vdc, $I_E = 0$)	I_{CBO}	-	100	nAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 5.0$ mAdc, $V_{CE} = 10$ Vdc	h_{FE}	40	400	-
DYNAMIC CHARACTERISTICS				
Current-Gain-Bandwidth Product ($I_C = 5.0$ mAdc, $V_{CE} = 10$ Vdc, f = 20 MHz)	f_T	20	-	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 100 kHz)	C_{ob}	-	4.0	pF

FIGURE 1 – NORMALIZED DC CURRENT GAIN

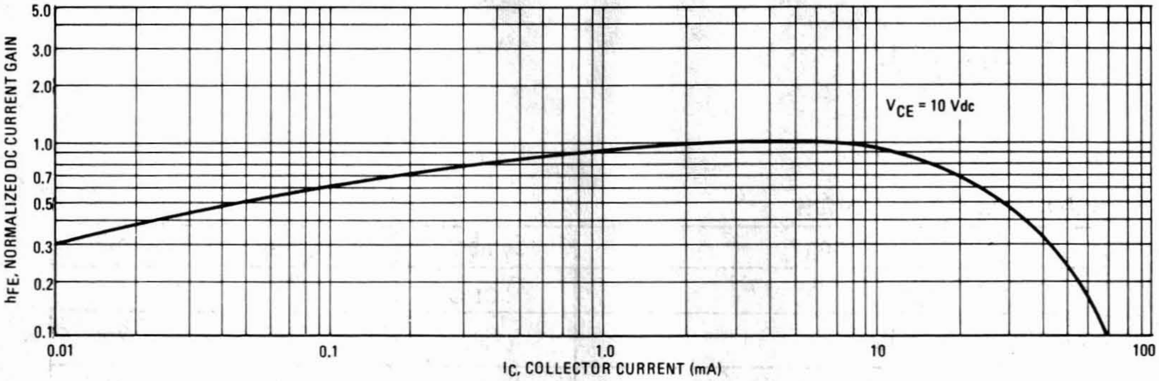


FIGURE 2 – CAPACITANCE versus VOLTAGE

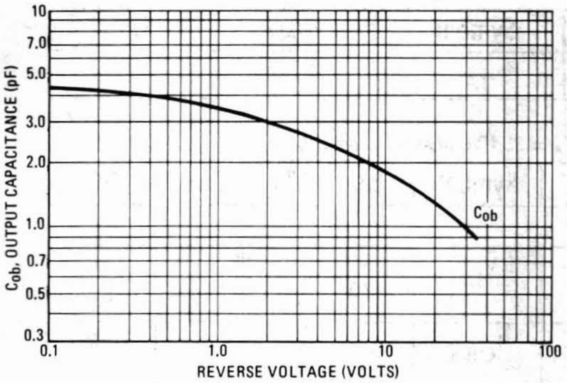


FIGURE 3 – CURRENT-GAIN-BANDWIDTH PRODUCT versus COLLECTOR CURRENT

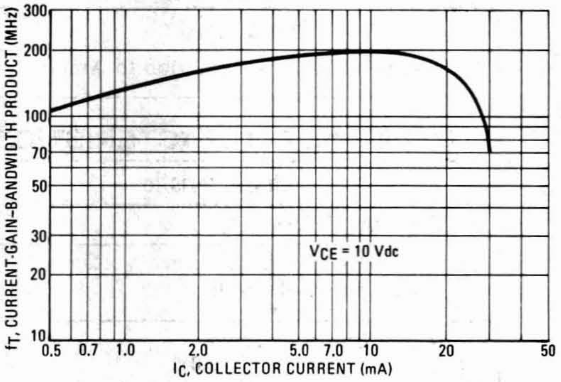
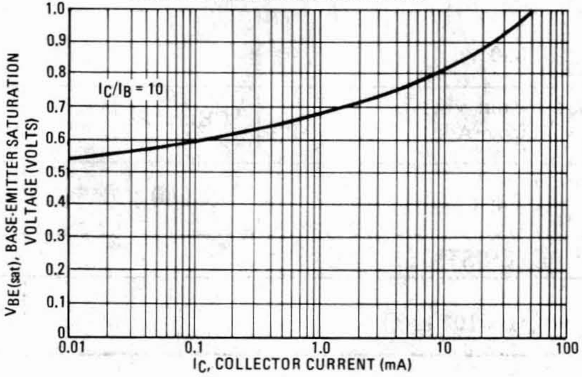


FIGURE 4 – BASE-EMITTER SATURATION VOLTAGE versus COLLECTOR CURRENT



MPS-A12 (SILICON)

CASE 29(1)
(TO-92)

NPN silicon darlington amplifier transistors designed for pre-amplifier input applications requiring input impedance of several megohms.

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	20	Vdc
Emitter-Base Voltage	V_{EB}	10	Vdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.81	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ_{JA}	0.357	°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage ($I_C = 10$ mAdc, $I_B = 0$)	BV_{CEO}	20	-	-	Vdc
Collector Cutoff Current ($V_{CE} = 15$ Vdc, $V_{BE} = 0$)	I_{CES}	-	-	100	nAdc
Collector Cutoff Current ($V_{CB} = 15$ Vdc, $I_E = 0$)	I_{CBO}	-	-	100	nAdc
Emitter Cutoff Current ($V_{EB} = 10$ Vdc, $I_C = 0$)	I_{EBO}	-	-	100	nAdc
ON CHARACTERISTICS					
DC Current Gain ($I_C = 10$ mAdc, $V_{CE} = 5.0$ Vdc)	h_{FE}	20,000	-	-	-
Collector-Emitter Saturation Voltage ($I_C = 10$ mAdc, $I_B = 0.01$ mAdc)	$V_{CE(sat)}$	-	-	1.0	Vdc
Base-Emitter On Voltage ($I_C = 10$ mAdc, $V_{CE} = 5.0$ Vdc)	$V_{BE(on)}$	-	-	1.4	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, $f = 100$ kHz)	C_{ob}	-	8.0	-	pF
Small-Signal Current Gain ($I_C = 10$ mAdc, $V_{CE} = 5.0$ Vdc, $f = 1.0$ kHz)	h_{fe}	-	35	-	-

FIGURE 1 – NORMALIZED DC CURRENT GAIN

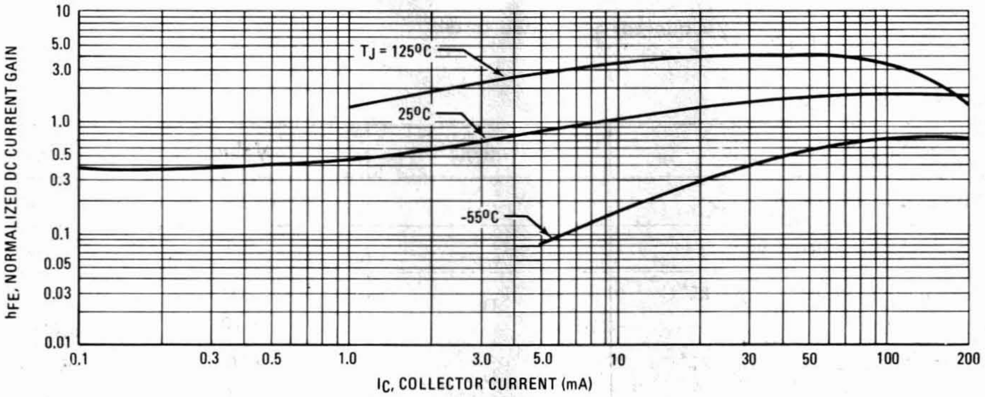


FIGURE 2 – COLLECTOR-EMITTER SATURATION VOLTAGE versus COLLECTOR CURRENT

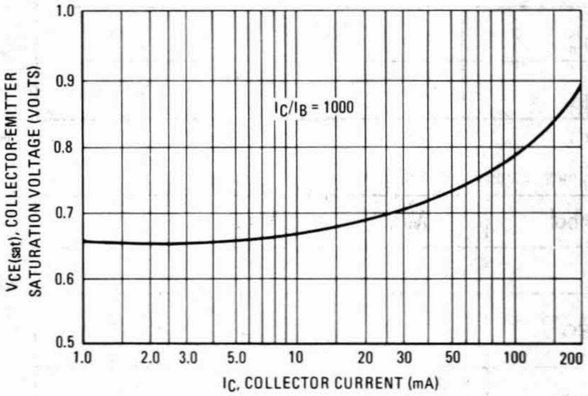


FIGURE 3 – BASE EMITTER "ON" VOLTAGE versus COLLECTOR CURRENT

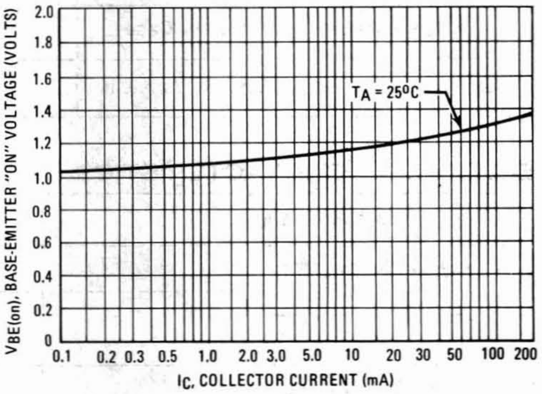
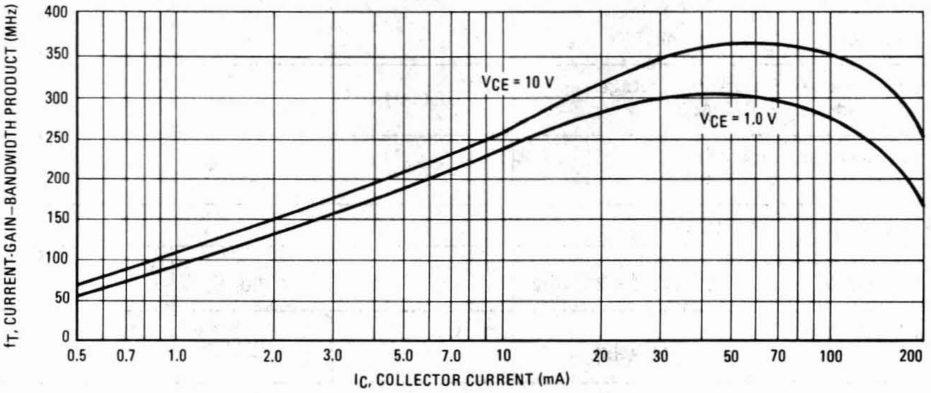


FIGURE 4 – CURRENT-GAIN–BANDWIDTH PRODUCT versus COLLECTOR CURRENT



MPS-U01 (SILICON)

CASE 152

NPN silicon annular transistors designed for audio circuits. Complement to PNP MPS-U51.

Collector connected to tab

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector Current-Continuous	I_C	1.5	Adc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	1.0 9.10	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	8.0 72.8	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	13.7	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	0.110	°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector Cutoff Current ($V_{CE} = 30$ Vdc, $I_B = 0$)	I_{CEO}††	-	1.0	mAdc
Collector Cutoff Current ($V_{CB} = 30$ Vdc, $I_E = 0$)	I_{CBO}	-	0.1	μAdc
Emitter Cutoff Current ($V_{BE} = 3.0$ Vdc, $I_C = 0$)	I_{EBO}	-	0.1	μAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 150$ mAdc, $V_{CE} = 1.0$ Vdc) ($I_C = 1.0$ Adc, $V_{CE} = 1.0$ Vdc)††	h_{FE}	 70 50	 - -	-
Collector-Emitter Saturation Voltage ($I_C = 1.0$ Adc, $I_B = 0.1$ Adc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter On Voltage†† ($I_C = 1.0$ Adc, $V_{CE} = 1.0$ Vdc)	$V_{BE(on)}$††	-	1.3	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc, f = 20 MHz)	f_T	50	-	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 100 kHz)	C_{ob}	-	30	pF

†† Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 1 – NORMALIZED DC CURRENT GAIN

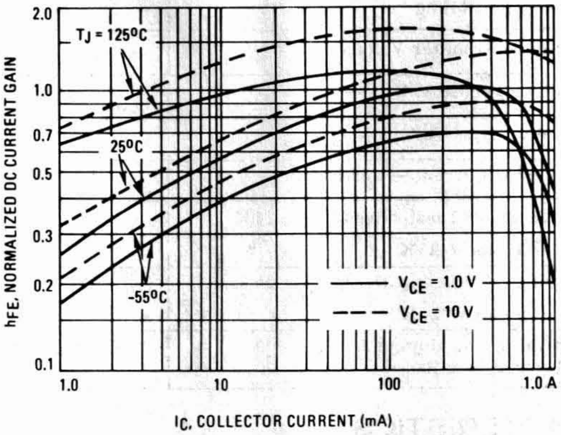


FIGURE 2 – COLLECTOR-EMITTER SATURATION VOLTAGE versus BASE CURRENT

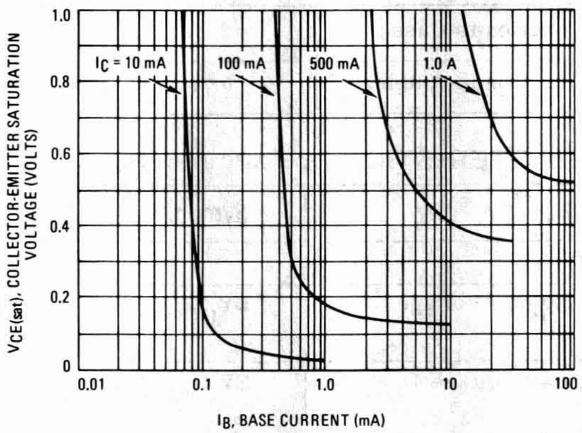


FIGURE 3 – TRANSCONDUCTANCE

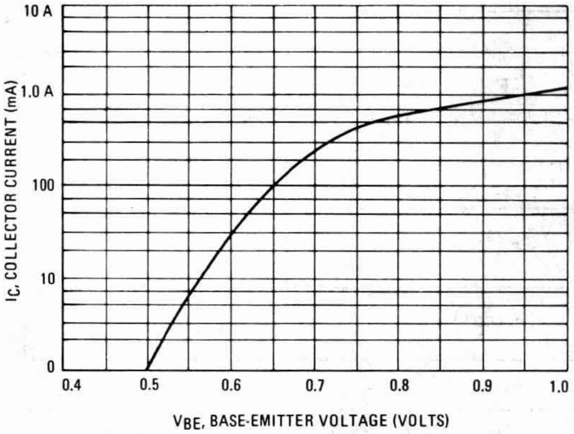
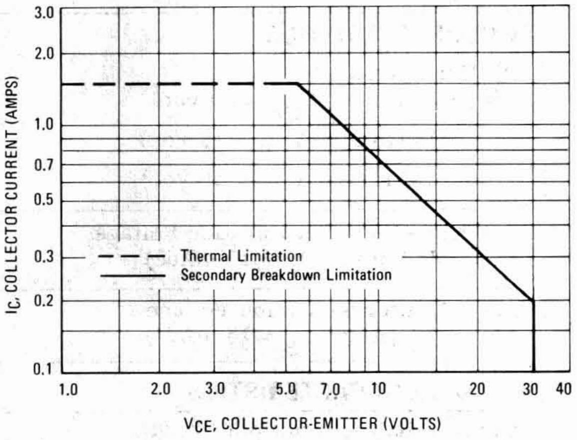
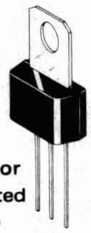


FIGURE 4 – DC SAFE OPERATING AREA



MPS-**U02** (SILICON)

NPN silicon annular amplifier transistors designed for general-purpose amplifier and driver applications. Complement to PNP MPS-U52.



Collector
connected
to tab

CASE 152

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current — Continuous	I_C	800	mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	1.0 9.1	Watt mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	6.0 54.5	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	18.3	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	0.110	°C/mW

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage (I_C = 1.0 mAdc, I_B = 0)	BV_{CEO}	40	-	Vdc
Collector-Base Breakdown Voltage (I_C = 100 μAdc, I_E = 0)	BV_{CBO}	60	-	Vdc
Collector Cutoff Current (V_{CB} = 40 Vdc, I_E = 0)	I_{CBO}	-	100	nAdc
ON CHARACTERISTICS				
DC Current Gain	h_{FE}			-
(I_C = 10 mAdc, V_{CE} = 10 Vdc)		50	-	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)		50	300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)		30	-	
Collector-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{CE(sat)}$	-	0.4	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)	$V_{BE(sat)}$	-	1.3	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product (I_C = 20 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	150	-	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	8.0	pF

FIGURE 1 – NORMALIZED DC CURRENT GAIN

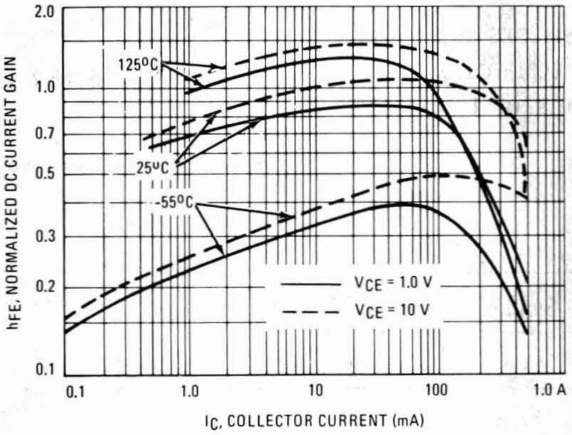


FIGURE 2 – COLLECTOR-EMITTER SATURATION VOLTAGE versus BASE CURRENT

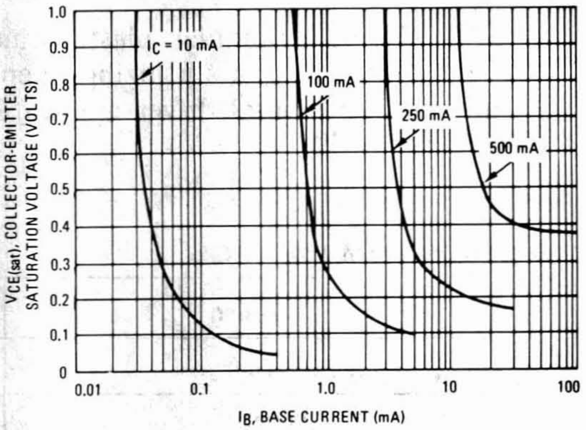


FIGURE 3 – BASE-EMITTER VOLTAGE versus COLLECTOR CURRENT

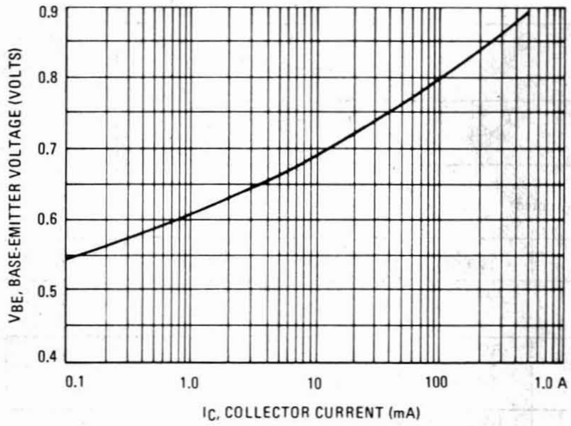


FIGURE 4 – CAPACITANCE versus VOLTAGE

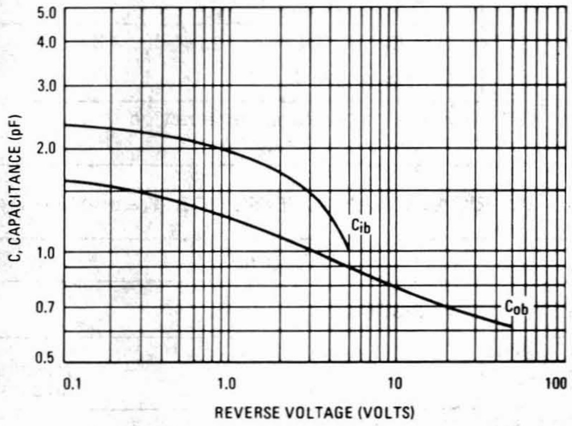


FIGURE 5 – CURRENT-GAIN-BANDWIDTH PRODUCT versus COLLECTOR CURRENT

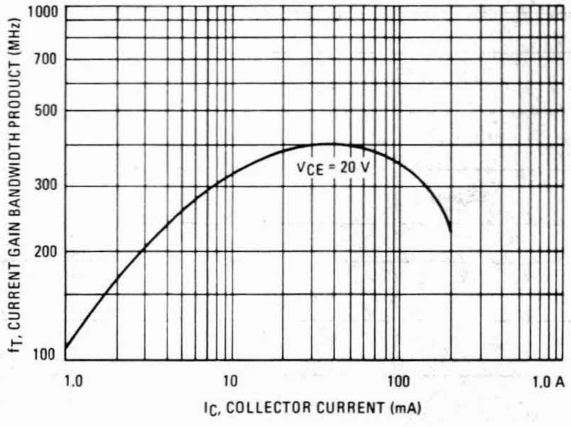
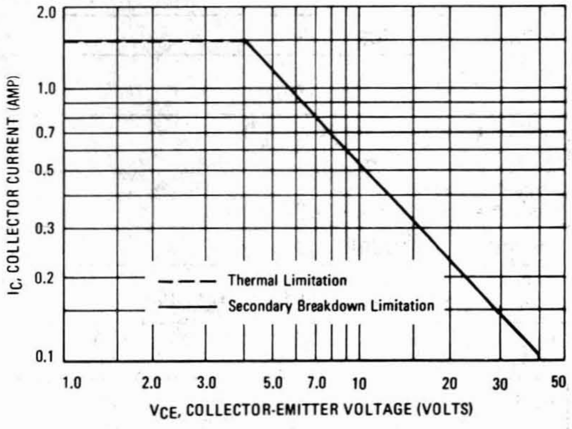
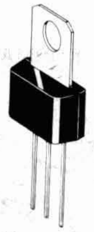


FIGURE 6 – ACTIVE REGION DC SAFE OPERATING AREA



MPS-U03 (SILICON)
MPS-U04



CASE 152

Collector connected to tab

NPN silicon annular plastic transistors designed for video output circuits utilizing an emitter-follower driver and for horizontal driver applications in television receivers.

MAXIMUM RATINGS

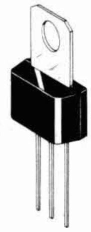
Rating	Symbol	MPS-U03	MPS-U04	Unit
Collector-Emitter Voltage	V_{CEO}	120	180	Vdc
Collector-Base Voltage	V_{CB}	120	180	Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current — Continuous	I_C	1.0		Adc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	1.0 9.09		Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	8.0 72.8		Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135		°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic		Symbol	Min	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage ($I_C = 1.0$ mAdc, $I_B = 0$)	MPSU03 MPSU04	BV_{CEO}	120 180	- -	Vdc
Collector-Base Breakdown Voltage ($I_C = 100$ μAdc, $I_E = 0$)	MPSU03 MPSU04	BV_{CBO}	120 180	- -	Vdc
Emitter-Base Breakdown Voltage ($I_E = 100$ μAdc, $I_C = 0$)		BV_{EBO}	5.0	-	Vdc
Collector Cutoff Current ($V_{CB} = 100$ Vdc, $I_E = 0$) ($V_{CB} = 150$ Vdc, $I_E = 0$)	MPSU03 MPSU04	I_{CBO}	- -	0.1 0.1	μAdc
ON CHARACTERISTICS					
DC Current Gain ($I_C = 10$ mAdc, $V_{CE} = 10$ Vdc)		h_{FE}	40	-	-
Collector-Emitter Saturation Voltage ($I_C = 200$ mAdc, $I_B = 20$ mAdc)		$V_{CE(sat)}$	-	0.5	Vdc
Base-Emitter On Voltage ($I_C = 200$ mAdc, $V_{CE} = 1.0$ Vdc)		$V_{BE(on)}$	-	1.0	Vdc
DYNAMIC CHARACTERISTICS					
Current-Gain—Bandwidth Product ($I_C = 50$ mAdc, $V_{CE} = 20$ Vdc, f = 100 MHz)		f_T	100	-	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 100 kHz)		C_{ob}	-	12	pF
Input Capacitance ($V_{BE} = 0.5$ Vdc, $I_C = 0$, f = 100 kHz)		C_{ib}	-	110	pF

MPS-U51 (SILICON)

PNP silicon annular transistors designed for audio circuits. Complement to NPN MPS-U01.



CASE 152

Collector connected to tab

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	30	Vdc
Collector Current-Continuous	I_C	1.5	Adc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	1.0 9.10	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	8.0 72.8	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	13.7	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	0.110	°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector Cutoff Current ($V_{CE} = 30$ Vdc, $I_B = 0$)	I_{CEO}††	-	1.0	mAdc
Collector Cutoff Current ($V_{CB} = 30$ Vdc, $I_E = 0$)	I_{CBO}	-	0.1	μAdc
Emitter Cutoff Current ($V_{BE} = 3.0$ Vdc, $I_C = 0$)	I_{EBO}	-	0.1	μAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 150$ mAdc, $V_{CE} = 1.0$ Vdc) ($I_C = 1.0$ Adc, $V_{CE} = 1.0$ Vdc)††	h_{FE}	 70 50	 - -	-
Collector-Emitter Saturation Voltage ($I_C = 1.0$ Adc, $I_B = 0.1$ Adc)	$V_{CE(sat)}$	-	1.0	Vdc
Base-Emitter On Voltage†† ($I_C = 1.0$ Adc, $V_{CE} = 1.0$ Vdc)	$V_{BE(on)}$††	-	1.3	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product ($I_C = 50$ mAdc, $V_{CE} = 10$ Vdc, f = 20 MHz)	f_T	50	-	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 100 kHz)	C_{ob}	-	30	pF

†† Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.

FIGURE 1 – NORMALIZED DC CURRENT GAIN

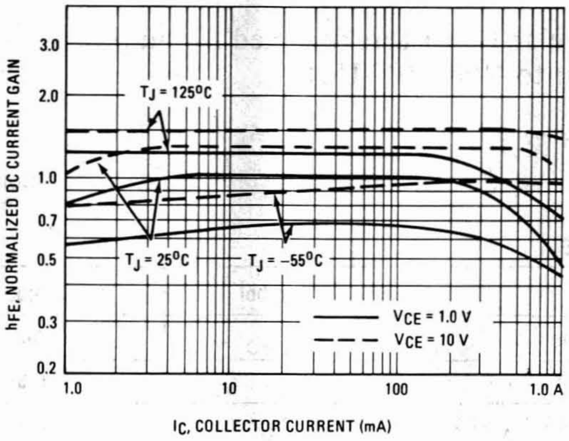


FIGURE 2 – COLLECTOR-EMITTER SATURATION VOLTAGE versus BASE CURRENT

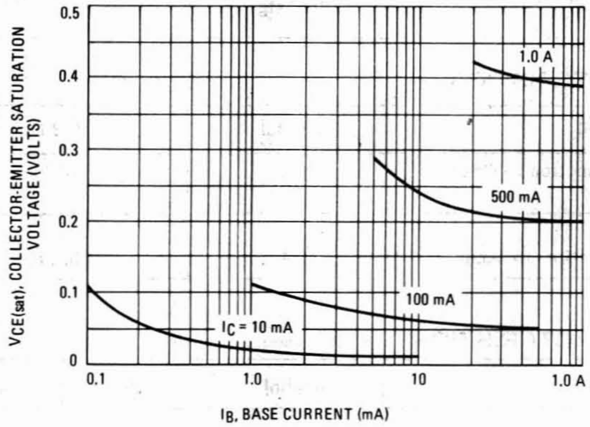


FIGURE 3 – TRANSCONDUCTANCE

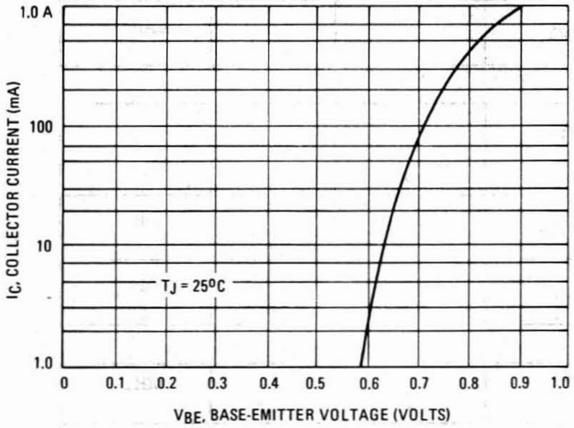
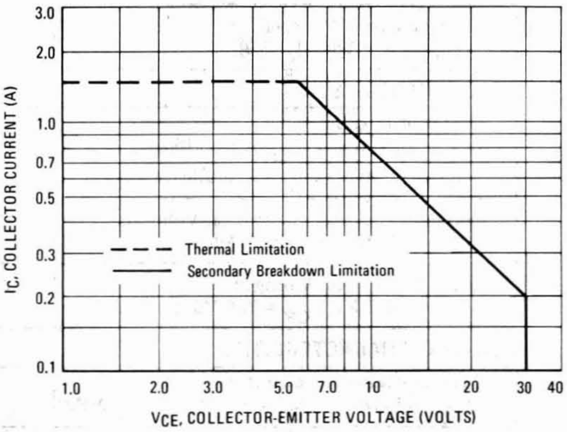
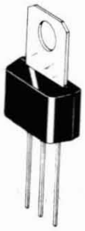


FIGURE 4 – DC SAFE OPERATING AREA



MPSU52 (SILICON)

PNP silicon annular amplifier transistors designed for general-purpose amplifier and driver applications. Complement to NPN MPS-U02.



CASE 152

Collector connected to tab

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Vdc
Collector-Base Voltage	V_{CB}	60	Vdc
Emitter-Base Voltage	V_{EB}	5.0	Vdc
Collector Current — Continuous	I_C	800	mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	1.0 9.1	Watt mW/°C
Total Device Dissipation @ $T_C = 25°C$ Derate above 25°C	P_D	6.0 54.5	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	18.3	°C/W
Thermal Resistance, Junction to Ambient	θ_{JA}	0.110	°C/mW

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage ($I_C = 1.0$ mAdc, $I_B = 0$)	BV_{CEO}	40	-	Vdc
Collector-Base Breakdown Voltage ($I_C = 100\,\mu$Adc, $I_E = 0$)	BV_{CBO}	60	-	Vdc
Collector Cutoff Current ($V_{CB} = 40$ Vdc, $I_E = 0$)	I_{CBO}	-	100	nAdc
ON CHARACTERISTICS				
DC Current Gain ($I_C = 10$ mAdc, $V_{CE} = 10$ Vdc) ($I_C = 150$ mAdc, $V_{CE} = 10$ Vdc) ($I_C = 500$ mAdc, $V_{CE} = 10$ Vdc)	h_{FE}	 50 50 30	 - 300 -	-
Collector-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{CE(sat)}$	-	0.4	Vdc
Base-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc)	$V_{BE(sat)}$	-	1.3	Vdc
DYNAMIC CHARACTERISTICS				
Current-Gain—Bandwidth Product ($I_C = 20$ mAdc, $V_{CE} = 20$ Vdc, f = 100 MHz)	f_T	150	-	MHz
Output Capacitance ($V_{CB} = 10$ Vdc, $I_E = 0$, f = 100 kHz)	C_{ob}	-	8.0	pF

FIGURE 1 — NORMALIZED DC CURRENT GAIN

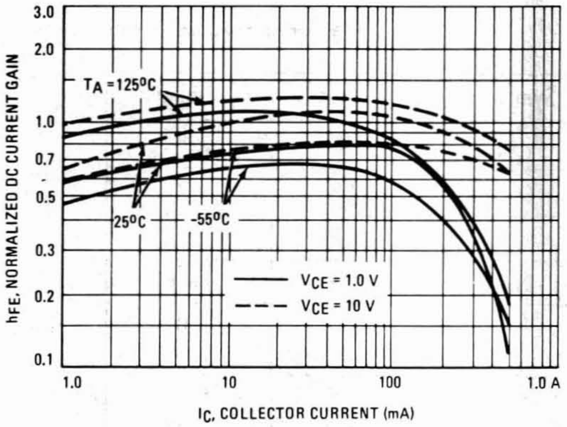


FIGURE 2 — COLLECTOR-EMITTER SATURATION VOLTAGE versus BASE CURRENT

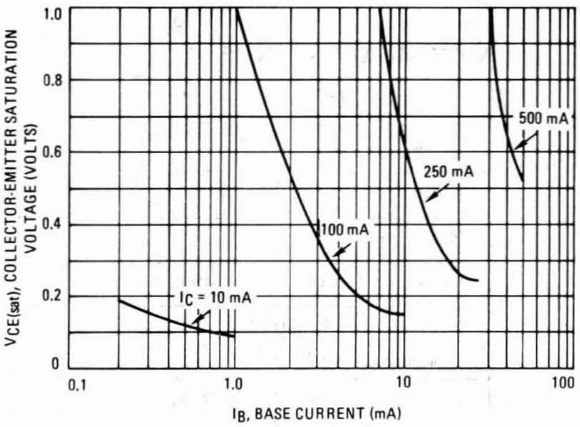


FIGURE 3 — TRANSCONDUCTANCE

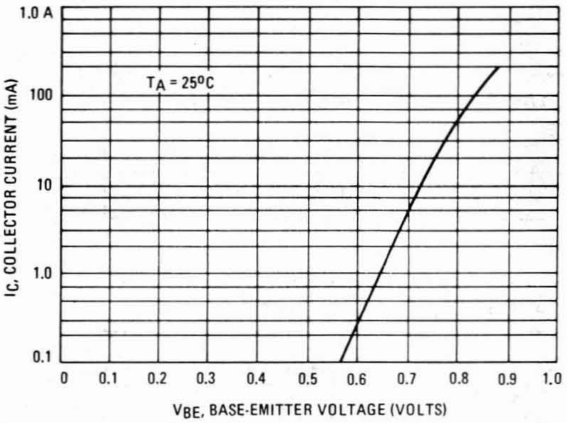


FIGURE 4 — CAPACITANCE versus VOLTAGE

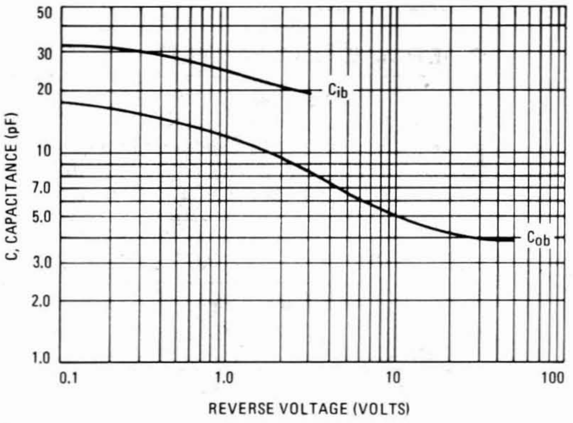


FIGURE 5 — CURRENT-GAIN — BANDWIDTH PRODUCT versus COLLECTOR CURRENT

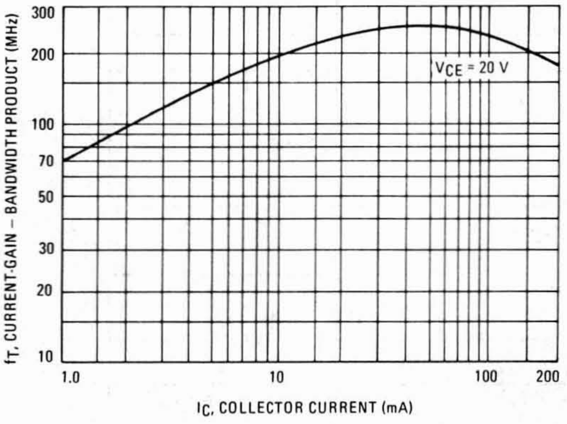
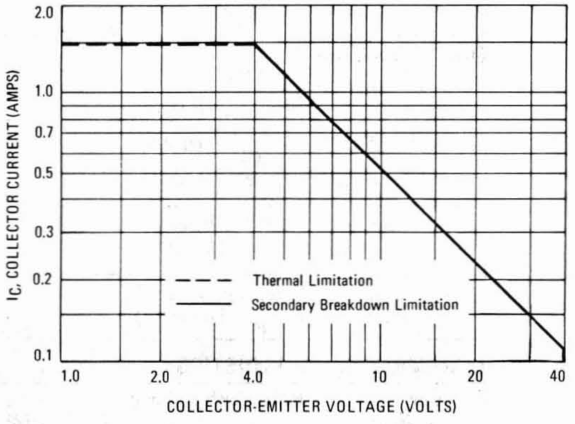


FIGURE 6 — ACTIVE DC SAFE OPERATING AREA



MPT**20** (SILICON)

CASE 182
(Formerly CASE 29 B)

Plastic silicon 3-layer bilateral triggers are two-terminal devices that exhibit bi-directional negative resistance switching characteristics. These economical, durable devices have been developed for use in thyristor triggering circuits for lamp drivers and universal motor speed controls.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Pulse Current (30 μs duration, 120 Hz repetition rate)	I_{pulse}	2.0	Amp
Power Dissipation @ T_A = -40 to +25°C Derate above 25°C	P_D	300 4.0	mW mW/°C
Operating Junction Temperature Range	T_J	-40 to +100	°C
Storage Temperature Range	T_{stg}	-40 to +150	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Plastic Trigger (MPT) devices have bi-directional characteristics and as such the terminal leads are interchangeable. For purposes of symbol clarification, the leads have arbitrarily been designated 1 and 2. A 12 designation indicates that terminal 1 is positive with respect to terminal 2, vice versa for a 21 designation. (See Figure 1)

Characteristic	Symbol	Min	Typ	Max	Unit
Breakover (Switching) Voltage - both directions	$V_{(BR)12}$ & $V_{(BR)21}$	16	20	24	Volt
Breakover (Switching) Current - both directions	$I_{(BR)12}$ & $I_{(BR)21}$	-	35	100	μAmp
Switchback (Delta) Voltage - both directions ($I_{12} = I_{21}$ = 10 mAdc)	ΔV_{12} & ΔV_{21}	5.0	7.0	-	Volt
Peak Blocking Current - both directions Voltage Applied = 14 V	$I_{(BL)12}$ & $I_{(BL)21}$	-	0.5	10	μA

TYPICAL ELECTRICAL CHARACTERISTICS

FIGURE 1 – VOLT-AMPERE CHARACTERISTICS

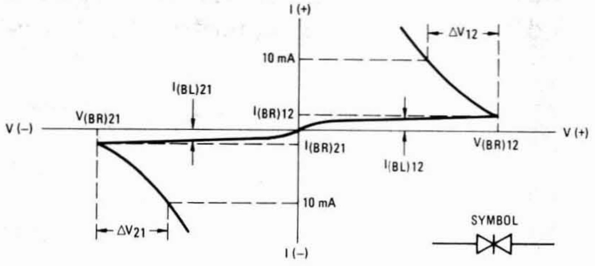


FIGURE 2 – INSTANTANEOUS "ON" VOLTAGE

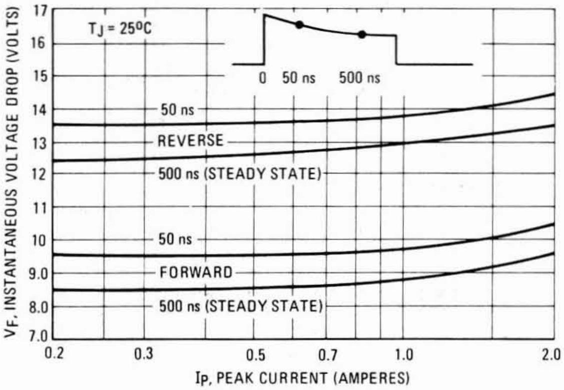


FIGURE 3 – BREAKOVER VOLTAGE BEHAVIOR

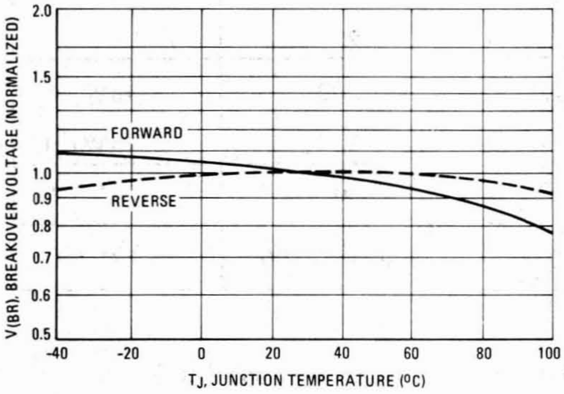


FIGURE 4 – NORMALIZED OUTPUT VOLTAGE BEHAVIOR

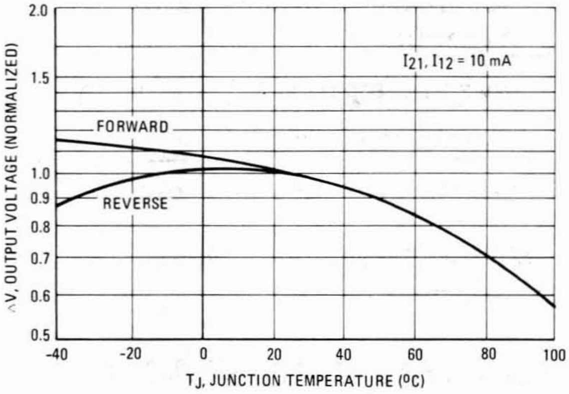


FIGURE 5 – SWITCHING TIMES

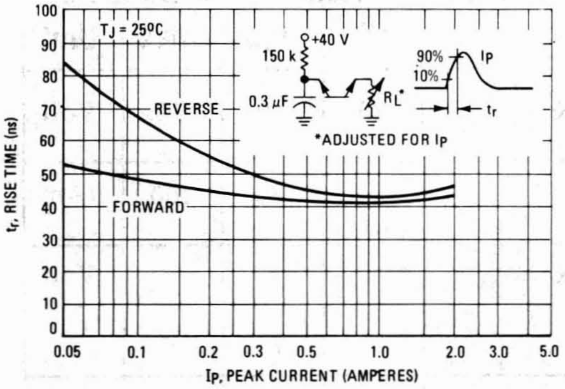
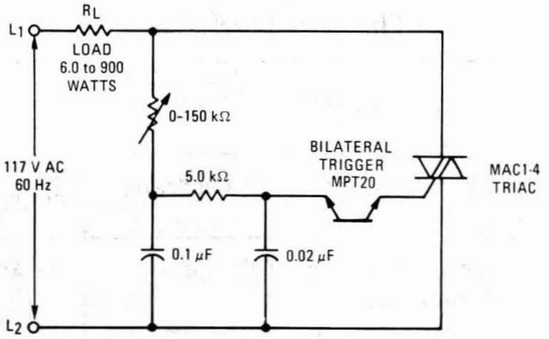
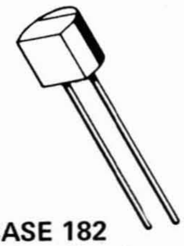


FIGURE 6 – CONTROL CIRCUIT


RL
L1
LOAD
6.0 to 900
WATTS
0-150 kΩ
BILATERAL
TRIGGER
MPT20
117 V AC
60 Hz
5.0 kΩ
MAC1-4
TRIAC
0.1 μF
0.02 μF
L2

MPT28 (SILICON)
MPT32



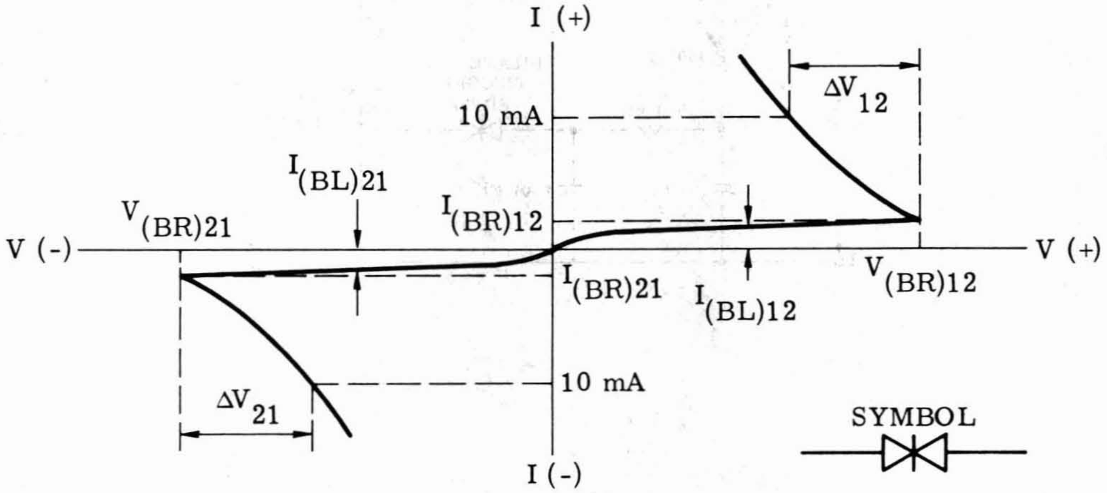
CASE 182
(Formerly CASE 29 B)

Plastic silicon annular 3-layer bilateral triggers, two-terminal devices which exhibit symmetrical negative resistance switching characteristics. These economical, durable devices have been developed for use in thyristor triggering circuits, signal switching and detection circuits.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Pulse Current (30 µs duration, 120 Hz repetition rate)	I_{pulse}	2.0	Amp
Power Dissipation @ T_A = -40 to +25°C Derate above 25°C	P_D	300 4.0	mW mW/°C
Operating Junction Temperature Range	T_J	-40 to +100	°C
Storage Temperature Range	T_{stg}	-40 to +150	°C

FIGURE 1 — VOLT AMPERE CHARACTERISTICS

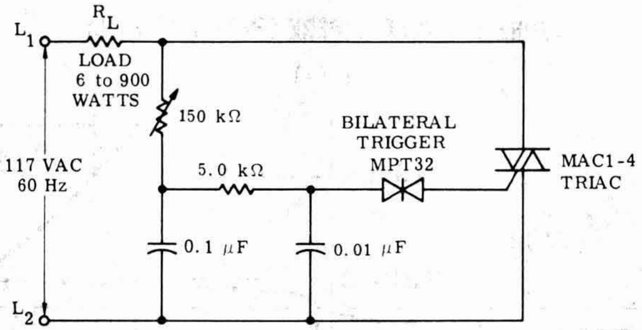


ELECTRICAL CHARACTERISTICS ($T_C = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Breakover (switching) Voltage – both directions	$V_{(BR)12}$ & $V_{(BR)21}$				Volt
MPT28		24	28	32	
MPT32		28	32	36	
Breakover (switching) Current – both directions	$I_{(BR)12}$ & $I_{(BR)21}$	-	20	50	μAmp
Switchback (delta) Voltage – both directions	ΔV_{12} & ΔV_{21}				Volt
MPT28		7.0	10	-	
MPT32		7.0	10	-	
Peak Blocking Current – both directions Voltage Applied = 18 V	$I_{(BL)12}$ & $I_{(BL)21}$	-	0.5	10	μA
Breakover (switching) Voltage Temperature Coefficient, T_A = -40 C to +100°C		-	0.03	-	%/ C

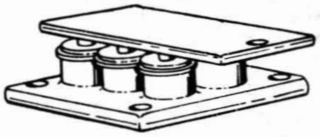
Plastic trigger devices have symmetrical characteristics and as such the terminal leads are interchangeable. For purposes of symbol clarification, the leads have arbitrarily been designated 1 and 2. A 12 designation indicates that terminal 1 is positive with respect to terminal 2, vice versa for a 21 designation.

FIGURE 2 — TYPICAL CONTROL CIRCUIT



MPZ5-16 SERIES (SILICON)
MPZ5-32 SERIES
MPZ5-180 SERIES

Silicon power transient suppressor designed for applications requiring protection of voltage sensitive electronic devices in danger of destruction by high energy voltage transients. Individual cells are matched to insure current-sharing under high current pulse conditions.



CASE 119

MAXIMUM RATINGS

Transient Power Dissipation: 40 kW
Pulse Width: 0.1 ms, (See Figure 1)

DC Power Dissipation: 350 Watts @ $T_C = 25°C$
(Derate 2.33 W/°C above 25°C)

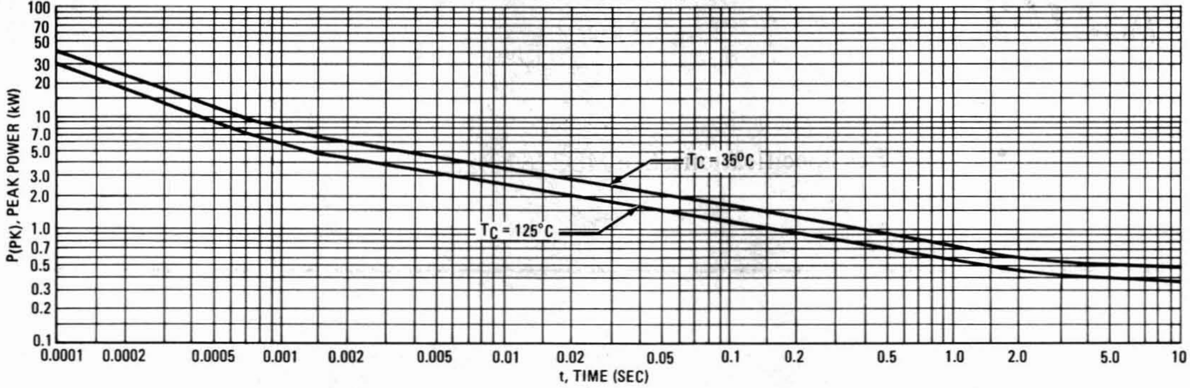
Operating Junction & Storage Temperature
Range: −65°C to +175°C

Polarity:
Anode-to-Case is Standard
Cathode-to-Case Available Upon Request

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$) (V_F = 1.5 V max @ 10 A for all types)

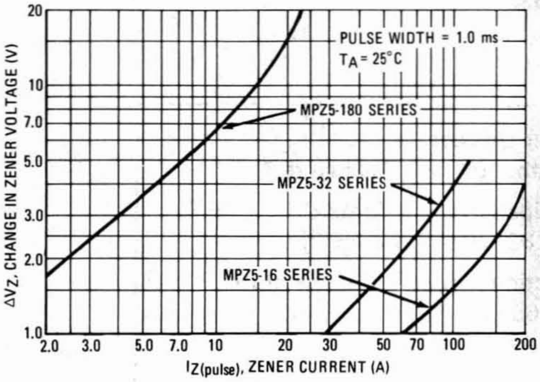
Type	Nominal Operating Voltage (Note 1)		Maximum Device Clamping Factor	Minimum Zener Voltage		Maximum Zener Voltage Pulse Width = 1.0 ms		Maximum Reverse Current $I_{R(max)}$ @ $V_R = V_{OP(PK)}$	Typical Capacitance C (typ) @ $V_R = V_{OP(PK)}$
	$V_{OP(PK)}$ Vdc	$V_{OP(RMS)}$ V rms	$CF = \frac{V_Z @ I_{Z(pulse)}}{V_Z @ I_{ZT}}$ (Note 2)	$V_{Z(min)}$ @ Vdc	I_{ZT} Adc	$V_{Z(max)}$ @ Vdc	$I_{Z(pulse)}$ Adc	μAdc	μF
MPZ5-16A	14	10	1.25	16	0.4	24	200	50	0.025
-16B	14	10	1.25	16	0.4	20	200	↑	0.025
-32A	28	20	1.25	32	0.2	50	100		0.011
-32B	28	20	1.25	32	0.2	45	100		0.011
-32C	28	20	1.25	32	0.2	40	100		0.011
-180A	165	117	1.14	180	0.03	250	20		0.0012
-180B	165	117	1.14	180	0.03	225	20	↓	0.0012
-180C	165	117	1.14	180	0.03	205	20	50	0.0012

FIGURE 1 – MAXIMUM NON-REPETITIVE SURGE POWER
(RECTANGULAR WAVEFORM)



MPZ5-16 series, MPZ5-32 series, MPZ5-180 series (continued)

FIGURE 2 – TYPICAL DYNAMIC ZENER VOLTAGE CHARACTERISTICS (Note 2)



NOTE 1: Nominal operating voltage is defined as normal input voltage to device for non-operating condition. If non-sinusoidal wave or dc input is present, peak voltage input values $V_{OP(PK)}$ should be used to select device type.

NOTE 2: The maximum device clamping factor C_F is a ratio of V_Z measured at I_Z (pulse) given in the Electrical Characteristics Table divided by V_Z measured at I_{ZT} under steady state conditions. This value guarantees the sharpness of the voltage breakdown of individual devices. Figure 2 demonstrates the typical sharpness of the breakdown, and indicates the voltage regulation over a wide range of currents.

$$\Delta V_Z = V_Z \ @ \ I_{Z\,(pulse)} - V_Z \ @ \ I_{ZT}$$

MQ3467

For Specifications, See MD3467 Data.

MQ3725

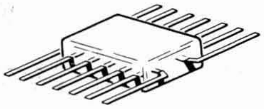
For Specifications, See MD3725 Data.

MQ3762

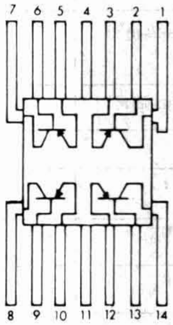
For Specifications, See MD3762 Data.

MQ3799 (SILICON)
MQ3799A

Quad PNP silicon annular transistors specifically designed for differential amplifier applications.



CASE 83
(TO-86)



Lead 1 identified by color dot or by elbow on lead. All leads electrically isolated from package.

MAXIMUM RATINGS (each transistor)

Rating	Symbol	Value		Unit
Collector-Emitter Voltage	V_{CEO}	60		Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current	I_C	50		mAdc
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200		°C
		One Device	Four Devices	
Total Device Dissipation @ T_A = 25°C	P_D	250	500	mW
Derate above 25°C		1.5	2.85	mW/°C

ELECTRICAL CHARACTERISTICS (each transistor) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS					
Collector-Emitter Breakdown Voltage* (I_C = 10 mAdc, I_B = 0)	BV_{CEO}*	60	90	-	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)	BV_{CBO}	60	-	-	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)	BV_{EBO}	5.0	-	-	Vdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0) (V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	I_{CBO}	- -	- -	0.01 10	μAdc
Emitter Cutoff Current ($V_{BE(off)}$ = 4.0 Vdc, I_C = 0)	I_{EBO}	-	-	20	nAdc

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2%

MQ3799, MQ3799A (continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	Min	Typ	Max	Unit
ON CHARACTERISTICS					
DC Current Gain*	h_{FE}*				-
(I_C = 10 μAdc, V_{CE} = 5.0 Vdc)		225	-	-	
(I_C = 100 μAdc, V_{CE} = 5.0 Vdc)		300	-	900	
(I_C = 500 μAdc, V_{CE} = 5.0 Vdc)		300	-	900	
(I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc)		300	-	900	
Collector-Emitter Saturation Voltage*	$V_{CE(sat)}$*				Vdc
(I_C = 100 μAdc, I_B = 10 μAdc)		-	-	0.2	
(I_C = 1.0 mAdc, I_B = 100 μAdc)		-	-	0.25	
Base-Emitter Saturation Voltage*	$V_{BE(sat)}$*				Vdc
(I_C = 100 μAdc, I_B = 10 μAdc)		-	-	0.7	
(I_C = 1.0 mAdc, I_B = 100 μAdc)		-	-	0.8	
Base-Emitter On Voltage (I_C = 100 μAdc, V_{CE} = 5.0 Vdc)	$V_{BE(on)}$	-	-	0.7	Vdc
SMALL-SIGNAL CHARACTERISTICS					
Current-Gain—Bandwidth Product (I_C = 1.0 mAdc, V_{CE} = 5.0 Vdc, f = 100 MHz)	f_T	100	-	500	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 100 kHz)	C_{ob}	-	-	4.0	pF
Input Capacitance (V_{BE} = 0.5 Vdc, I_C = 0, f = 100 kHz)	C_{ib}	-	-	8.0	pF
Input Impedance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{ie}	-	12	-	k ohms
Voltage Feedback Ratio (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{re}	-	2.5	-	$\times 10^{-4}$
Small-Signal Current Gain (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{fe}	-	500	-	-
Output Admittance (I_C = 1.0 mAdc, V_{CE} = 10 Vdc, f = 1.0 kHz)	h_{oe}	-	12	-	μmhos
Noise Figure	NF				dB
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, f = 100 Hz)		-	2.5	-	
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, f = 1.0 kHz)		-	0.8	-	
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, f = 10 kHz)		-	0.8	-	
(I_C = 100 μAdc, V_{CE} = 10 Vdc, R_S = 3.0 k ohms, Noise Bandwidth = 10 Hz to 15.7 kHz)		-	1.5	-	
MATCHING CHARACTERISTICS					
DC Current Gain Ratio** (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) MQ3799A	h_{FEi}/h_{FEj}** ①	0.9	-	1.0	-
Base Voltage Differential (I_C = 100 μAdc, V_{CE} = 5.0 Vdc) MQ3799A	$\left\|V_{BEi}-V_{BEj}\right\|$ ②	-	-	3.0	mVdc
Base Voltage Differential Gradient (I_C = 100 μAdc, V_{CE} = 5.0 Vdc, T_A = -55°C to +125°C) MQ3799A	$\frac{\Delta\left(V_{BEi}-V_{BEj}\right)}{\Delta T_A}$ ③	-	-	10	μV/°C

* Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%

** $h_{FEi} \leq h_{FEj}$

① i = Transistor 1, 2, 3 or 4

② j = Transistor 1, 2, 3 or 4

③ j > i

FIGURE 1 — BASE-EMITTER "ON" VOLTAGE versus TEMPERATURE

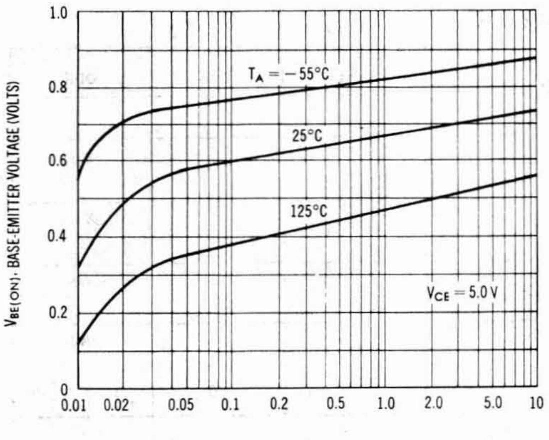
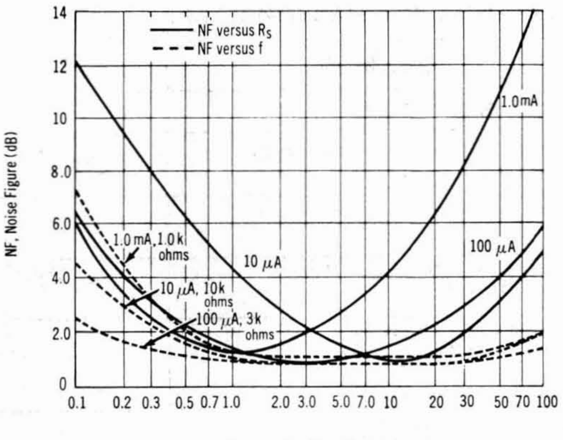
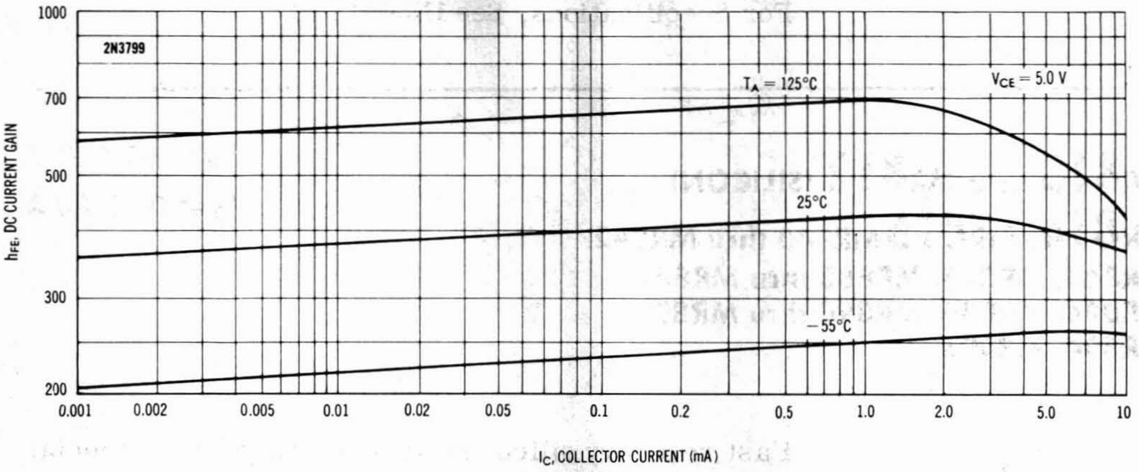


FIGURE 2 — NOISE FIGURE versus FREQUENCY AND SOURCE RESISTANCE



MQ3799, MQ3799A (continued)

FIGURE 3 — TYPICAL CURRENT GAIN CHARACTERISTICS



SMALL SIGNAL h PARAMETERS

(V_{CE} = 10 Vdc, T_A = 25°C, f = 1.0 kHz)

FIGURE 4 — CURRENT GAIN

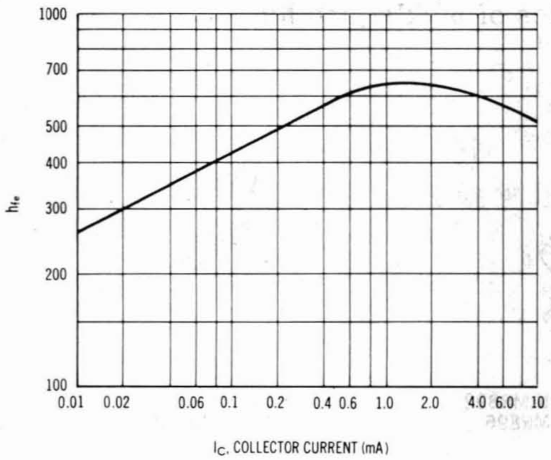


FIGURE 5 — OUTPUT ADMITTANCE

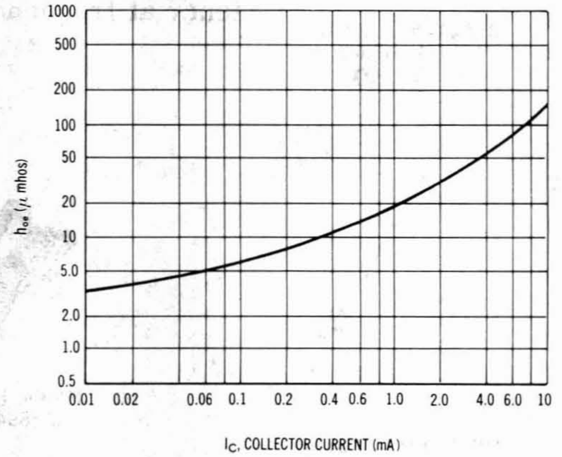


FIGURE 6 — INPUT IMPEDANCE

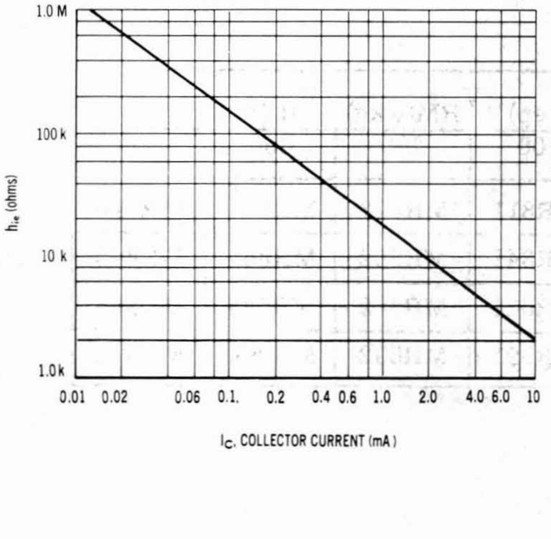
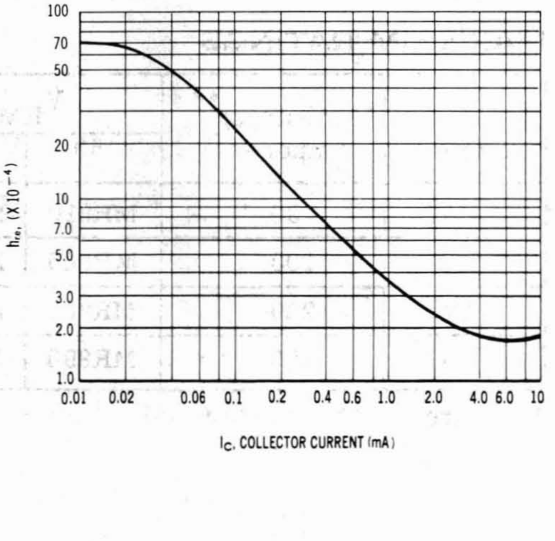


FIGURE 7 — VOLTAGE FEEDBACK RATIO



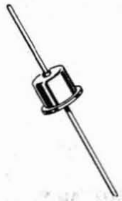
MR322 thru MR326
MR327, MR328, MR330, MR331

For Specifications, See 1N3491 Data.

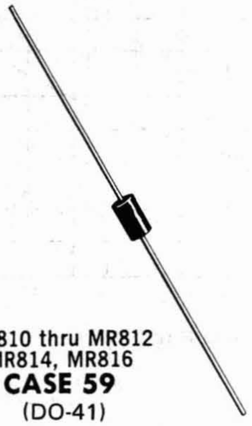
MR810 thru MR812 (SILICON)
MR814, MR816 MR840 thru MR842
MR844, MR846, MR880 thru MR882
MR884, MR886, MR890 thru MR892
MR894, MR896

V_R = 50-600 V
I_O = 0.75-30 A

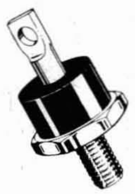
Fast recovery silicon rectifiers designed for special applications such as high frequency rectification, inverters, free-wheeling diodes, and other fast switching circuits. A complete line of rectifiers having typical recovery time of 0.5 microseconds providing high efficiency at frequencies of 50 kHz and higher.



MR840 thru MR842
MR844, MR846
CASE 60

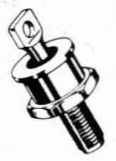


MR810 thru MR812
MR814, MR816
CASE 59
(DO-41)



MR890 thru MR892
MR894, MR896

CASE 42
(DO-5)



MR880 thru MR882
MR884, MR886

CASE 56A
(DO-4)

MAXIMUM RATINGS

I_O * Ampere	$I_{FM(surge)}$ ** Ampere	$V_{RM(rep)}$, $V_{RM(wkg)}$, V_R (volts)				
		50	100	200	400	600
0.75	30	MR810	MR811	MR812	MR814	MR816
3.0	100	MR840	MR841	MR842	MR844	MR846
12	200	MR880	MR881	MR882	MR884	MR886
30	350	MR890	MR891	MR892	MR894	MR896

* Figure 3 ** Figure 4

THERMAL CHARACTERISTICS

Characteristic	Symbol	Value	Unit
Maximum Junction Operating Temperature Range	T_J	-65 to +150	°C
Maximum Case Storage Temperature Range	T_{stg}	-65 to +175	°C

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
MR810 - MR816			
DC Forward Voltage Drop (I_F = 1.0 Adc, T_A = 25°C)	V_F	1.4	Vdc
DC Reverse Current (Rated V_R) T_A = 25°C	I_R	0.01	mA
T_A = 100°C		0.2	
MR840 - MR846			
DC Forward Voltage Drop (I_F = 3.0 Adc, T_A = 25°C	V_F	1.4	Vdc
DC Reverse Current (Rated V_R) T_A = 25°C	I_R	0.075	mA
T_A = 100°C		3.5	
MR880 - MR886			
DC Forward Voltage Drop (I_F = 12 Adc, T_C = 25°C)	V_F	1.4	Vdc
DC Reverse Current (Rated V_R) T_C = 25°C	I_R	0.5	mA
T_C = 100°C		4.0	
MR890 - MR896			
DC Forward Voltage Drop (I_F = 30 Adc, T_C = 25°C)	V_F	1.4	Vdc
DC Reverse Current (Rated V_R) T_C = 25°C	I_R	1.2	mA
T_C = 100°C		15	

REVERSE RECOVERY TIME CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Maximum Reverse Recovery Time (I_F = 1 Amp min, Figure 2 test circuit) All Types	t_{rr}	1.0	µs
Maximum Overshoot Current (Figure 2)	I_{os}		Amp
MR810, 840, 880 Series		2.0	
MR890 Series		3.0	

FIGURE 1 — TYPICAL RECOVERY PATTERN

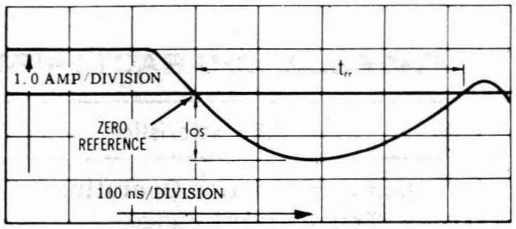
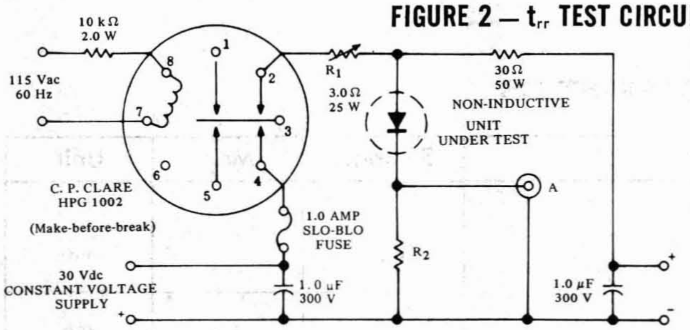


FIGURE 2 — t_{rr} TEST CIRCUIT


10 kΩ
2.0 W
115 Vac
60 Hz
1
2
3
4
5
6
7
8
C. P. CLARE
HPG 1002
(Make-before-break)
30 Vdc
CONSTANT VOLTAGE
SUPPLY
R1
3.0 Ω
25 W
30 Ω
50 W
NON-INDUCTIVE
UNIT
UNDER TEST
A
1.0 AMP
SLO-BLO
FUSE
R2
1.0 µF
300 V
1.0 µF
300 V
+
-

A — TEKTRONIX 545A, K PLUG-IN PRE-AMP, P6000 PROBE OR EQUIVALENT

R_1 — ADJUST TO APPROXIMATELY 1.4 Ω TO GIVE A MAX I_{os} WHICH IS NOT GREATER THAN THE MAX SPECIFIED VALUE. t_{rr} IS THEN MEASURED.

R_2 — TEN 1.0 W, 10 Ω, 1% CARBON COMPOUND RESISTORS IN PARALLEL

$T_A = 25^{+10}_{-0}$ °C FOR RECTIFIER

MINIMIZE ALL LEAD LENGTHS

1.0 Adc FROM CONSTANT VOLTAGE SUPPLY
RIPPLE = 3.0 mV RMS MAX
Z_{out} = 1/2 Ω Max dc to 2.0 kHz.

FIGURE 3 — MAXIMUM CURRENT RATING

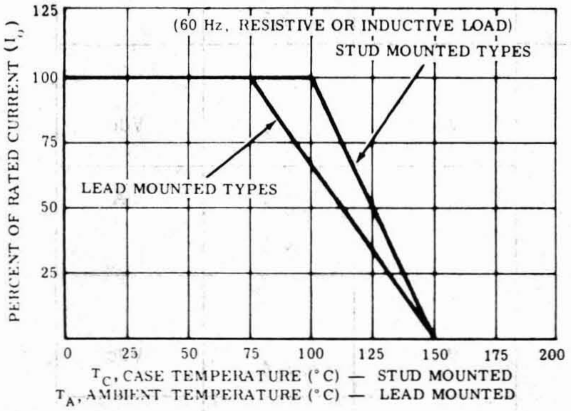
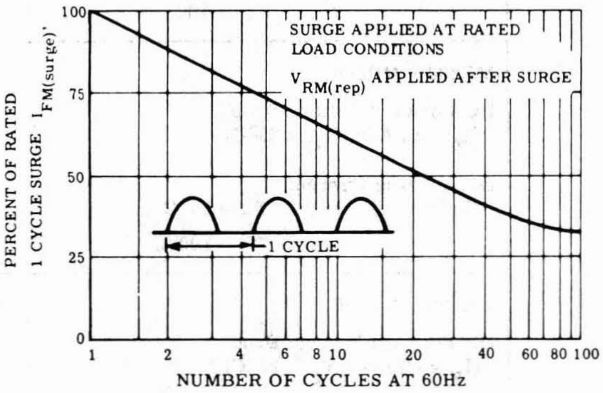


FIGURE 4 — MAXIMUM ALLOWABLE SURGE CURRENT



MR830 thru MR836

For Specifications, See 1N4933 Data.

MR840 thru MR842
MR844
MR846
MR880 thru MR882
MR884, MR886
MR890 thru MR892
MR894
MR896

For Specifications, See MR810 Data.

MR990A (SILICON)
thru
MR996A

High-voltage, low-current rectifiers designed for applications where high-voltages in subminiature packages are required. These devices feature efficient high-temperature current-handling performance, high surge-current capabilities and surface passivation.

CASE 169
(Formerly Case 59A)

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	MR990A	MR991A	MR992A	MR993A	MR994A	MR995A	MR996A	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	1000	1500	2000	2500	3000	4000	5000	Volts
RMS Reverse Voltage	V_r	700	1050	1400	1750	2100	2800	3500	Volts
Average Rectified Forward Current (single phase, resistive load, 60 Hz, T_A = 75°C)	I_O	250							mA
Peak Repetitive Forward Current (T_A = 75°C)	$I_{FM(rep)}$	2.0							Amp
Non-Repetitive Peak Surge Current (superimposed on rated current at rated voltage, T_A = 75°C)	$I_{FM(surge)}$	15 (for 1/2 cycle)							Amp
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +150							°C

THERMAL CHARACTERISTICS

Characteristics	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient (1 inch lead length)	θ_{JA}	100	°C/W

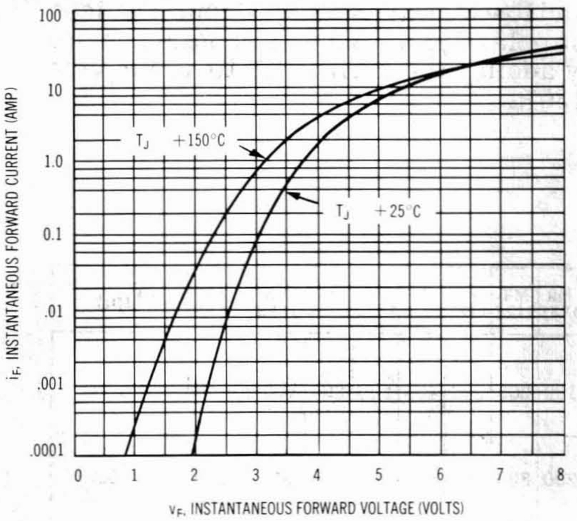
ELECTRICAL CHARACTERISTICS (At 60 Hz Sinusoidal, Resistive or Inductive)

Characteristic	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop (I_O = 0.25 Amp and Rated V_r, T_A = 75°C, Half Wave Rectifier)	$V_{F(AV)}$	1.7	Volts
DC Forward Voltage Drop (I_F = 0.25 Adc, T_A = 25°C)	V_F	3.5	Volts
Full Cycle Average Reverse Current (I_O = 0.25 Amp and Rated V_r, T_A = 75°C, Half Wave Rectifier)	$I_{R(AV)}$	100	µA
DC Reverse Current (Rated V_R, T_A = 25°C)	I_R	10	µA

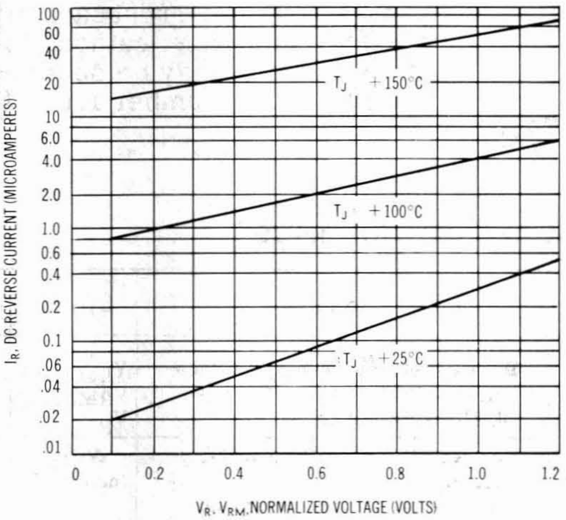
MECHANICAL CHARACTERISTICS

CASE: Void free, flame-proof silicone polymer case
FINISH: All external surfaces corrosion-resistant and leads readily solderable
POLARITY: Indicated by polarity band
MOUNTING POSITIONS: Any
WEIGHT: 0.40 Gram (approx)
MAXIMUM LEAD TEMPERATURE FOR SOLDERING PURPOSES: 350°C, 3/8" from case for 10 seconds

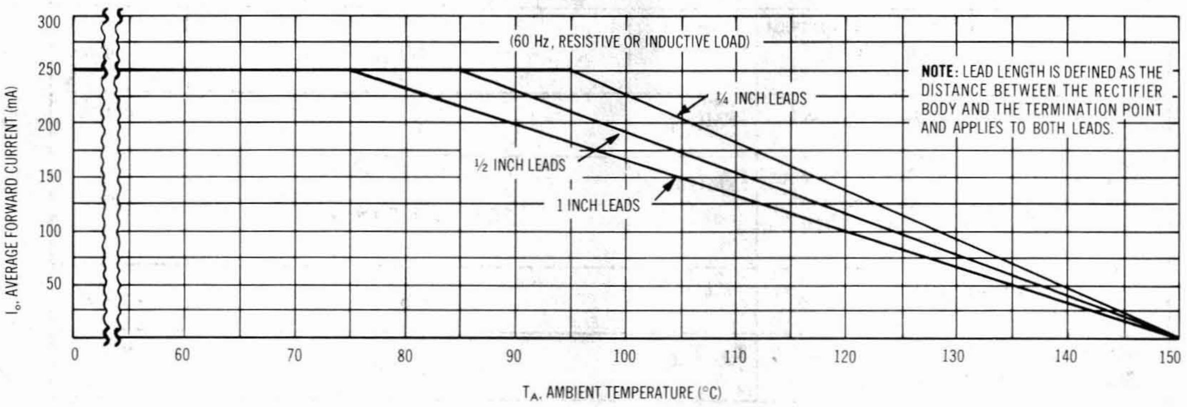
TYPICAL FORWARD CHARACTERISTICS



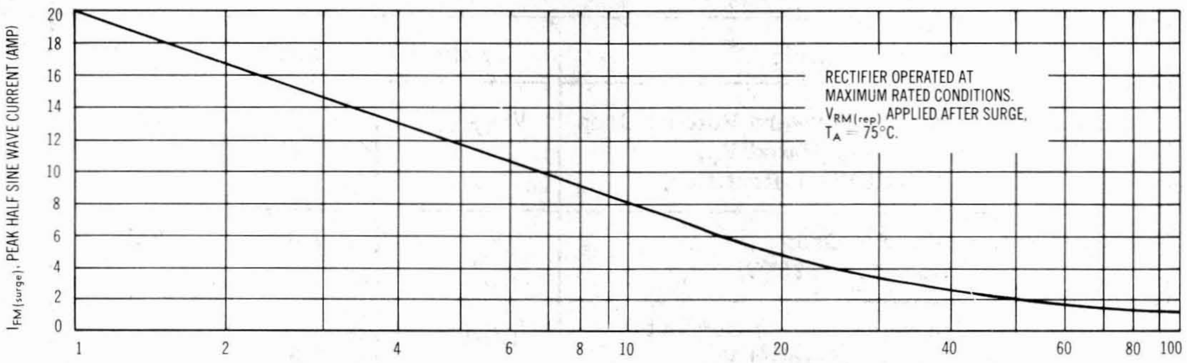
TYPICAL REVERSE CHARACTERISTICS



CURRENT DERATING



MAXIMUM ALLOWABLE NON-REPETITIVE SURGE CURRENT



MR1030 thru MR1036

MR1038, MR1040

For Specifications, See 1N4719 Data.

MR1120 thru MR1126 (SILICON)
MR1128
MR1130

V_R — to 1000 V
I_O = 12 A

CASE 56A
(DO-4)

Medium-current silicon rectifiers feature high surge current capacity, and low forward voltage drop. Devices have cathode-to-case polarity, but reverse polarity units may be obtained by adding the suffix "R" to the device number i.e. MR1130R.

MAXIMUM RATINGS

Rating	Symbol	MR 1120	MR 1121	MR 1122	MR 1123	MR 1124	MR 1125	MR 1126	MR 1128	MR 1130	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RM} (rep) V_{RM} (wkg) V_R	50	100	200	300	400	500	600	800	1000	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single phase, 60 cycle peak)	V_{RM} (non-rep)	100	200	300	400	500	600	720	1000	1200	Volts
RMS Reverse Voltage	V_r	35	70	140	210	280	350	420	560	700	Volts
Average Rectified Forward Current (single phase, resistive load, 60 cps, $T_C = 150^oC$)	I_O	12.0									Amp
Peak Repetitive Forward Current ($T_C = 150^oC$)	$I_{FM(rep)}$	75									Amp
Non-Repetitive Peak Surge Current (superimposed on rated current at rated voltage, $T_C = 150^oC$)	$I_{FM(surge)}$	300 (for 1/2 cycle)									Amp
I^2t Rating (non-repetitive, 1 msec < t < 8.3 ms)	I^2t	375									$A(rms)^2s$
Maximum Junction Operating and Storage Temperature Range	T_J, T_{stg}	-65 to +190									^oC

ELECTRICAL CHARACTERISTICS (All Types)

Characteristic	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop (I_O = 12.0 Amps and Rated V_r, $T_C = 150^oC$, Half Wave Rectifier)	$V_{F(AV)}$	0.55	Volts
DC Forward Voltage Drop (I_F = 12.0 Adc, $T_C = 25^oC$)	V_F	1.0	Volts
Full Cycle Average Reverse Current (I_O = 12.0 Amps and Rated V_r, $T_C = 150^oC$, Half Wave Rectifier)	$I_{R(AV)}$	1.5	mA
DC Reverse Current (Rated V_R, $T_C = 25^oC$)	I_R	0.5	mA

MR1120 thru MR1126, MR1128, MR1130 (continued)

THERMAL CHARACTERISTICS

Maximum Steady State DC Thermal Resistance, θ_{JC}: 2.5°C/Watt

MECHANICAL CHARACTERISTICS

CASE: Welded, hermetically sealed construction.

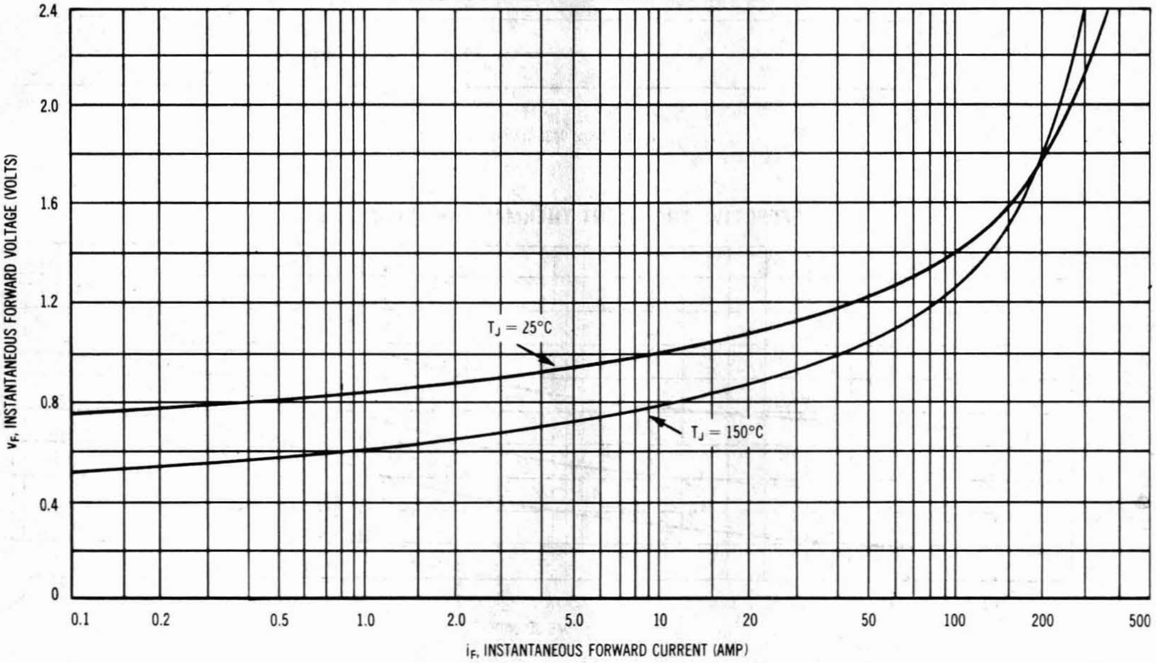
FINISH: All external surfaces corrosion-resistant and the terminal lug is readily solderable.

POLARITY: CATHODE-TO-CASE (reverse polarity units are available upon request and are designated by an "R" suffix i. e. MR1120R).

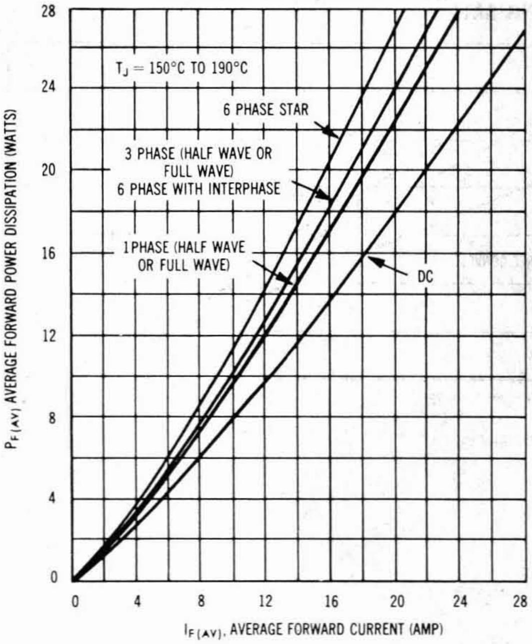
MOUNTING POSITIONS: Any

STUD TORQUE: 15 in-lbs maximum.

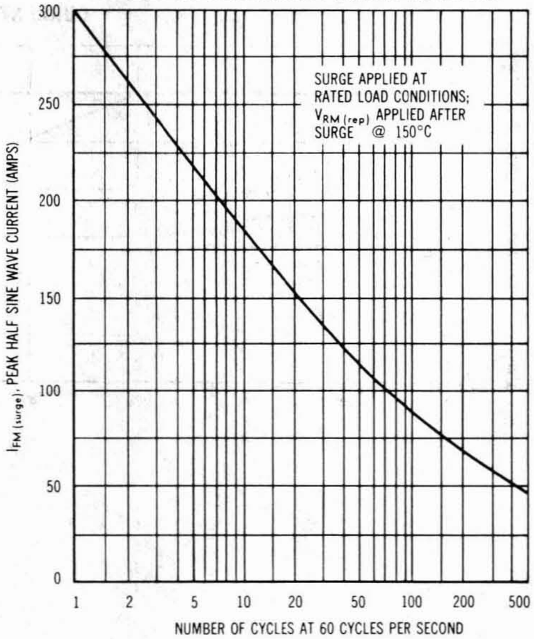
TYPICAL FORWARD CHARACTERISTICS



FORWARD POWER DISSIPATION

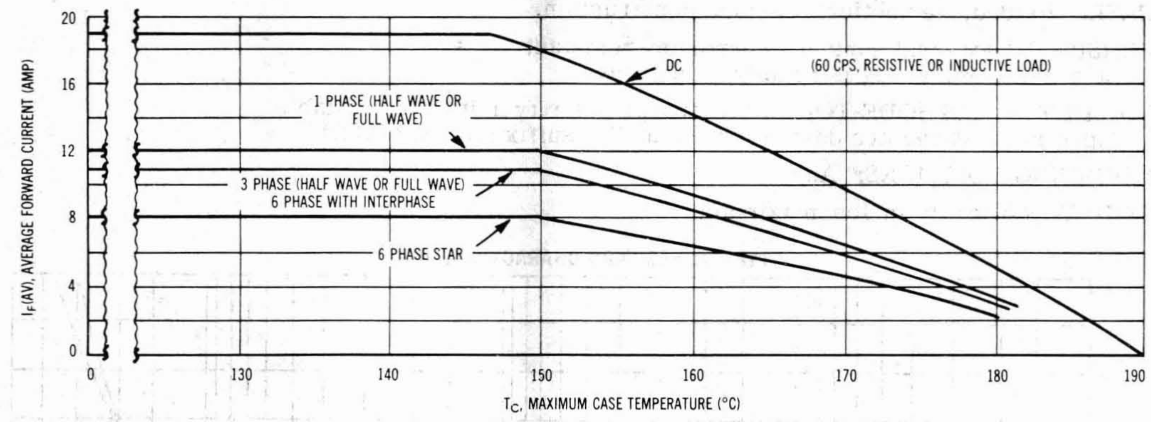


MAXIMUM ALLOWABLE SURGE CURRENT

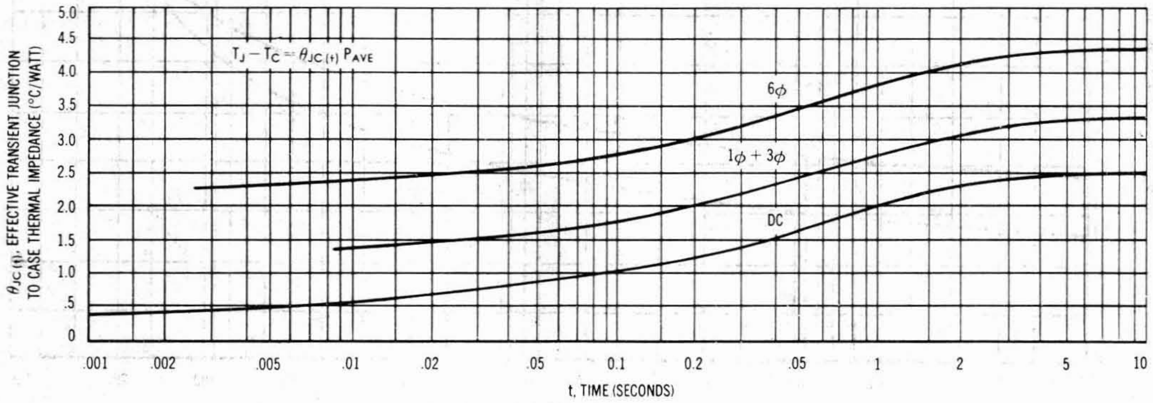


MR1120 thru MR1126, MR1128, MR1130 (continued)

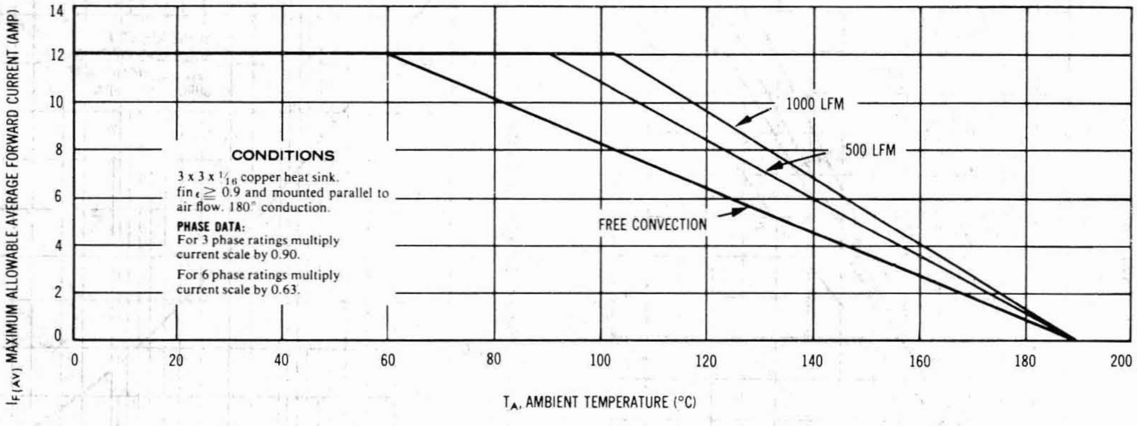
MAXIMUM CURRENT RATINGS



EFFECTIVE TRANSIENT THERMAL IMPEDANCE



CURRENT DERATING DATA



CONDITIONS

3 x 3 x 1/16 copper heat sink. fin ε ≥ 0.9 and mounted parallel to air flow. 180° conduction.

PHASE DATA:
For 3 phase ratings multiply current scale by 0.90.

For 6 phase ratings multiply current scale by 0.63.

RECTIFIER SUBSTITUTION GUIDE

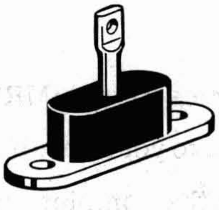
Due to its optimized design, this 12-ampere rectifier series (types MR1120 - MR1130) provides a high performance, economical solution to your specification and procurement requirements. Only nine types, covering the complete voltage range from 50 to 1000 volts, can substitute for a multitude of devices as typified in the table below. This table is only a guide and general reference to the EIA registered types which can be replaced; minor specification variations may exist.

MR1120 50V	MR1121 100V	MR1122 200V	MR1123 300V	MR1124 400V	MR1125 500V	MR1126 600V	MR1128 800V	MR1130 1000V
1N607	1N253	1N254	1N334	1N255	1N554	1N256	1N562	1N563
1N607A	1N338	1N336	1N335	1N332	1N613	1N555	1N3649	1N3650
1N1199	1N339	1N337	1N343	1N333	1N613A	1N614	1N3670	1N3672
1N1199A	1N340	1N345	1N344	1N341	1N1119	1N614A	1N3670A	1N3672A
1N1341	1N348	1N346	1N552	1N342	1N1127	1N1120	1N3671	1N3673
1N1341A	1N349	1N551	1N611	1N553	1N1127A	1N1128	1N3671A	1N3673A
1N1537	1N550	1N609	1N611A	1N612	1N1205	1N1128A	1N3987	1N3989
1N1612	1N608	1N609A	1N1117	1N612A	1N1205A	1N1206	1N3988	1N3990
	1N608A	1N610	1N1125	1N1118	1N1347	1N1206A		
	1N1115	1N610A	1N1125A	1N1126	1N1347A	1N1348		
	1N1200	1N1116	1N1203	1N1126A	1N1543	1N1348A		
	1N1200A	1N1124	1N1203A	1N1204	1N3573	1N1544		
	1N1342	1N1124A	1N1345A	1N1204A		1N1616		
	1N1342A	1N1201	1N1541	1N1346		1N3574		
	1N1538	1N1201A	1N3571	1N1346A				
	1N1613	1N1202		1N1542				
	1N3569	1N1202A		1N1615				
		1N1343		1N3572				
		1N1343A						
		1N1344						
		1N1344A						
		1N1539						
		1N1540						
		1N1614						
		1N3570						

NOTE: While the MR1120 through MR1130 are preferred device types, the above listed EIA types are also available upon request.

MR1200 thru MR1203 (SILICON)
MR1205, MR1207 thru MR1209

V_R — to 600 V
$I_O = 50$ A



CASE 100

Silicon power rectifiers designed with double-case, multi-cell construction for extreme reliability and ruggedness. Standard cathode-to-case polarity, but available with reverse polarity by adding suffix "R" to type number.

MAXIMUM RATINGS

Rating	Symbol	MR 1200	MR 1201	MR 1202	MR 1203	MR 1205	MR 1207	MR 1208	MR 1209	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	150	200	300	400	500	600	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single phase, 60 cycle peak)	$V_{RM\,(non\text{-}rep)}$	100	200	250	300	400	500	600	720	Volts
RMS Reverse Voltage	V_r	35	70	105	140	210	280	350	420	Volts
Average Rectified Forward Current (single phase, resistive load, 60 Hz, see Figure 3) $T_C = 150°C$	I_O	50								Amp
Non-Repetitive Peak Surge Current (surge applied at rated load conditions, see Figure 5) $T_C = 150°C$	$I_{FM\,(surge)}$	800 (for 1/2 cycle) 500 (for six consecutive cycles)								Amp
I^2t Rating (non-repetitive, for t greater than 1 ms and less than 8.3 ms)	I^2t	1,300								$A_{(rms)}^2s$
Operating and Storage Junction Temperature Range (see Figure 4 for other conditions)	T_J, T_{stg}	-65 to +190								°C

ELECTRICAL CHARACTERISTICS

Characteristics and Conditions	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop (rated I_O and V_r, single phase, 60 cps, $T_C = 150°C$)	$V_{F(AV)}$	0.4	Volts
Full Cycle Average Reverse Current (rated I_O and V_r, single phase, 60 cps, $T_C = 150°C$)	$I_{R(AV)}$	10	mA

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.60	°C/Watt

MR1200 thru MR1203, MR1205, MR1207 thru MR1209 (continued)

MECHANICAL CHARACTERISTICS

PACKAGE CONFIGURATION:

MR1200FL rectifiers are designed for flat mounting and have a solid lug terminal.

All units have a plated copper base and terminal. Molded external case with internal hermetically sealed, metallic case rectifier cells.

POLARITY:

Standard polarity devices are CATHODE-TO-CASE.

Reverse polarity devices are ANODE-TO-CASE and are designated by an "R" suffix i.e. MR1205FLR.

MOUNTING POSITION: Any.

MOUNTING BOLT TORQUES:

For Flat Mounted "FL" rectifiers use 8-32 bolts torqued to 30 in-lbs min., 40 in-lbs max. Use an alternating procedure when torquing the two bolts and do not tighten one bolt completely without tightening the other.

FIGURE 1 — MAXIMUM FORWARD VOLTAGE DROP

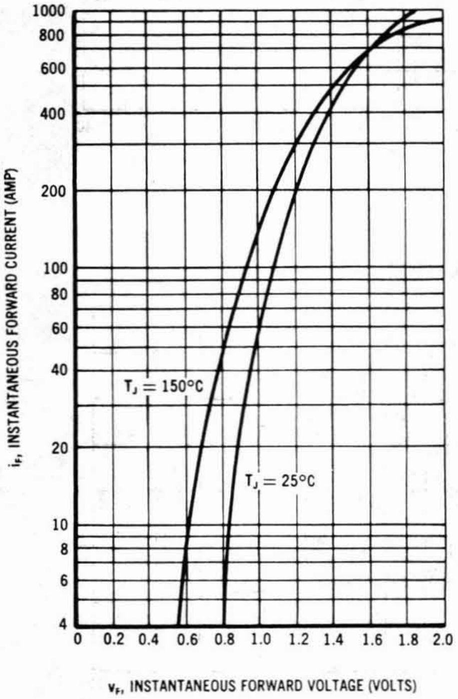


FIGURE 2 — FORWARD POWER DISSIPATION

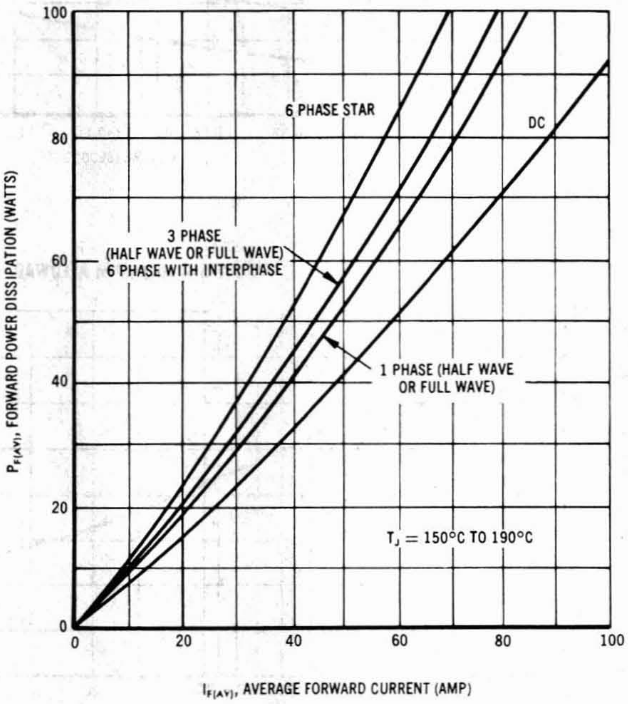


FIGURE 3 — MAXIMUM CURRENT RATINGS

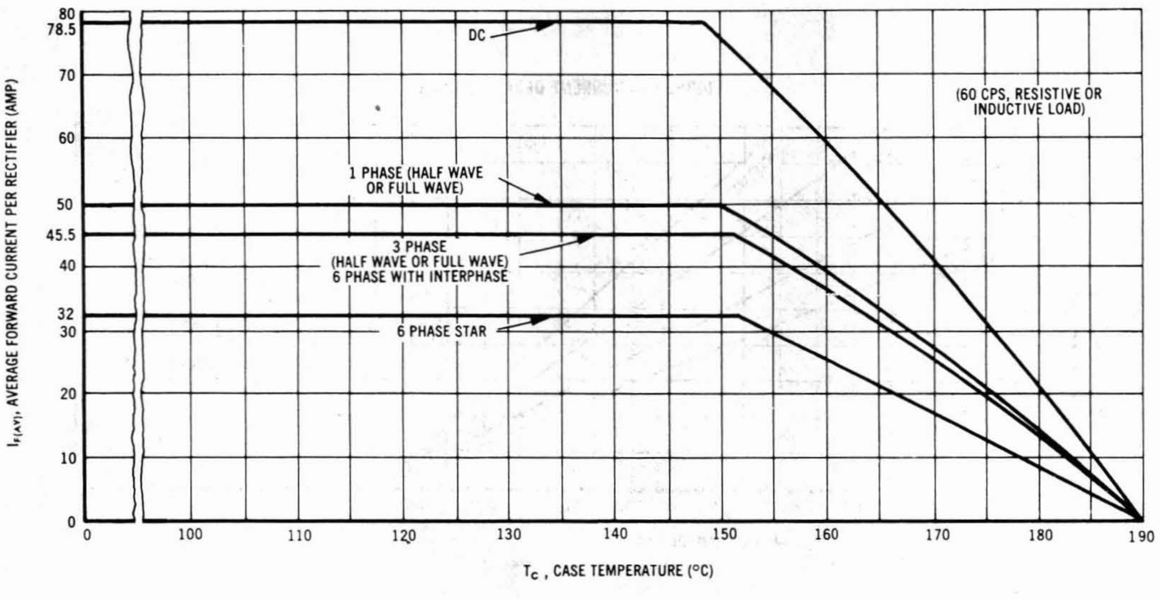


FIGURE 4 — EFFECTIVE TRANSIENT THERMAL IMPEDANCE

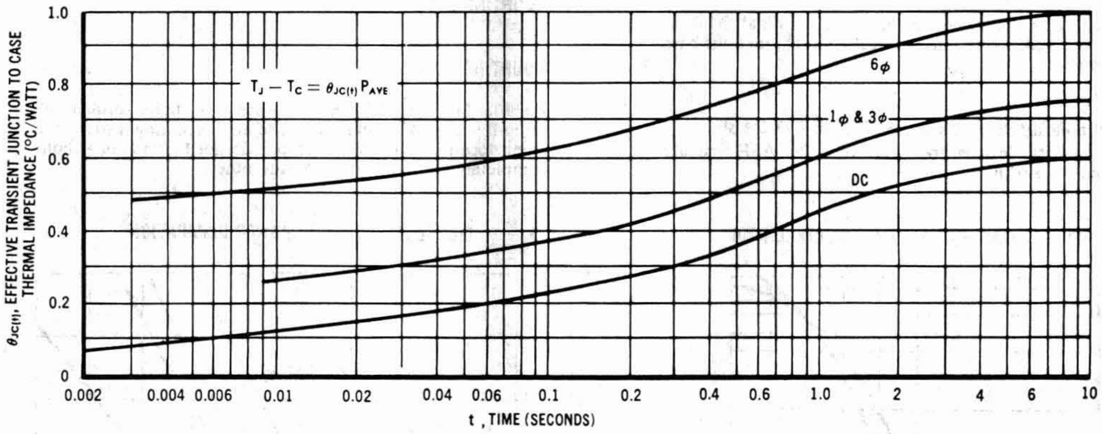


FIGURE 5 — MAXIMUM ALLOWABLE SURGE CURRENT

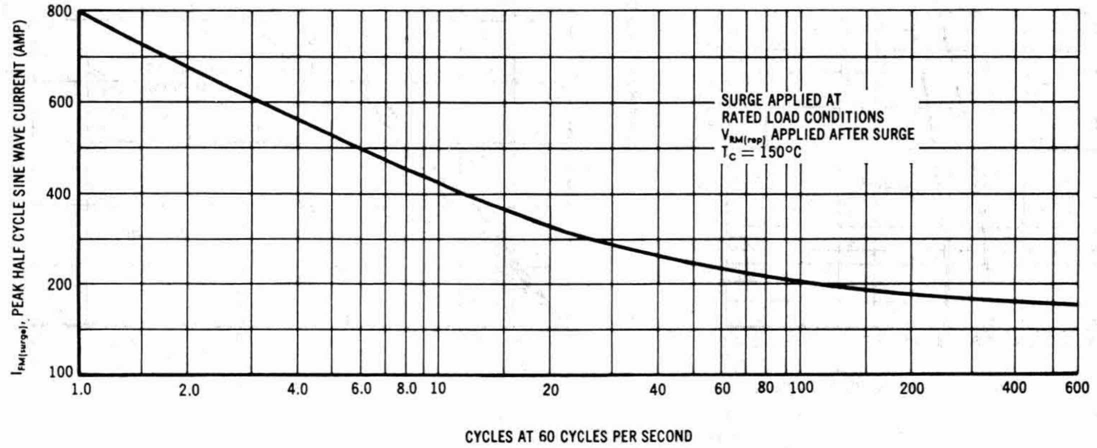
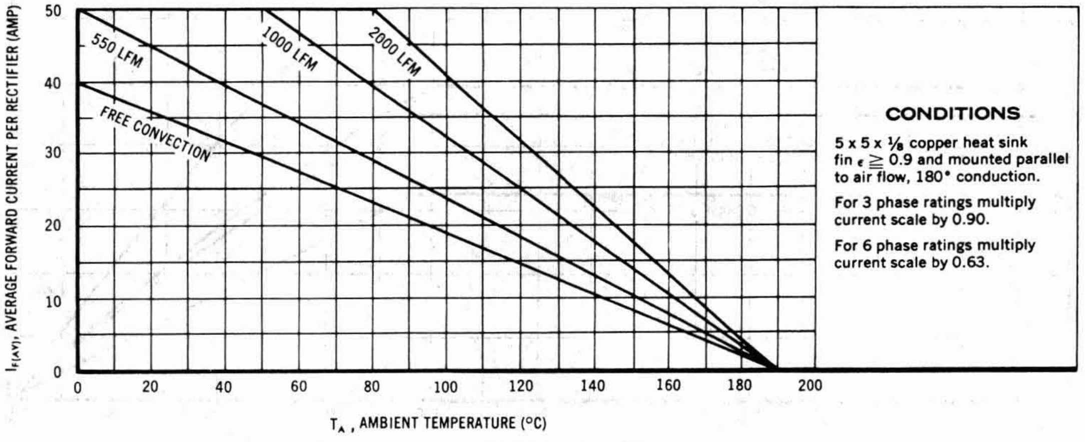


FIGURE 6 — CURRENT DERATING DATA



CONDITIONS

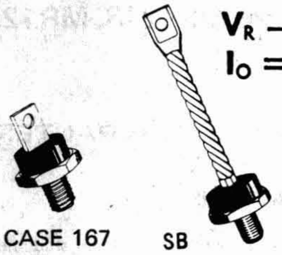
5 x 5 x ⅛ copper heat sink fin $\epsilon \geqq 0.9$ and mounted parallel to air flow, 180° conduction.

For 3 phase ratings multiply current scale by 0.90.

For 6 phase ratings multiply current scale by 0.63.

MR1210 thru MR1213 (SILICON)
MR1215, MR1217 thru MR1219

V_R — to 600 V
I_O = 100 A


SL CASE 167 SB CASE 168

Silicon power rectifiers designed with double-case, multi-cell construction for extreme reliability and ruggedness. Standard cathode-to-case polarity, but available with reverse polarity by adding suffix "R" to type number. Available in two package styles having identical ratings and characteristics. Desired package can be selected by adding suffix "SB" or "SL" to type number.

MAXIMUM RATINGS

Rating	Symbol	MR 1210	MR 1211	MR 1212	MR 1213	MR 1215	MR 1217	MR 1218	MR 1219	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	150	200	300	400	500	600	Volts
Non-Repetitive Peak Reverse Voltage (one halfwave, single phase, 60 cycle peak)	$V_{RM\,(non-rep)}$	100	200	250	300	400	500	600	720	Volts
RMS Reverse Voltage	V_r	35	70	105	140	210	280	350	420	Volts
Average Rectified Forward Current (single phase, resistive load, 60 Hz, see Figure 3) $T_C = 135°C$ $T_C = 150°C$	I_O	100 80								Amp
Non-Repetitive Peak Surge Currents (surge applied at rated load conditions, see Figure 5) $T_C = 150°C$	$I_{FM\,(surge)}$	2,000 (for 1/2 cycle) 1,200 (for six consecutive cycles)								Amp
I^2t Rating (non-repetitive, for t greater than 1 ms and less than 8.3 ms)	I^2t	8,300								A^2s
Operating and Storage Junction Temperature Range (see Figure 4 for other conditions)	T_J, T_{stg}	-65 to +190								°C

ELECTRICAL CHARACTERISTICS

Characteristics and Conditions	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop (rated I_O and V_r, single phase, 60 Hz $T_C = 150°C$)	$V_{F(AV)}$	0.4	Volts
Full Cycle Average Reverse Current (rated I_O and V_r, single phase, 60 Hz $T_C = 150°C$)	$I_{R(AV)}$	15	mA

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.40	°C/Watt

MECHANICAL CHARACTERISTICS

PACKAGE CONFIGURATIONS:

MR1210SB rectifiers are designed for stud mounting and have a flexible braided lead terminal.

MR1210SL rectifiers are designed for stud mounting and have a solid lug terminal.

All units have a plated copper base and terminal. Molded external case with internal hermetically sealed, metallic case rectifier cells.

POLARITY:

Standard polarity devices are CATHODE-TO-CASE. Reverse polarity devices are ANODE-TO-CASE and are designated by an "R" suffix i.e. MR1215SLR.

MOUNTING POSITION: Any.

STUD MOUNTING TORQUES:

For Stud Mounted "SB" and "SL" rectifiers, 25 in-lbs min., 30 in-lbs max.

FIGURE 1 — MAXIMUM FORWARD VOLTAGE DROP

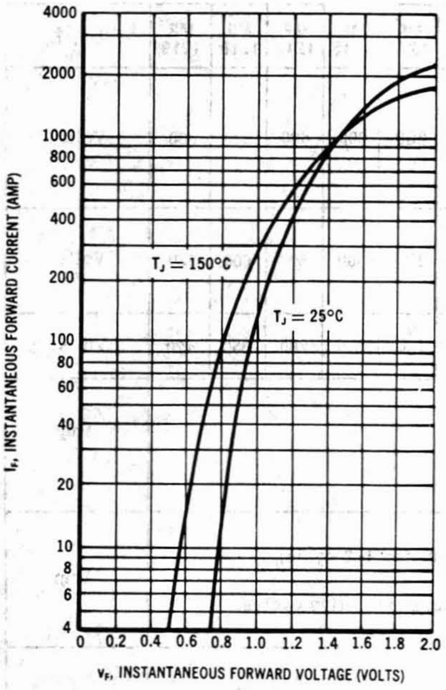


FIGURE 2 — FORWARD POWER DISSIPATION

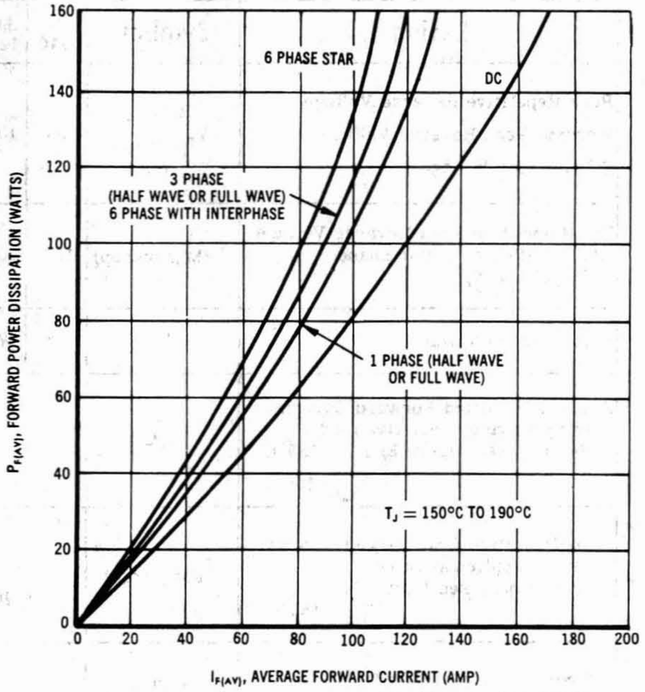
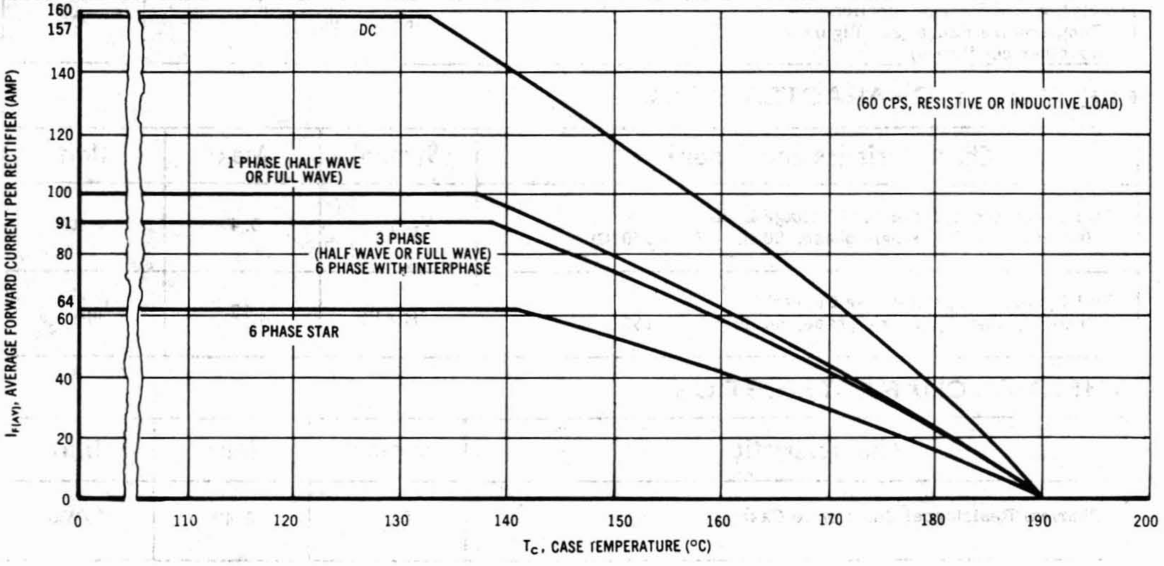


FIGURE 3 — MAXIMUM CURRENT RATINGS



MR1210 thru MR1213, MR1215, MR1217 thru MR1219 (continued)

FIGURE 4 — EFFECTIVE TRANSIENT THERMAL IMPEDANCE

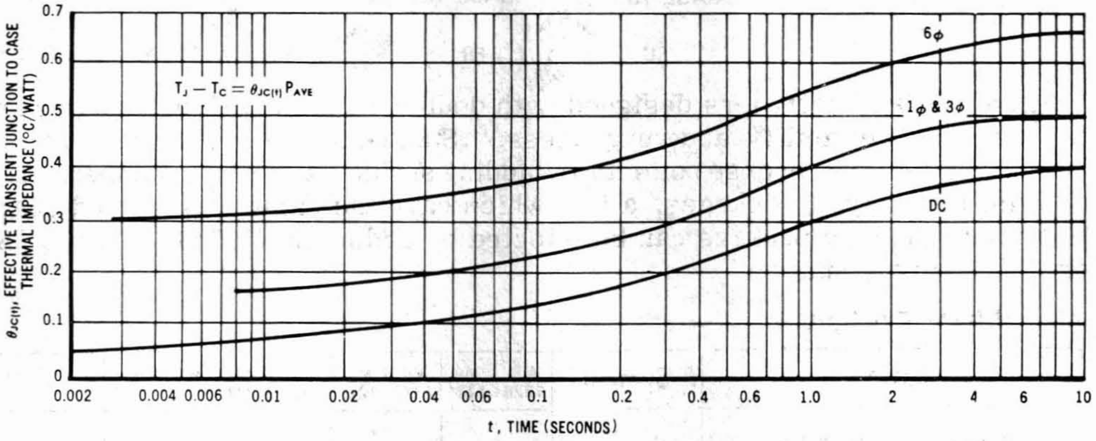


FIGURE 5 — MAXIMUM ALLOWABLE SURGE CURRENT

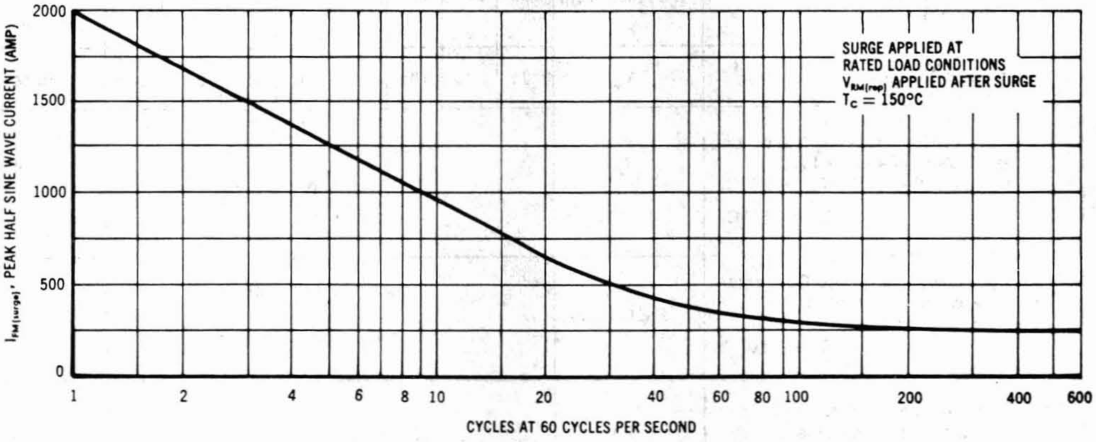
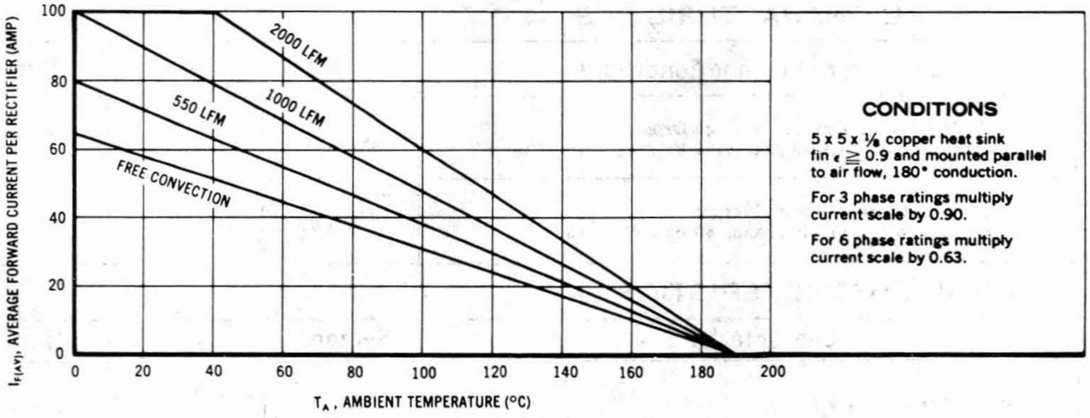


FIGURE 6 — CURRENT DERATING DATA



CONDITIONS

5 x 5 x ⅛ copper heat sink fin $\epsilon \geqq 0.9$ and mounted parallel to air flow, 180° conduction.

For 3 phase ratings multiply current scale by 0.90.

For 6 phase ratings multiply current scale by 0.63.

MR1220 thru MR1223 (SILICON)
MR1225
MR1227 thru MR1229

V_R — to 600 V
I_O = 200 A

CASE 130
SB

CASE 137
FB

SL CASE 126

FL CASE 133

Silicon power rectifiers designed with double-case, multi-cell construction for extreme reliability and ruggedness. Standard cathode-to-case polarity, but available with reverse polarity by adding suffix "R" to type number. Available in a variety of packages, all of which have the same ratings and characteristics. Desired package can be selected by adding suffix "SB", "FB", "SL", or "FL" to type number.

MAXIMUM RATINGS

Rating	Symbol	MR 1220	MR 1221	MR 1222	MR 1223	MR 1225	MR 1227	MR 1228	MR 1229	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	150	200	300	400	500	600	Volts
Non-Repetitive Peak Reverse Voltage (one halfwave, single phase, 60 cycle peak)	$V_{RM(non-rep)}$	100	200	250	300	400	500	600	720	Volts
RMS Reverse Voltage	V_r	35	70	105	140	210	280	350	420	Volts
Average Rectified Forward Current (single phase, resistive load, 60 Hz, see Figure 3) T_C = 135°C T_C = 150°C	I_O	200 160								Amp
Non-Repetitive Peak Surge Currents (surge applied at rated load conditions, see Figure 5) T_C = 150°C	$I_{FM(surge)}$	3,600 (for 1/2 cycle) 2,000 (for six consecutive cycles)								Amp
I^2t Rating (non-repetitive, for t greater than 1 ms and less than 8.3 ms)	I^2t	27,000								A^2s
Operating and Storage Junction Temperature Range (see Figure 4 for other conditions)	T_J, T_{stg}	-65 to +190								°C

ELECTRICAL CHARACTERISTICS

Characteristics and Conditions	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop (rated I_O and V_r, single phase, 60 Hz, T_C = 150°C)	$V_{F(AV)}$	0.4	Volts
Full Cycle Average Reverse Current (rated I_O and V_r, single phase, 60 Hz, T_C = 150°C)	$I_{R(AV)}$	20	mA

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.20	°C/Watt

MECHANICAL CHARACTERISTICS

PACKAGE CONFIGURATIONS:

MR1220SB rectifiers are designed for stud mounting and have a flexible braided lead terminal.

MR1220FB rectifiers are designed for flat mounting and have a flexible braided lead terminal.

MR1220SL rectifiers are designed for stud mounting and have a solid lug terminal.

MR1220FL rectifiers are designed for flat mounting and have a solid lug terminal.

All units have a plated copper base and terminal. Molded external case with internal hermetically sealed, metallic case rectifier cells.

POLARITY:

Standard polarity devices are CATHODE-TO-CASE. Reverse polarity devices are ANODE-TO-CASE and are designated by an "R" suffix i.e. MR1225FLR.

MOUNTING POSITION: Any.

STUD AND MOUNTING BOLT TORQUES:

For Stud Mounted "SB" and "SL" rectifiers, 300 in-lbs min., 400 in-lbs max.

For Flat Mounted "FB" and "FL" rectifiers use No. 10 bolts torqued to 25 in-lbs min., 30 in-lbs max. Use an alternating procedure when torquing the four bolts and do not tighten one bolt completely without tightening the others.

FIGURE 1 — MAXIMUM FORWARD VOLTAGE DROP

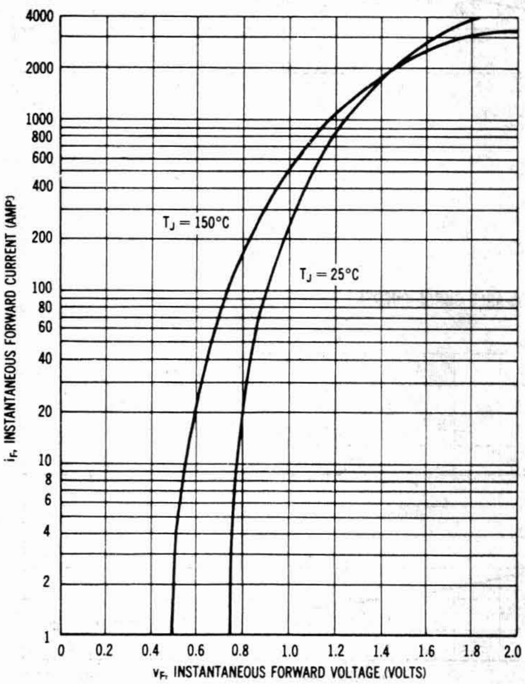


FIGURE 2 — FORWARD POWER DISSIPATION

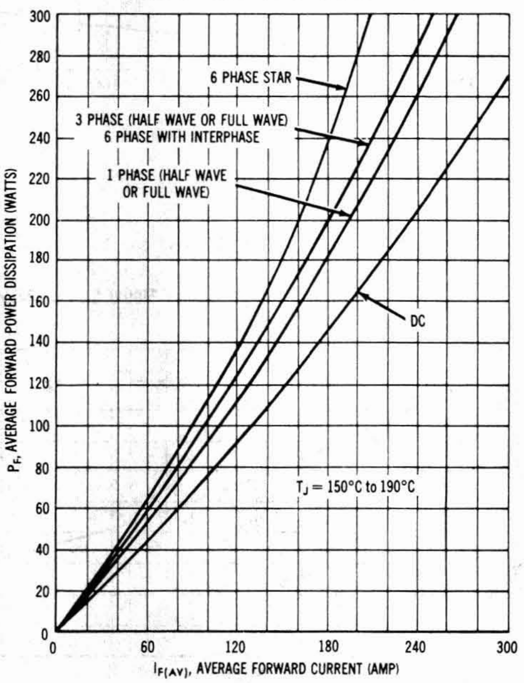
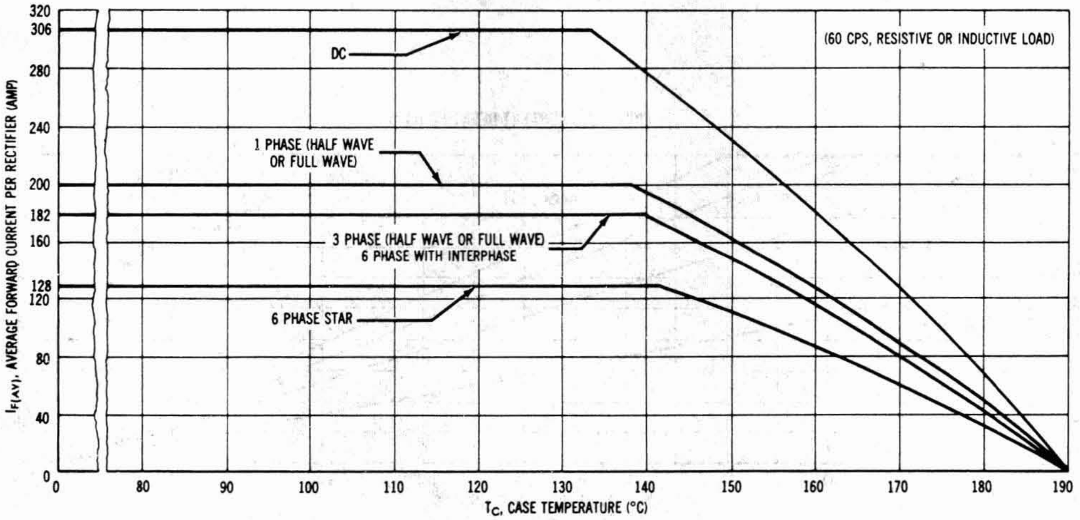


FIGURE 3 — MAXIMUM CURRENT RATING



MR1220 thru MR1223, MR1225, MR1227 thru MR1229 (continued)

FIGURE 4 — EFFECTIVE TRANSIENT THERMAL IMPEDANCE

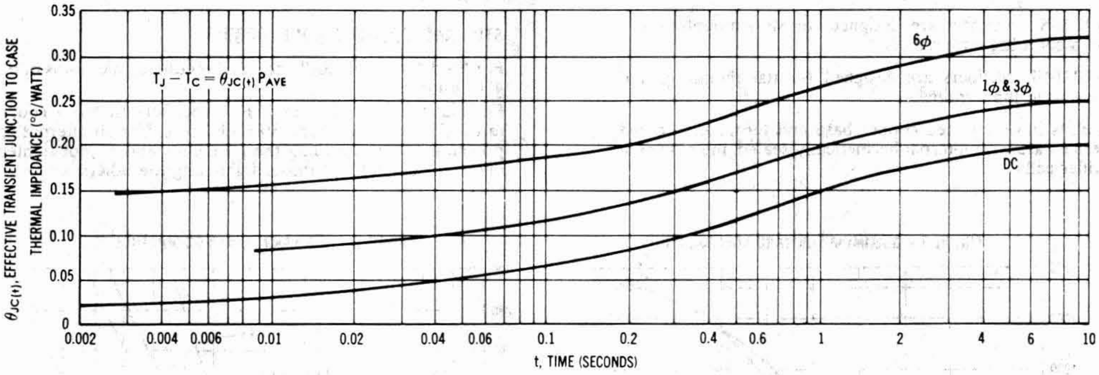


FIGURE 5 — MAXIMUM ALLOWABLE SURGE CURRENT

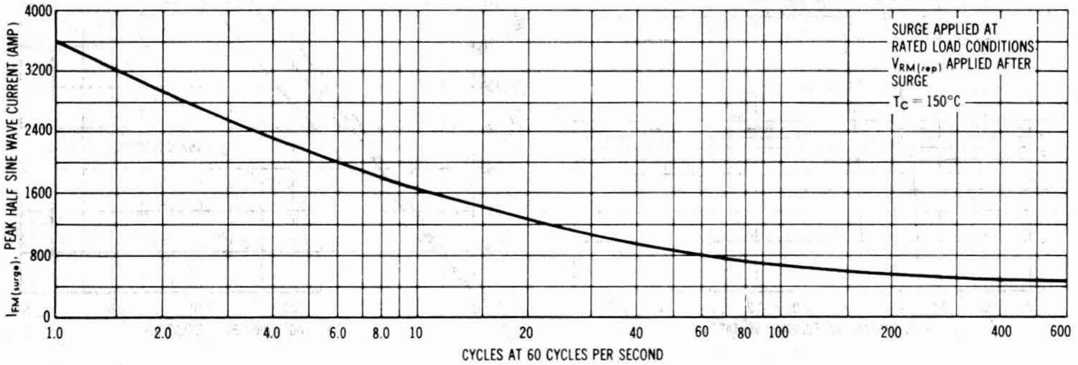
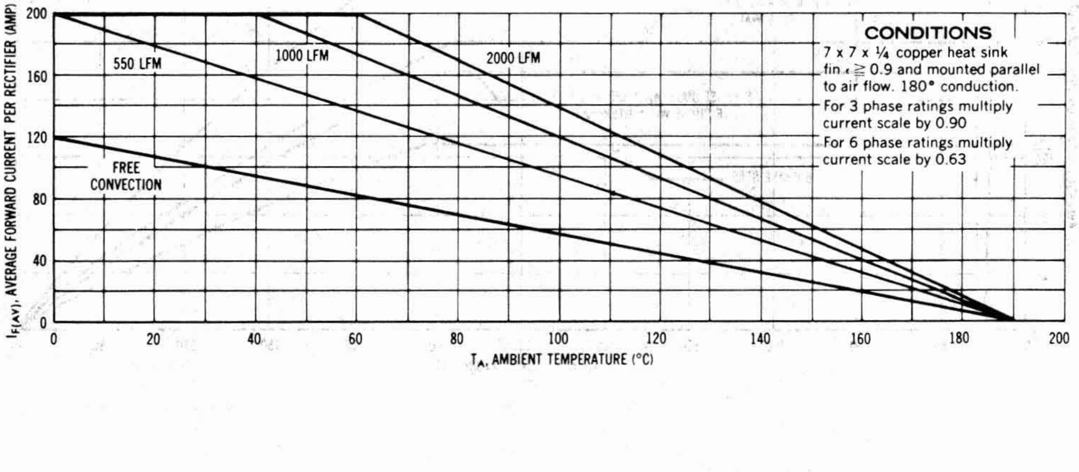
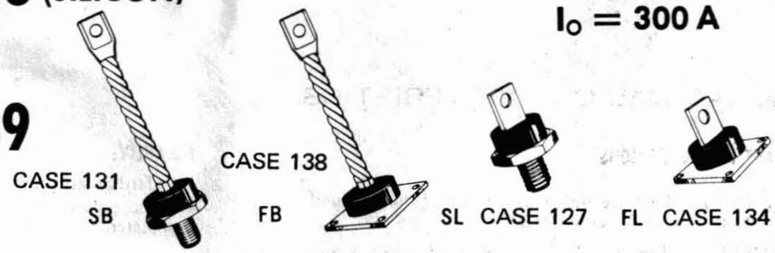


FIGURE 6 — CURRENT DERATING DATA



MR1230 thru MR1233 (SILICON)
MR1235
MR1237 thru MR1239

V_R = to 600 V
I_O = 300 A



Silicon power rectifiers designed with double-case, multi-cell construction for extreme reliability and ruggedness. Standard cathode-to-case polarity, but available with reverse polarity by adding suffix "R" to type number. Available in a variety of packages, all of which have the same ratings and characteristics. Desired package can be selected by adding suffix "SB", "FB", "SL", or "FL" to type number.

MAXIMUM RATINGS

Rating	Symbol	MR 1230	MR 1231	MR 1232	MR 1233	MR 1235	MR 1237	MR 1238	MR 1239	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	150	200	300	400	500	600	Volts
Non-Repetitive Peak Reverse Voltage (one halfwave, single phase, 60 cycle peak)	$V_{RM(non\text{-}rep)}$	100	200	250	300	400	500	600	720	Volts
RMS Reverse Voltage	V_r	35	70	105	140	210	280	350	420	Volts
Average Rectified Forward Current (single phase, resistive load, 60 Hz, see Figure 3) $T_C = 135°C$ $T_C = 150°C$	I_O	300 240								Amp
Non-Repetitive Peak Surge Currents (surge applied at rated load conditions, see Figure 5) $T_C = 150°C$	$I_{FM(surge)}$	5,000 (for 1/2 cycle) 3,000 (for six consecutive cycles)								Amp
I^2t Rating (non-repetitive, for t greater than 1 ms and less than 8.3 ms)	I^2t	52,000								A^2s
Operating and Storage Junction Temperature Range (see Figure 4 for other conditions)	T_J, T_{stg}	-65 to +190								°C

ELECTRICAL CHARACTERISTICS

Characteristics and Conditions	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop (rated I_O and V_r, single phase, 60 Hz, $T_C = 150°C$)	$V_{F(AV)}$	0.4	Volts
Full Cycle Average Reverse Current (rated I_O and V_r, single phase, 60 Hz, $T_C = 150°C$)	$I_{R(AV)}$	35	mA

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.12	°C/Watt

MECHANICAL CHARACTERISTICS

PACKAGE CONFIGURATIONS:

MR1230SB rectifiers are designed for stud mounting and have a flexible braided lead terminal.

MR1230FB rectifiers are designed for flat mounting and have a flexible braided lead terminal.

MR1230SL rectifiers are designed for stud mounting and have a solid lug terminal.

MR1230FL rectifiers are designed for flat mounting and have a solid lug terminal.

All units have a plated copper base and terminal. Molded external case with internal hermetically sealed, metallic case rectifier cells.

POLARITY:

Standard polarity devices are CATHODE-TO-CASE. Reverse polarity devices are ANODE-TO-CASE and are designated by an "R" suffix i.e. MR1235FLR.

MOUNTING POSITION: Any.

STUD AND MOUNTING BOLT TORQUES:

For Stud Mounted "SB" and "SL" rectifiers, 300 in-lbs min., 400 in-lbs max.

For Flat Mounted "FB" and "FL" rectifiers use ¼ inch bolts torqued to 60 in-lbs min., 80 in-lbs max. Use an alternating procedure when torquing the four bolts and do not tighten one bolt completely without tightening the others.

FIGURE 1 — MAXIMUM FORWARD VOLTAGE DROP

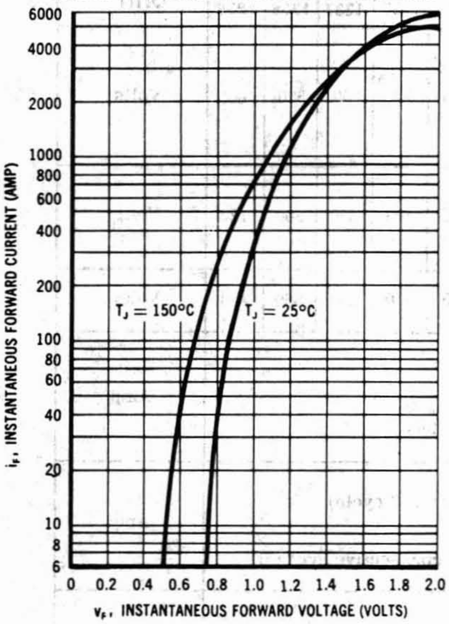


FIGURE 2 — FORWARD POWER DISSIPATION

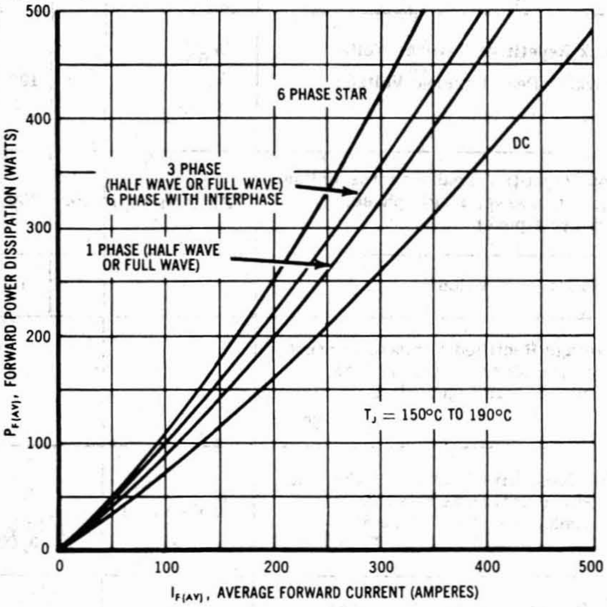


FIGURE 3 — MAXIMUM CURRENT RATINGS

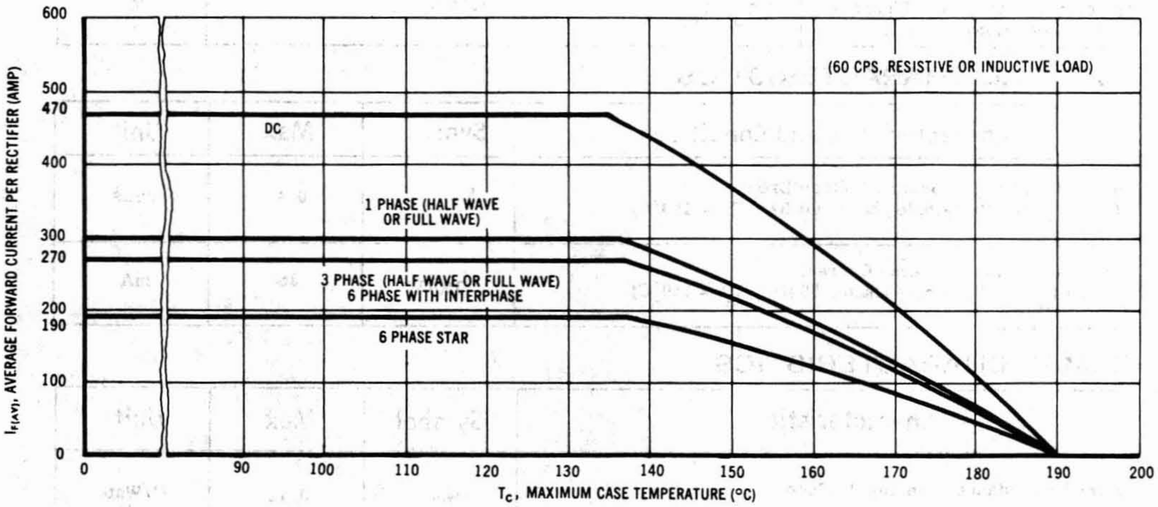


FIGURE 4 — EFFECTIVE TRANSIENT THERMAL IMPEDANCE

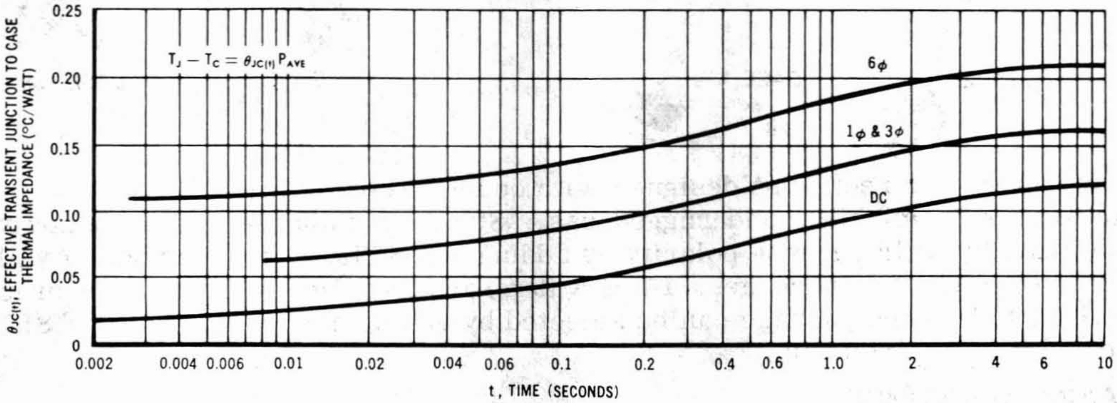


FIGURE 5 — MAXIMUM ALLOWABLE SURGE CURRENT

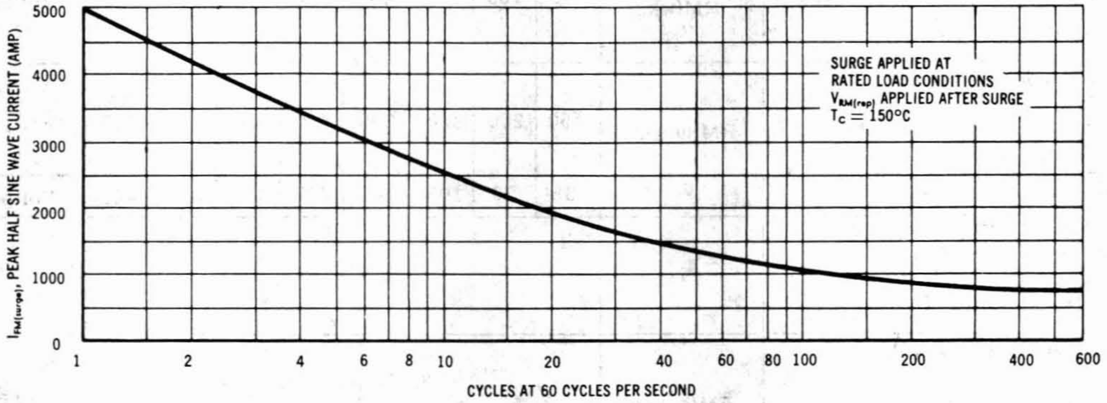
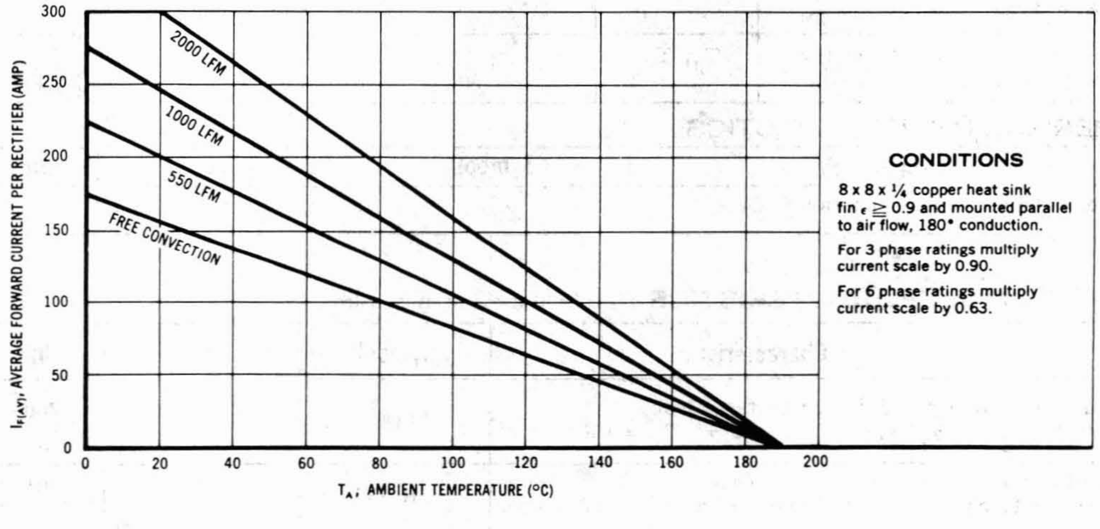


FIGURE 6 — CURRENT DERATING DATA



CONDITIONS

8 x 8 x ¼ copper heat sink fin $\epsilon \geqq 0.9$ and mounted parallel to air flow, 180° conduction.

For 3 phase ratings multiply current scale by 0.90.

For 6 phase ratings multiply current scale by 0.63.

MR1240 thru MR1243 (SILICON)
MR1245, MR1247 thru MR1249

V_R — to 600 V
I_O = 400 A

CASE 132
SB

CASE 139
FB

SL CASE 128

FL CASE 135

Silicon power rectifiers designed with double-case, multi-cell construction for extreme reliability and ruggedness. Standard cathode-to-case polarity, but available with reverse polarity by adding suffix "R" to type number. Available in a variety of packages, all of which have the same ratings and characteristics. Desired package can be selected by adding suffix "SB", "FB", "SL", or "FL" to type number.

MAXIMUM RATINGS

Rating	Symbol	MR 1240	MR 1241	MR 1242	MR 1243	MR 1245	MR 1247	MR 1248	MR 1249	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	150	200	300	400	500	600	Volts
Non-Repetitive Peak Reverse Voltage (one halfwave, single phase, 60 cycle peak)	$V_{RM(non-rep)}$	150	200	250	300	400	500	600	720	Volts
RMS Reverse Voltage	V_r	35	70	105	140	210	280	350	420	Volts
Average Rectified Forward Current (single phase, resistive load, 60 Hz, T_C = 150° C	I_O	400								Amperes
Non-Repetitive Peak Surge Currents (superimposed on rated current at rated voltage, T_C = 150° C)	$I_{FM(surge)}$	8, 000 (for 1/2 cycle) 4, 500 (for six consecutive 1/2 cycles)								Amperes
I^2t Rating (non-repetitive for t greater than 1.0 ms and less than 8.3 ms)	I^2t	133, 000								A^2s
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +190								°C

THERMAL CHARACTERISTICS

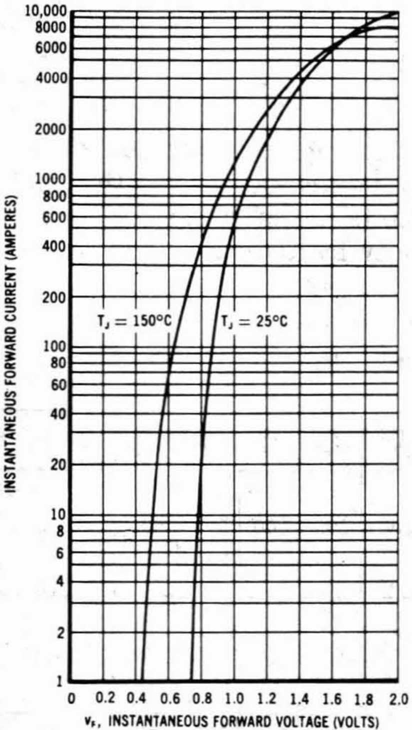
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.075	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

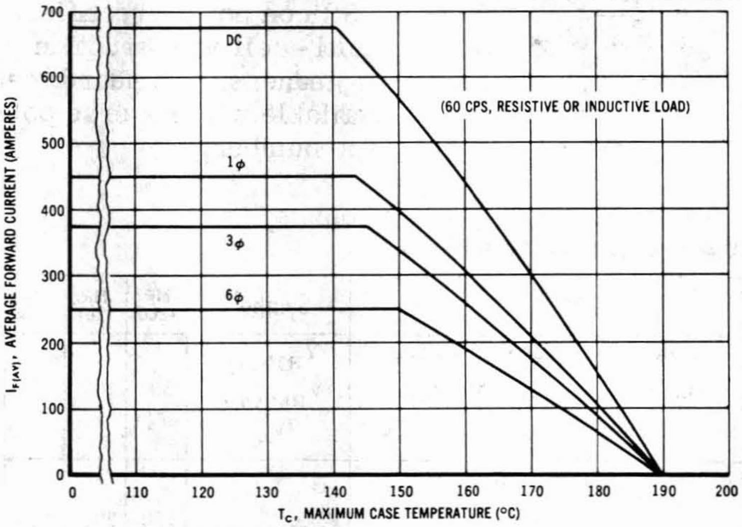
Characteristic	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop (rated I_O and V_r, single phase 60 Hz, T_C = 150° C)	$V_{F(AV)}$	0.4	Volts
Full Cycle Average Reverse Current (rated I_O and V_r, single phase 60 Hz, T_C = 150° C)	$I_{R(AV)}$	50	mA

MR1240 thru MR1243, MR1245, MR1247 thru MR1249 (continued)

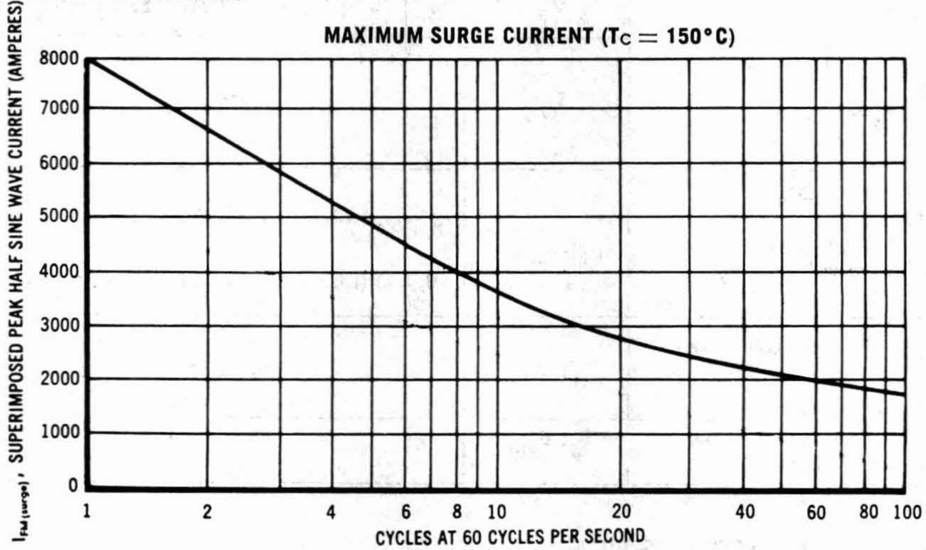
FORWARD VOLTAGE CHARACTERISTICS



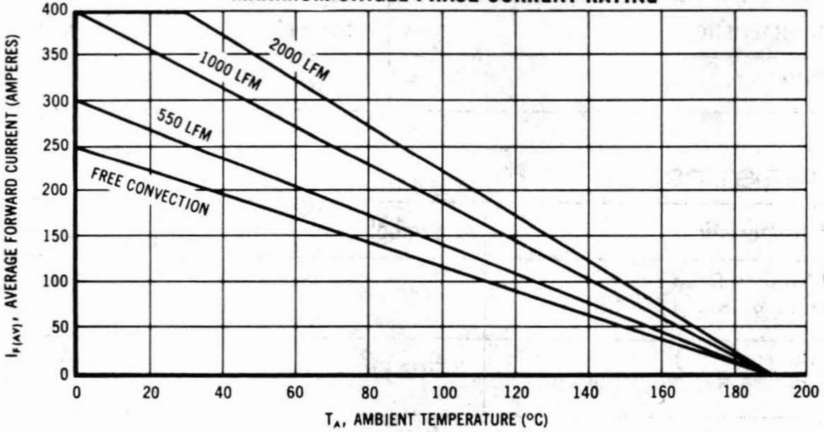
MAXIMUM FORWARD CURRENT versus MAXIMUM CASE TEMPERATURE



MAXIMUM SURGE CURRENT ($T_C = 150°C$)



MAXIMUM SINGLE-PHASE CURRENT RATING



CONDITIONS

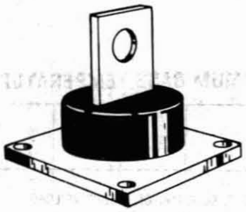
8 x 8 x ¼ copper heat sink fin $\epsilon \geqq 0.9$ and mounted parallel to air flow. 180° conduction.

For 3 phase ratings multiply current scale by 0.85.

For 6 phase ratings multiply current scale by 0.60.

MR1260 thru MR1263 (SILICON)
MR1265, MR1267 thru MR1269

V_R — to 600 V
I_O = 650 A


CASE 136

Silicon power rectifiers designed with double-case, multi-cell construction for extreme reliability and ruggedness. Standard cathode-to-case polarity, but available with reverse polarity by adding suffix "R" to type number.

MAXIMUM RATINGS

Rating	Symbol	MR 1260	MR 1261	MR 1262	MR 1263	MR 1265	MR 1267	MR 1268	MR 1269	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	150	200	300	400	500	600	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single phase, 60 cycle peak)	$V_{RM(non-rep)}$	150	200	250	300	400	500	600	720	Volts
RMS Reverse Voltage	V_r	35	70	105	140	210	280	350	420	Volts
Average Rectified Forward Current (single phase, resistive load, 60 Hz, T_C = 150°C)	I_O	650								Amperes
Non-Repetitive Peak Surge Currents (superimposed on rated current at rated voltage, T_C = 150°C)	$I_{FM(surge)}$	12,000 (for 1/2 cycle) 8,000 (for six consecutive 1/2 cycles)								Amperes
I^2t Rating (non-repetitive, for t greater than 1 ms and less than 8.3 ms)	I^2t	300,000								A^2s
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +190								°C

THERMAL CHARACTERISTICS

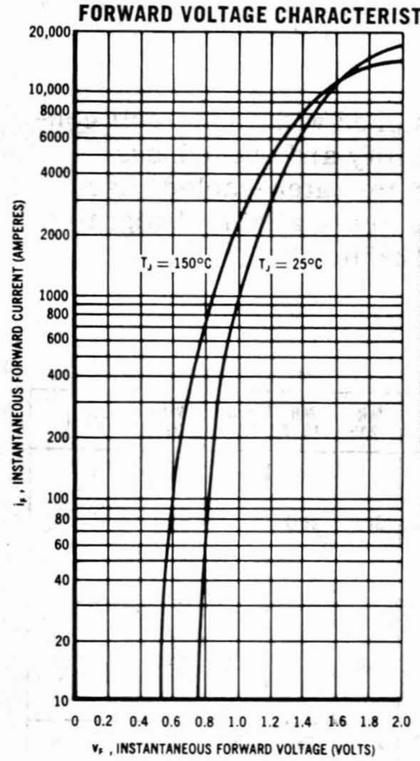
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}	0.045	°C/Watt

ELECTRICAL CHARACTERISTICS

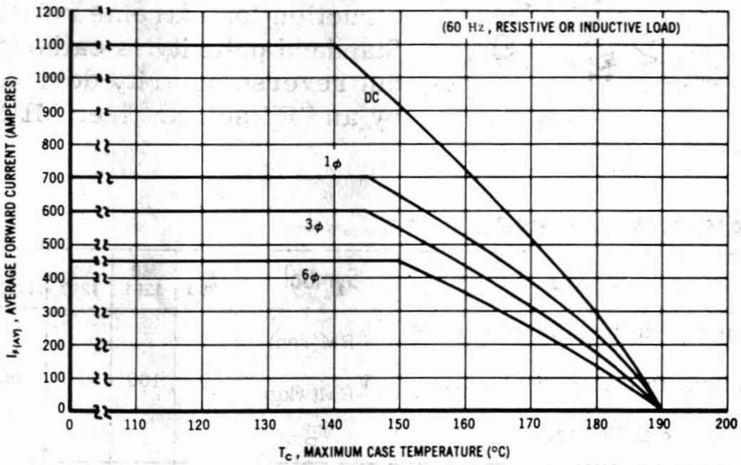
Characteristic	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop (rated I_O and V_r, single phase, 60 Hz, T_C = 150°C)	$V_{F(AV)}$	0.4	Volts
Full Cycle Average Reverse Current (rated I_O and V_r, single phase, 60 Hz, T_C = 150°C)	$I_{R(AV)}$	100	mA

MR1260 thru MR1263 (continued)
MR1265, MR1267 thru MR1269

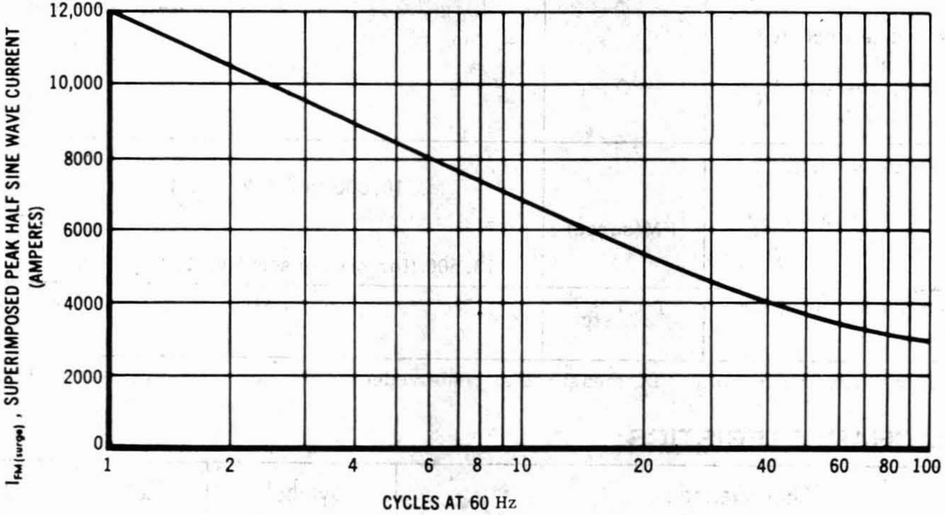
FORWARD VOLTAGE CHARACTERISTICS



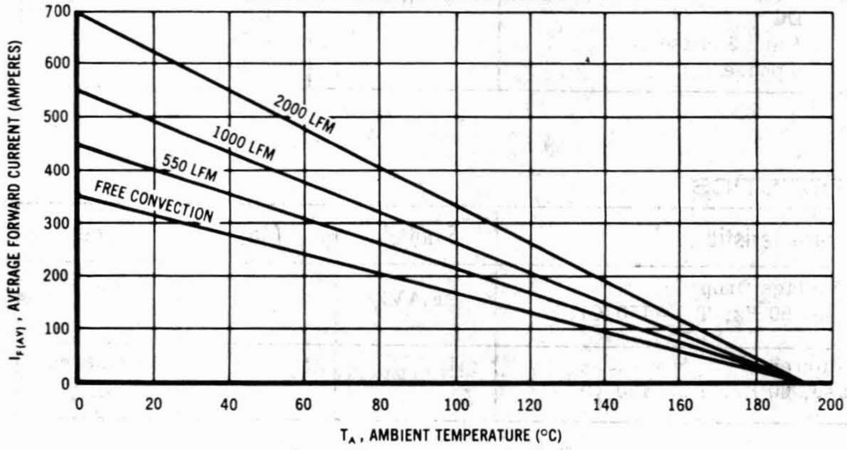
MAXIMUM FORWARD CURRENT versus MAXIMUM CASE TEMPERATURE



MAXIMUM SURGE CURRENT (T_C = 150°C)



MAXIMUM SINGLE-PHASE CURRENT RATING



CONDITIONS

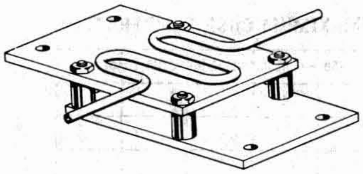
10 x 10 x ¼ copper heat sink fin $\epsilon \geqq 0.9$ and mounted parallel to air flow, 180° conduction.

For 3 phase ratings multiply current scale by 0.85.

For 6 phase ratings multiply current scale by 0.60.

MR1290 thru MR1293 (SILICON)
MR1295, MR1297 thru MR1299

V_R — to 600 V
I_O = 1000 A



CASE 105

Silicon power rectifiers designed with multi-cell construction for extreme reliability and ruggedness. Standard polarity is cathode-to-water-cooled case, but reverse polarity devices are available designated by an "R" suffix. i.e. MR1295R

MAXIMUM RATINGS

Rating	Symbol	MR 1290	MR 1291	MR 1292	MR 1293	MR 1295	MR 1297	MR 1298	MR 1299	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	150	200	300	400	500	600	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single phase, 60 cycle peak)	$V_{RM(non\text{-}rep)}$	100	200	250	300	400	500	600	720	Volts
RMS Reverse Voltage	V_r	35	70	105	140	210	280	350	420	Volts
Continuous Average Rectified Forward Current (single phase, resistive load, 60 Hz, T_C = 150°C)	I_O	1000								Amperes
Non-Repetitive Peak Surge Currents (superimposed on rated current at rated voltage, T_C = 150°C)	$I_{FM(surge)}$	18,000 (for 1/2 cycle) 13,500 (for six consecutive 1/2 cycles)								Amperes
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +190								°C

Case Temperature Reference Point: T_C measured at center edge of the water cooled mounting bus.

THERMAL CHARACTERISTICS

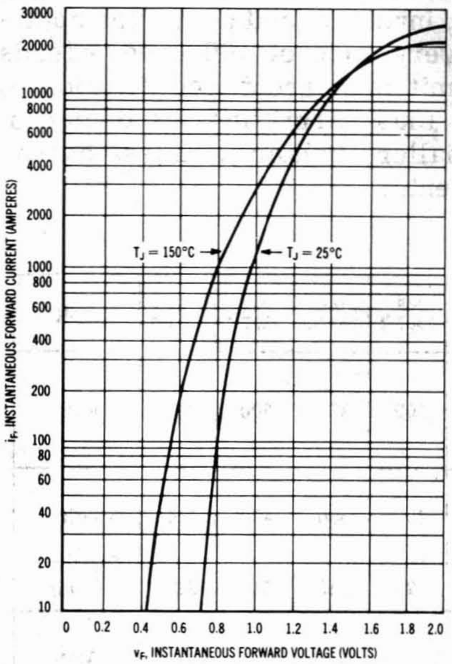
Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Case	θ_{JC}		°C/Watt
DC		0.035	
1 and 3 phase		0.045	
6 phase		0.060	

ELECTRICAL CHARACTERISTICS

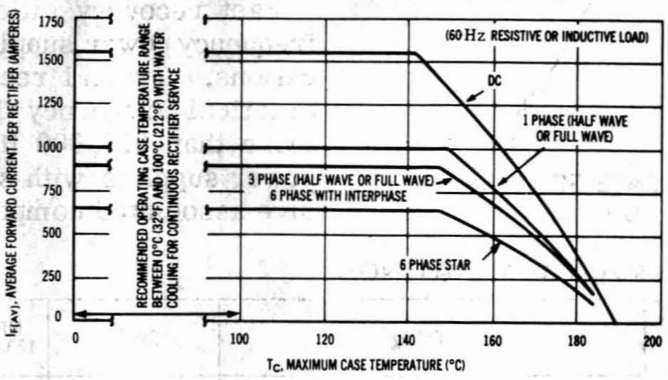
Characteristic	Symbol	Max	Unit
Full Cycle Average Forward Voltage Drop (rated I_O and V_r, single phase, 60 Hz, T_C = 150°C)	$V_{F(AV)}$	0.4	Volts
Full Cycle Average Reverse Current (rated I_O and V_r, single phase, 60 Hz, T_C = 150°C)	$I_{R(AV)}$	0.2	Amperes

MR1290 thru MR1293 (Continued)
MR1295, MR1297 thru MR1299

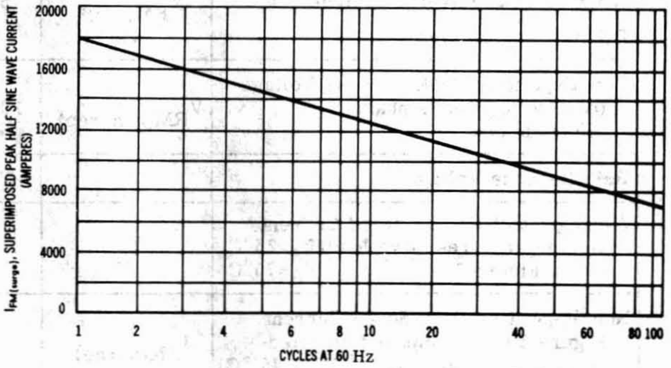
FORWARD VOLTAGE CHARACTERISTICS



MAXIMUM FORWARD CURRENT
versus MAXIMUM CASE TEMPERATURE (100% DUTY)



MAXIMUM SURGE CURRENT



TYPICAL COOLING RATES AT RATED LOAD CONDITIONS

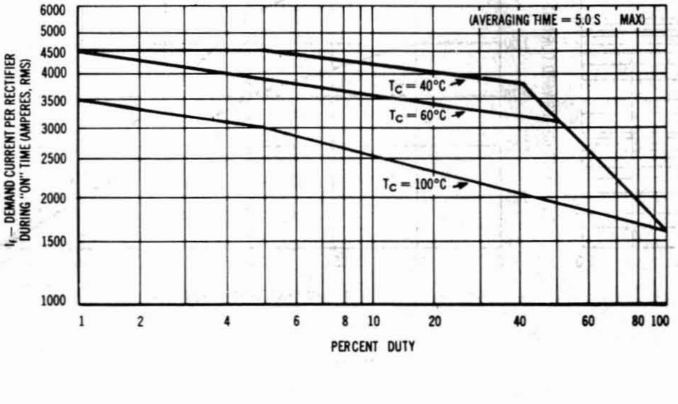
Inlet Water Temperature (°C)	**Minimum Water Flow Required** (Gallons/Hour)	**Approx. Water Temp. Rise at Specified Flow Rate** (°C)
15	2	10
50	5	8
75	10	5

NOTE: Water flow rates may be decreased at lighter load demands provided maximum case temperatures are not exceeded. In some applications where cooling systems are operated in series, it may be desirable to increase flow rates in order to minimize water temperature rises.

COOLING REQUIREMENTS

Type of Cooling — Water
Min Inlet Water Temp. — 0°C
Max Inlet Water Temp. — 75°C

MAXIMUM RMS DEMAND CURRENT versus PERCENT DUTY



NOTE:

Curves apply to normal rectifier service conditions with maintained Rectifier Case Temperature (T_C) equal to or less than the values specified.

To determine the Maximum Average Current [$I_{F(AV)}$] per rectifier, multiply the RMS Current [I_f] rating by the factor given for the operating condition.

- $I_{F(AV)} = .64 I_f$ for Single Phase
- $I_{F(AV)} = .57 I_f$ for Three Phase and Six Phase with interphase
- $I_{F(AV)} = .40 I_f$ for Six Phase Star

MR1337-1 thru MR1337-5 (SILICON)

V_R — to 400 V
I_O = 1.0

CASE 52
(DO-13)

Fast recovery silicon rectifiers designed for high-frequency power supply, inverter, and converter applications. Typical recovery time of 100 nsec extends practical frequency limit of current rectification to more than 300,000 Hz thus permitting the design of power supplies with smaller, lighter, and less expensive associated components.

MAXIMUM RATINGS

Rating	Symbol	MR 1337-1	MR 1337-2	MR 1337-3	MR 1337-4	MR 1337-5	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	200	300	400	Volts
Non-Repetitive Peak Reverse Voltage (half-wave, single phase, 60 cycle peak)	$V_{RM(non\text{-}rep)}$	100	200	300	400	500	Volts
RMS Reverse Voltage	V_r	35	70	140	210	280	Volts
Average Rectified Forward Current (single-phase resistive load) $T_A=25°C$ Figure 2 $T_A=75°C$	I_O	1.0 0.75					Amp
Non-Repetitive Peak Surge Current Figure 3 (superimposed on rated current at rated voltage, T_A = 75 °C)	$I_{FM(surge)}$	30					Amp
Peak Repetitive Forward Current (T_A = 75°C)	$I_{FM(rep)}$	4.0					Amp
I^2t Rating (non-repetitive, for t greater than 1 ms and less than 8.3 ms)	I^2t	3.75					$A_{(rms)}^2s$
Maximum Junction Operating Temperature Range Maximum Case Storage Temperature Range	T_J T_{stg}	-65 to +150 -65 to +175					°C
Maximum Steady State DC Thermal Resistance	θ_{JA}	100					°C/Watt

FIGURE 1 — TYPICAL FORWARD CHARACTERISTICS

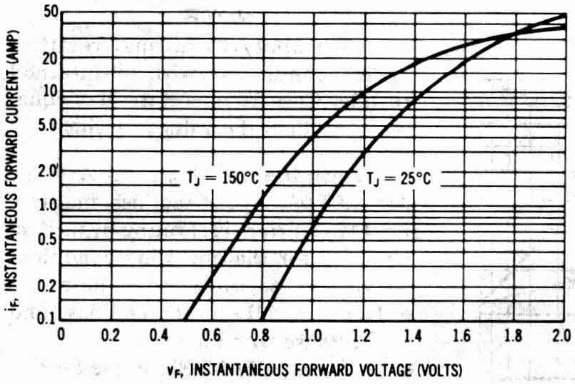
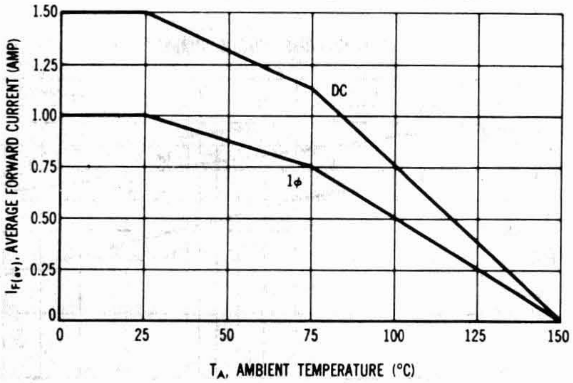


FIGURE 2 — MAXIMUM AVERAGE FORWARD CURRENT RATING versus MAXIMUM AMBIENT TEMPERATURE



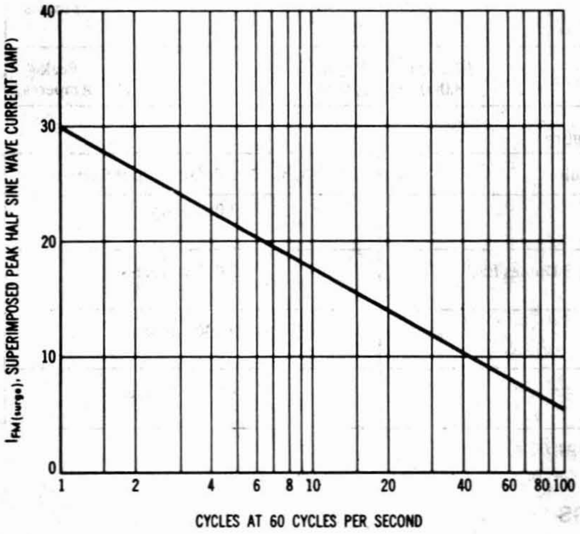
MR1337-1 thru MR1337-5 (continued)

ELECTRICAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
DC Forward Voltage Drop (I_F = 1.0 Adc, T_A = 25°C)	V_F	1.1	Vdc
Full Cycle Average Forward Voltage Drop (I_O = 0.75 Amp and Rated V_r, T_A = 75°C, Half Wave Rectifier)	$V_{F(AV)}$	0.55	Volts
Full Cycle Average Reverse Current (I_O = 0.75 Amp and Rated V_r, T_A = 75°C, single phase)	$I_{R(AV)}$	0.75	mA
DC Reverse Current (Rated V_R, T_A = 25°C)	I_R	0.25	mA
Maximum Reverse Recovery Time (I_F = 1 Amp min)	t_{rr}	200	ns
Maximum Overshoot Current	I_{os}	2.0	Amp

FIGURE 3 — MAXIMUM ALLOWABLE NON-REPETITIVE SURGE CURRENT

(SUPERIMPOSED ON RATED CONDITIONS, $V_{RM(rep)}$ APPLIED AFTER SURGE, T_A = 75°C)



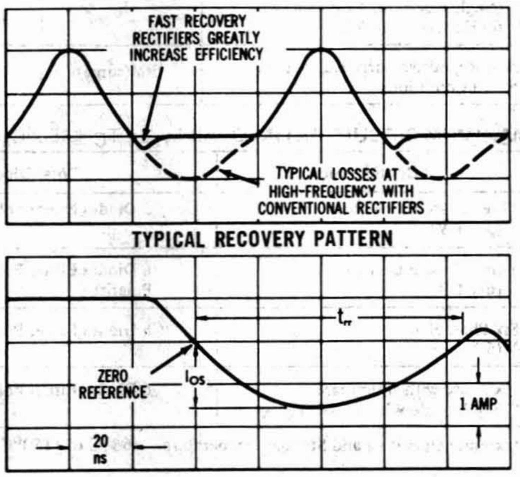
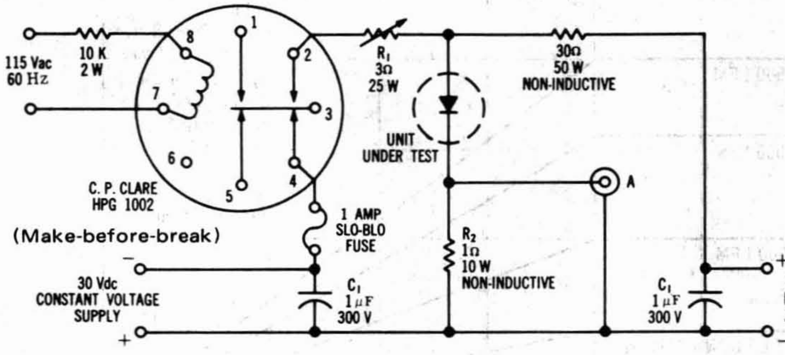


FIGURE 4 — t_{rr} TEST CIRCUIT


115 Vac
60 Hz
10 K
2 W
8
1
2
7
3
6
5
4
C. P. CLARE
HPG 1002
(Make-before-break)
R_1
3Ω
25 W
30Ω
50 W
NON-INDUCTIVE
UNIT UNDER TEST
A
1 AMP
SLO-BLO
FUSE
R_2
1Ω
10 W
NON-INDUCTIVE
30 Vdc
CONSTANT VOLTAGE SUPPLY
−
+
C_1
1 μF
300 V
C_1
1 μF
300 V
+
−

A — TEKTRONIX 545A, K PLUG-IN PRE-AMP, P6000 PROBE OR EQ

R_1 — ADJUSTED FOR 1.4Ω BETWEEN POINT 2 OF RELAY AND RECTIFIER. INDUCTANCE ≈ 38 μh

R_2 — TEN 1 W, 10Ω, 1% CARBON COMP. IN PARALLEL

$T_A = 25 \begin{smallmatrix}+10\\-0\end{smallmatrix}$ °C FOR RECTIFIER

MINIMIZE ALL LEAD LENGTHS

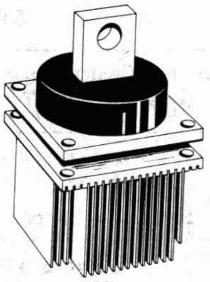
1 Adc FROM CONSTANT VOLTAGE SUPPLY
RIPPLE = 3 mVrms MAX
Z_{out} = ½Ω MAX, DC to 2 kHz

MR1366, MR1376, MR1386, MR1396

For Specifications, See 1N4933 Data.

MR2080HA (SILICON)
thru
MR2084HA

V_R = 50–400 V
I_o = 750 A



CASE 159

Multi-Cell II, power rectifier diodes designed for high-current rectifier service. The MR2080HA through MR2084HA provide single-output, high-current dc with forced air cooling.

MAXIMUM DIODE RATINGS

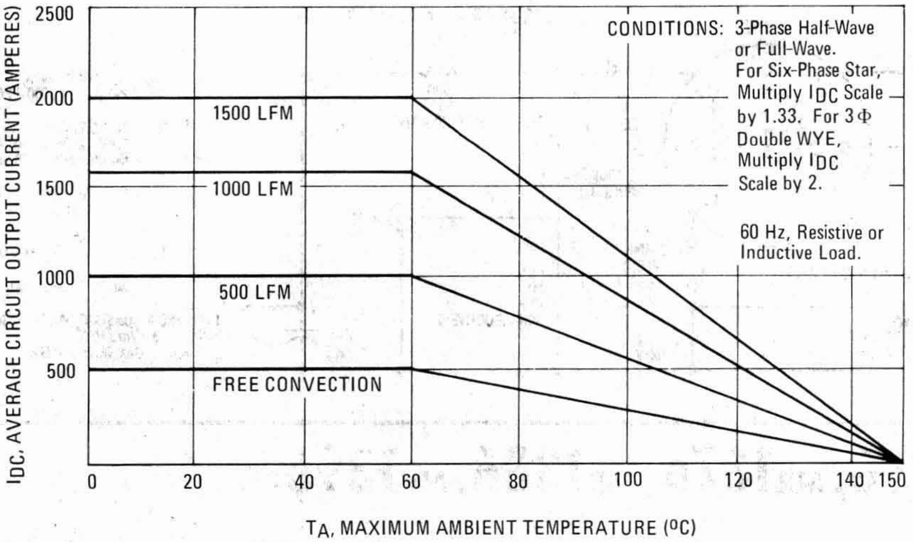
Rating	Symbol	MR2080HA	MR2081HA	MR2082HA	MR2083HA	MR2084HA	Units
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	200	300	400	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single-phase, 60 cycle peak)	$V_{RM(non-rep)}$	75	150	300	400	500	Volts
Continuous Average Rectified Forward Current (single-phase, resistive load, 60 Hz, T_C = 150°C)	I_o	750					Amperes
Non-Repetitive Surge Currents at Rated Conditions	$I_{FM(surge)}$	12,000 for 1/2 cycle 8,000 for 6 cycles					Peak Amperes

MAXIMUM CIRCUIT RATINGS (All Types, $T_C \leq 150°C$, See Figure 1)

Circuit Configuration	Total Diodes Required	Total Circuit DC Output Current
Three-Phase Half-Wave (3-1-1-Y)	3 Diodes Either Polarity	2,000 Amperes
Three-Phase Full-Wave (6-1-1-B)	6 Diodes Either Polarity or 3 Diodes Each Polarity	2,000 Amperes
Six-Phase Star (6-1-1-S)	6 Diodes Either Polarity	2,600 Amperes
Six-Phase with Interphase, 3 Φ Double WYE (6-1-1-Y)	6 Diodes Either Polarity	4,000 Amperes

Maximum Operating and Storage Temperature: −65°C to +150°C (All Types)

FIGURE 1 – MAXIMUM CIRCUIT RATINGS



CONDITIONS: 3-Phase Half-Wave or Full-Wave. For Six-Phase Star, Multiply I_{DC} Scale by 1.33. For 3Φ Double WYE, Multiply I_{DC} Scale by 2.

60 Hz, Resistive or Inductive Load.

MR2080HA thru MR2084HA (continued)

ELECTRICAL CHARACTERISTICS (All Types)

Characteristic And Conditions	Symbol	Maximum Limit	Units
Full-Cycle Average Forward Voltage Drop at Rated Load, $T_C = 150^oC$	$V_{F(AV)}$	0.5	Volts
Full-Cycle Average Reverse Current at Rated Load, $T_C = 150^oC$	$I_{R(AV)}$	80	Milliamperes
DC Reverse Current at Rated Reverse Voltage, V_R, $T_C = 25^oC$	I_R	4.0	Milliamperes

NOTE: A portion of the internal power losses of the rectifier may be conducted from the device by the connecting bus-bar or cables and can vary depending on mounting conditions. The above ratings are based on conditions where at any rating point of output current, ambient temperature and air flow, the assembly case temperature is not allowed to exceed 150°C. (See Figure 1).

MECHANICAL CHARACTERISTICS

POLARITY:

Standard polarity devices are CATHODE-TO-CASE, reverse polarity devices are ANODE-TO-CASE and designated by an "R" suffix, i.e., MR2083HAR.

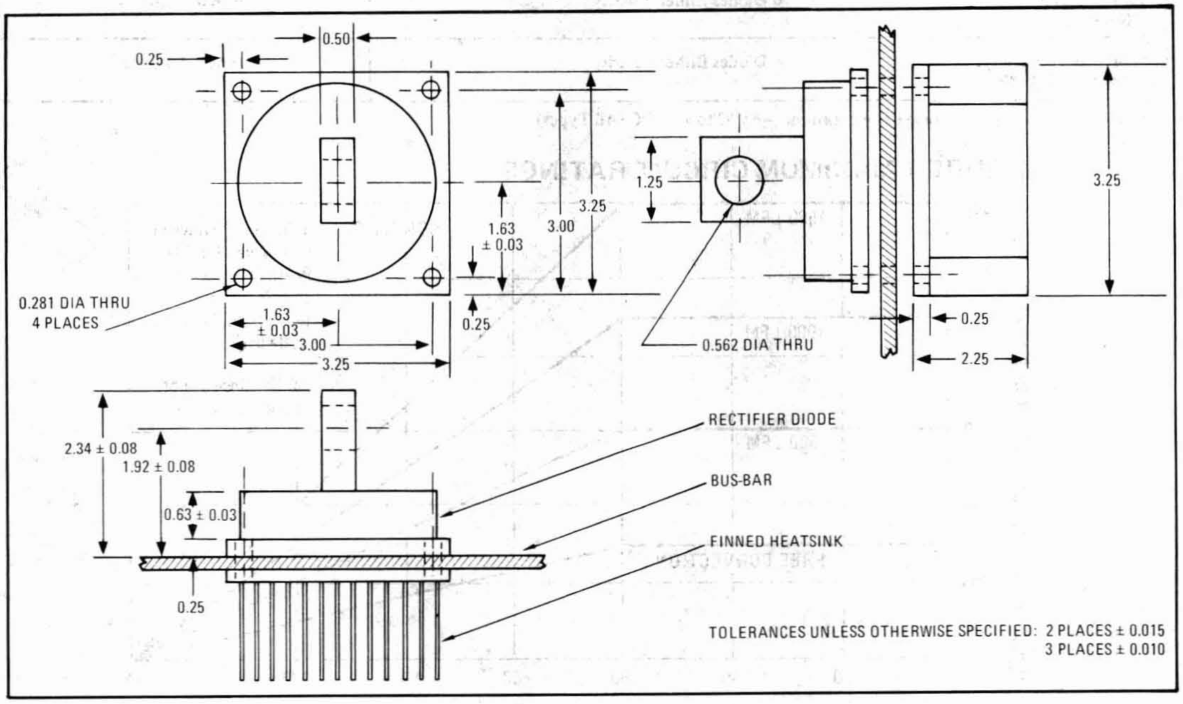
MOUNTING POSITION:

Cooling fins vertical for convection cooling or parallel to forced air flow.

MOUNTING CONFIGURATION:

The MR2080HA series is designed to be mounted as an integral part of the current carrying bus-bar network of the rectifier system as shown in the outline dimensions. The rectifier diode and finned heatsink are supplied as two separate pieces under one common type number.

OUTLINE DIMENSIONS

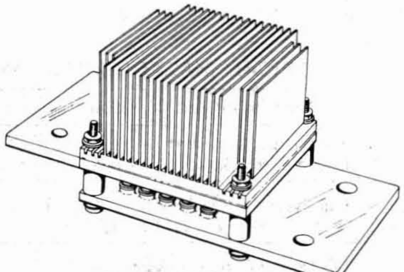

0.50
0.25
0.281 DIA THRU
4 PLACES
1.63
± 0.03
3.00
3.25
1.63
± 0.03
3.00
3.25
0.25
1.25
0.562 DIA THRU
3.25
0.25
2.25
2.34 ± 0.08
1.92 ± 0.08
0.63 ± 0.03
0.25
RECTIFIER DIODE
BUS-BAR
FINNED HEATSINK

TOLERANCES UNLESS OTHERWISE SPECIFIED: 2 PLACES ± 0.015
3 PLACES ± 0.010

MR2100HA (SILICON)
thru
MR2104HA

V_R = 50–400 V
I_o = 1100 A

Multi-Cell II, power rectifier diodes designed for high-current rectifier service. The MR2100HA through MR2104HA provide single-output, high-current dc with forced air cooling.



CASE 158

MAXIMUM DIODE RATINGS

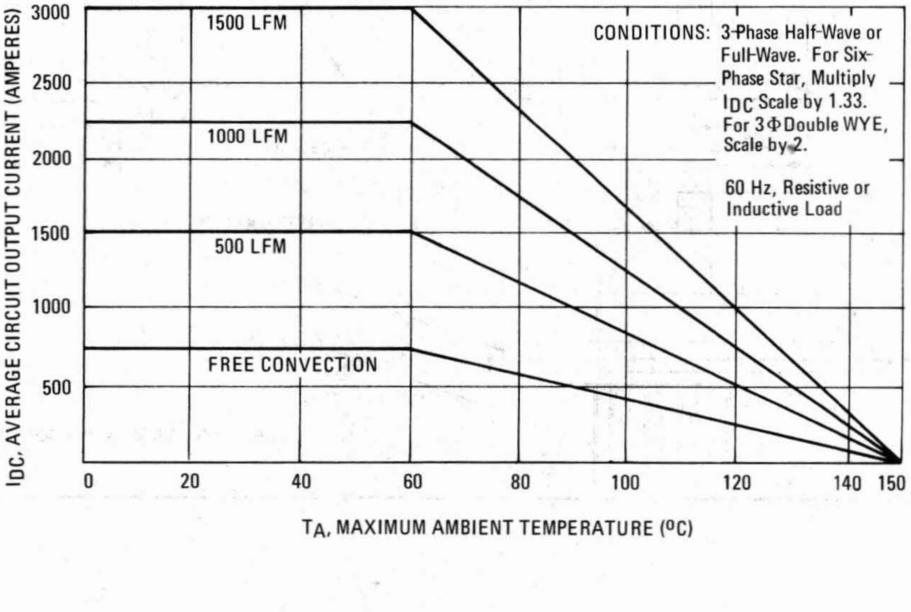
Rating	Symbol	MR2100HA	MR2101HA	MR2102HA	MR2103HA	MR2104HA	Units
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	200	300	400	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single-phase, 60 cycle peak)	$V_{RM(non-rep)}$	75	150	300	400	500	Volts
Continuous Average Rectified Forward Current (single-phase, resistive load, 60 Hz, T_C = 150°C)	I_o	1,100					Amperes
Non-Repetitive Surge Current at Rated Conditions	$I_{FM(surge)}$	18,000 for 1/2 cycle 14,000 for 6 cycles					Peak Amperes

MAXIMUM CIRCUIT RATINGS (All Types, $T_C \leq 150^{\circ}C$, See Figure 1)

Circuit Configuration	Total Diodes Required	Total Circuit DC Output Current
Three-Phase Half-Wave (3-1-1-Y)	3 Diodes Either Polarity	3,000 Amperes
Three-Phase Full-Wave (6-1-1-B)	6 Diodes Either Polarity or 3 Diodes Each Polarity	3,000 Amperes
Six-Phase Star (6-1-1-S)	6 Diodes Either Polarity	4,000 Amperes
Six-Phase with Interphase, 3 Φ Double WYE (6-1-1-Y)	6 Diodes Either Polarity	6,000 Amperes

Maximum Operating and Storage Temperature: −65°C to +150°C (All Types)

FIGURE 1 MAXIMUM CIRCUIT RATINGS



ELECTRICAL CHARACTERISTICS (All Types)

Characteristic And Conditions	Symbol	Maximum Limit	Units
Full-Cycle Average Forward Voltage Drop at Rated Load, $T_C = 150^oC$	$V_{F(AV)}$	0.5	Volts
Full-Cycle Average Reverse Current at Rated Load, $T_C = 150^oC$	$I_{R(AV)}$	100	Milliamperes
DC Reverse Current at Rated Reverse Voltage, V_R, $T_C = 25^oC$	I_R	5.0	Milliamperes

NOTE: A portion of the internal power losses of the rectifier may be conducted from the device by the connecting bus-bar or cables and can vary depending on mounting conditions. The above ratings are based on conditions where at any rating point of output current, ambient temperature and air flow, the assembly case temperature is not allowed to exceed 150°C (See Figure 1).

MECHANICAL CHARACTERISTICS

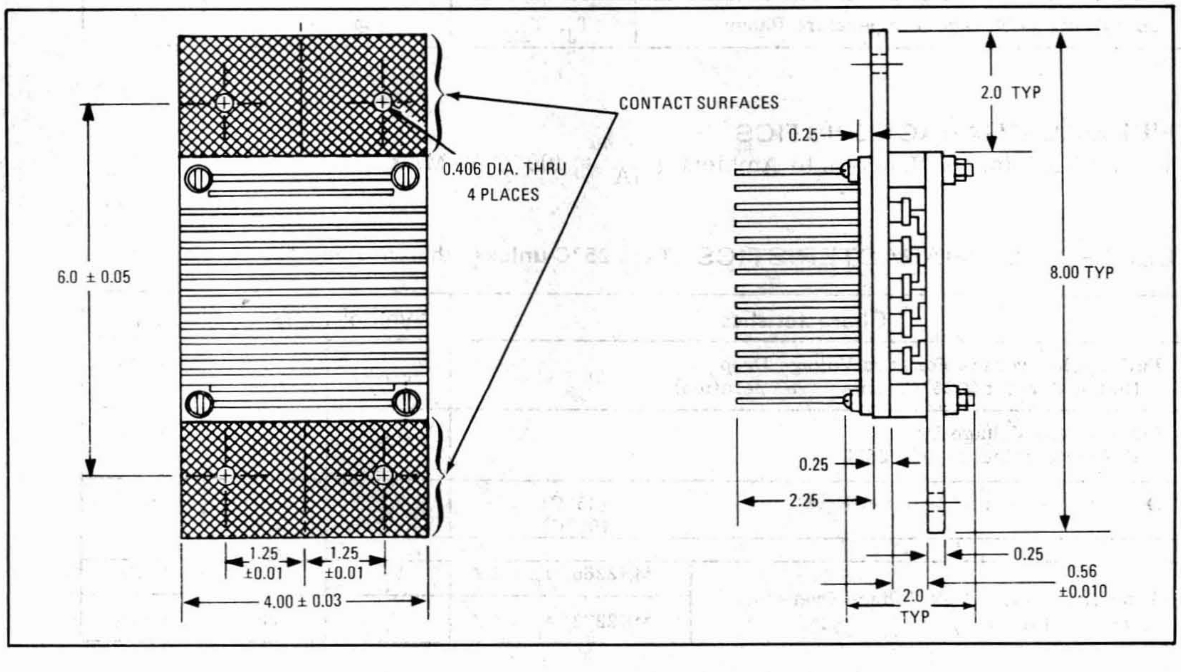
POLARITY:

Standard polarity devices are CATHODE-TO-FINNED BUS TERMINAL, reverse polarity devices are ANODE-TO-FINNED BUS TERMINAL and are designated by an "R" suffix, i.e., MR2102HAR.

MOUNTING POSITION:

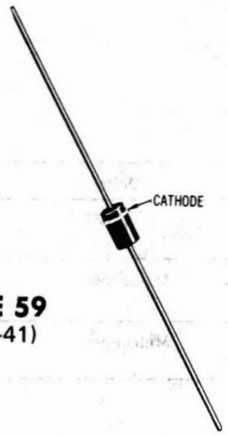
Bus terminals and cooling fins vertical for convection cooling or parallel to forced air flow.

OUTLINE DIMENSIONS



MR2266 (SILICON)
MR2273

V_R to 800V
I_O = 1.0 A



CASE 59
(DO-41)

High-voltage, axial-lead, silicon rectifiers, designed for television "damper" diode service, feature subminiature packages, high current-handling capability, excellent reliability, and economy. Flame-proof silicone polymer case.

MAXIMUM RATINGS

Rating	Symbol	MR2273	MR2266	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	200	800	Volts
RMS Reverse Voltage (Sine wave operation)	V_r	140	560	Volts
Average Rectified Forward Current (single-phase, resistive load, 60 Hz) (75°C Ambient) (100°C Ambient)	I_O	1.0 0.75	1.0 0.75	Amp
Peak Repetitive Forward Current (T_A = 25°C)	$I_{FM(rep)}$	10		Amp
Non-Repetitive Peak Surge Current (superimposed on rated current at rated voltage, T_A = 25°C)	$I_{FM(surge)}$	30 (for 1/2 cycle)		Amp
Operating and Storage Temperature Range	T_J, T_{stg}	-65 to +175		°C

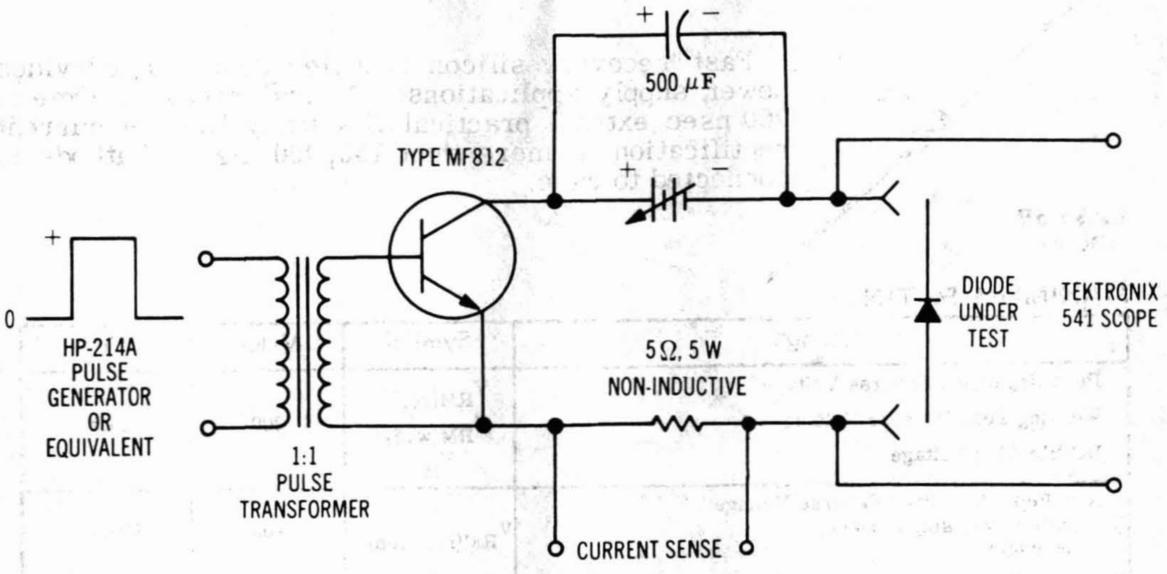
THERMAL CHARACTERISTICS

Thermal Resistance, Junction to Ambient: θ_{JA} = 100°C/W MAX

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristics		Symbol	Max	Unit
Full-Cycle Average Forward Voltage Drop (Rated Current @ 25°C, sine wave operation)		$V_{F(AV)}$	0.8	Volts
DC Forward Voltage Drop (1 Amp Continuous DC, 25°C)		V_F	1.1	Volts
DC Reverse Current @ Rated V_r	(25°C) (100°C)	I_R	0.01 0.05	mA
			Typical	
Typical Forward Peak Voltage Overshoot (Figure 1, Figure 2)	MR2266, I_F = 2 A	V_{fp}	10	Volts
	MR2273, I_F = 5 A	V_{fp}	28	Volts

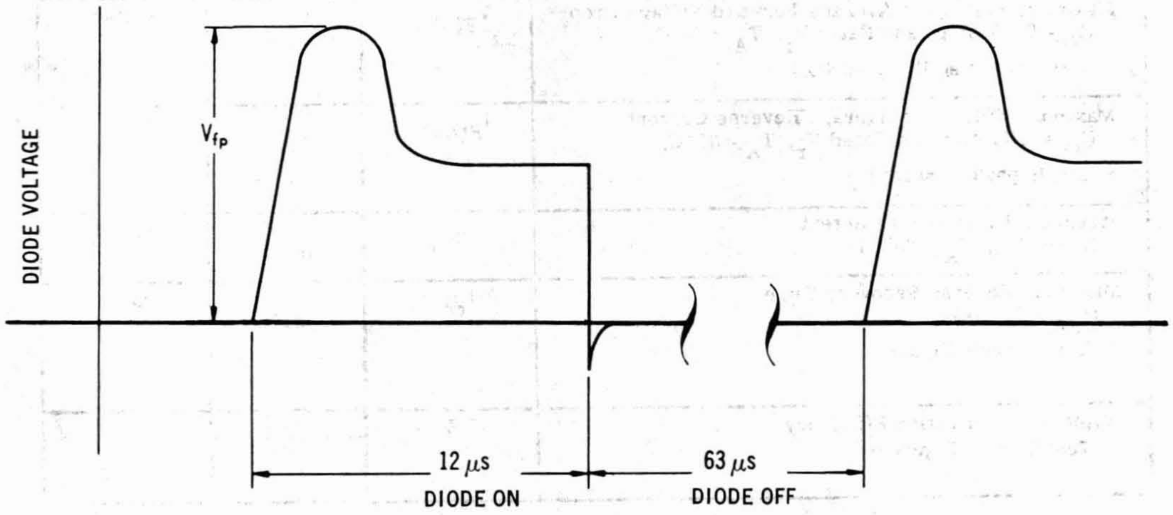
FIGURE 1 — FORWARD PEAK VOLTAGE OVERSHOOT TEST CIRCUIT


+
−
500 μF
TYPE MF812
+
−
+
0
HP-214A
PULSE
GENERATOR
OR
EQUIVALENT
1:1
PULSE
TRANSFORMER
5 Ω, 5 W
NON-INDUCTIVE
CURRENT SENSE
DIODE
UNDER
TEST
TEKTRONIX
541 SCOPE

TEST PROCEDURE:

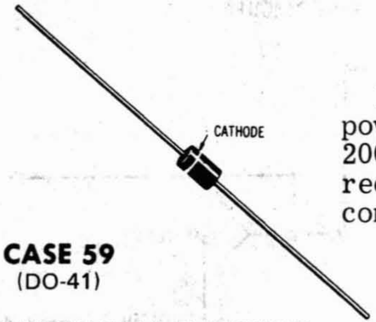
1. Adjust input pulse from generator to saturate MF812 transistor
2. Adjust battery voltage for the specified forward current after the voltage overshoot.
   $I_F = 2$ Amps, for MR2266
   $I_F = 5$ Amps, for MR2273
3. Read peak voltage overshoot across diode under test. (See Waveform Diagram).

FIGURE 2 — DIODE UNDER TEST, WAVEFORM DIAGRAM


DIODE VOLTAGE
V_{fp}
12 μs
DIODE ON
63 μs
DIODE OFF

MR2271 (SILICON)

$V_R = 300V$
$I_O = 1.0 A$



Fast recovery silicon rectifier designed for video power supply applications. Typical recovery time of 200 nsec extends practical frequency limit of current rectification to more than 150,000 Hz. Cathode is connected to case.

CASE 59
(DO-41)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	300	Volts
Non-Repetitive Peak Reverse Voltage (half-wave, single phase, 60 cycle peak)	$V_{RM(non-rep)}$	400	Volts
RMS Reverse Voltage (Sine wave operation)	V_r	210	Volts
Average Rectified Forward Current (Sine wave operation) (single-phase resistive load) $T_A = 25°C$ $T_A = 75°C$	I_O	1.0 0.75	Amp
Non-Repetitive Peak Surge Current (superimposed on rated current at rated voltage, $T_A = 75°C$)	$I_{FM(surge)}$	30 (for 1/2 cycle) @ 60 Hz	Amp
Peak Repetitive Forward Current ($T_A = 75°C$)	$I_{FM(rep)}$	4.0	Amp
Junction Operating and Storage Temperature Range	T_J, T_{stg}	-65 to +150	°C

THERMAL CHARACTERISTICS

Thermal Resistance, Junction to Ambient: $\theta_{JA} = 100^{\circ}C/W$ MAX

ELECTRICAL CHARACTERISTICS

Characteristics	Symbol	Max	Unit
Maximum DC Forward Voltage Drop ($I_F = 1.0$ Adc, $T_A = 25°C$)	V_F	1.1	Vdc
Maximum Full Cycle Average Forward Voltage Drop ($I_O = 0.75$ Amps and Rated V_r, $T_A = 75°C$, Half Wave Rectifier, 60 Hz)	$V_{F(AV)}$	0.55	Volts
Maximum Full Cycle Average Reverse Current ($I_O = 0.75$ Amp and Rated V_r, $T_A = 75°C$, single phase, 60 Hz)	$I_{R(AV)}$	0.75	mA
Maximum DC Reverse Current (Rated V_R, $T_A = 25°C$)	I_R	0.25	mA
Maximum Reverse Recovery Time ($I_{RR} = 50$ mA) Test Circuit Figure 3	t_{rr}	200	ns
Typical Rectification Efficiency Test Circuit Figure 6	RE	Typical 90	%

FIGURE 1

FORWARD CHARACTERISTICS

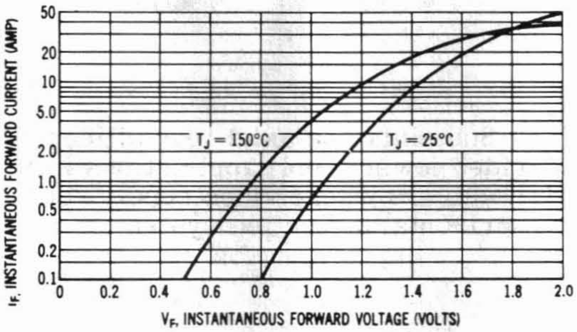


FIGURE 2

MAXIMUM AVERAGE FORWARD CURRENT RATING versus MAXIMUM AMBIENT TEMPERATURE

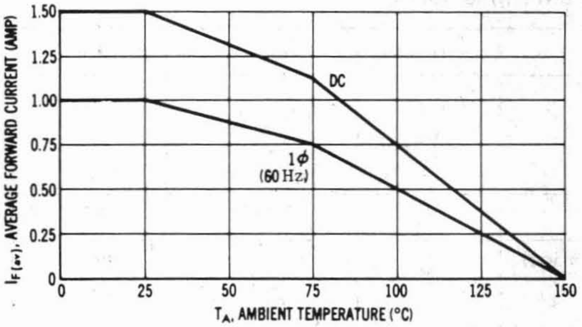


FIGURE 3

RECOVERY TIME TEST CIRCUIT

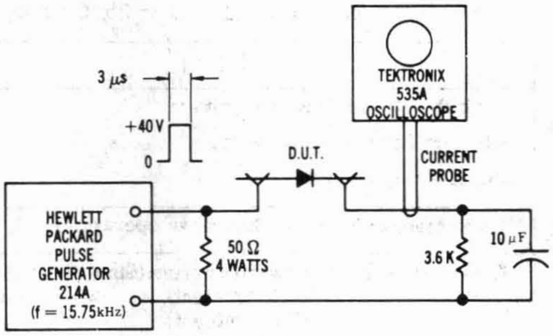

3 μs
+40 V
0
D.U.T.
TEKTRONIX
535A
OSCILLOSCOPE
CURRENT
PROBE
HEWLETT
PACKARD
PULSE
GENERATOR
214A
(f = 15.75kHz)
50 Ω
4 WATTS
3.6 K
10 μF

FIGURE 4

DIODE CURRENT WAVEFORM IN CIRCUIT OF FIGURE 6

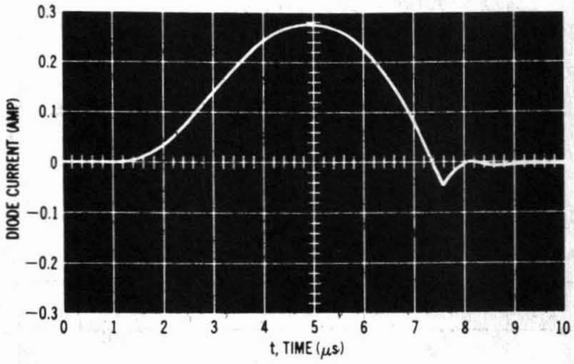


FIGURE 5

RECOVERY WAVEFORM IN CIRCUIT

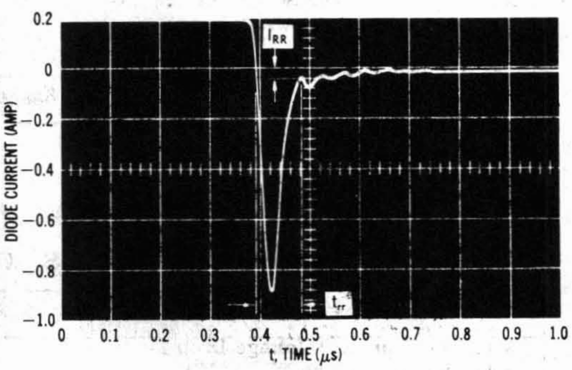
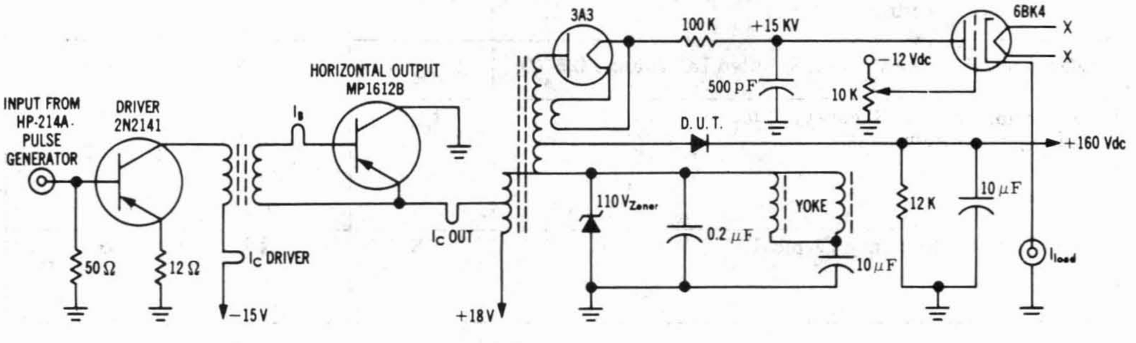


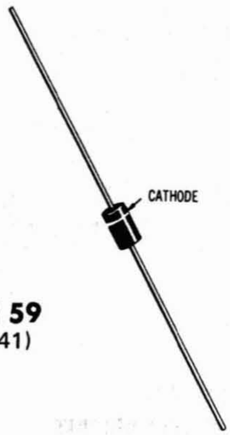
FIGURE 6

LOW VOLTAGE HORIZONTAL DEFLECTION TEST CIRCUIT


INPUT FROM
HP-214A
PULSE
GENERATOR
DRIVER
2N2141
50 Ω
12 Ω
I_C DRIVER
−15 V
I_B
HORIZONTAL OUTPUT
MP1612B
I_C OUT
+18 V
3A3
100 K
+15 KV
500 pF
−12 Vdc
10 K
6BK4
X
X
D. U. T.
+160 Vdc
110 V_{Zener}
0.2 μF
YOKE
10 μF
12 K
10 μF
I_{load}

MR2272 (SILICON)

$V_R = 400V$
$I_O = 1.0 A$



CASE 59
(DO-41)

Subminiature axial-lead silicon rectifier designed for video power-supply applications in low-voltage television receivers where video supply-voltage is obtained from horizontal deflection system.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	400	Volts
RMS Reverse Voltage (Sine wave operation)	V_r	280	Volts
Average Rectified Forward Current (Sine wave operation) (75°C Ambient) (100°C Ambient)	I_O	1.0 0.75	Amp
Peak Repetitive Forward Current ($T_A = 75°C$)	$I_{FM(rep)}$	10	Amp
Non-Repetitive Peak Surge Current (superimposed on rated current at rated voltage, $T_A = 75°C$)	$I_{FM(surge)}$	30 (for 1/2 cycle) @ 60 Hz	Amp
Juction Operating and Storage Temperature Range	T_J, T_{stg}	-65 to +175	°C

THERMAL CHARACTERISTICS

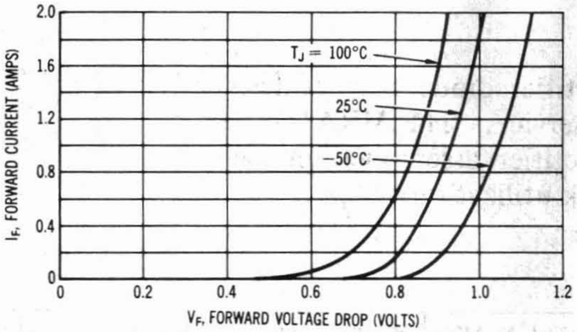
Thermal Resistance, Junction to Ambient: $\theta_{JA} = 100^{o}C/W$ MAX

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

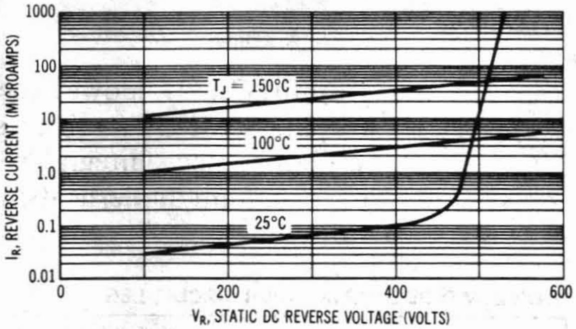
Characteristics	Symbol	Value	Unit
Maximum Forward Voltage Drop (1 Amp Continuous DC, 25°C)	V_F	1.1	Volts
Maximum Full Cycle Average Forward Voltage Drop ($I_O = 0.75$ Amps and Rated V_r, $T_A = 75°C$, Half Wave Rectifier, 60 Hz)	$V_{F(AV)}$	0.5	Volts
Maximum Reverse Current @ Rated DC Voltage (25°C)	I_R	0.01	mA
Maximum Reverse Recovery Time ($I_{RR} = 0.5$ Amp)	t_{rr}	1.5	µs
Rectification Efficiency (Typical)	RE	55	%

MR2272 (continued)

TYPICAL FORWARD CHARACTERISTICS

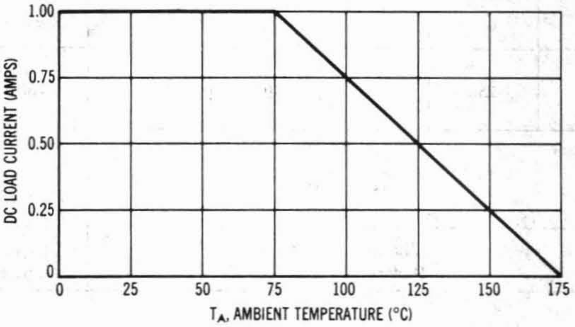


TYPICAL REVERSE CHARACTERISTICS

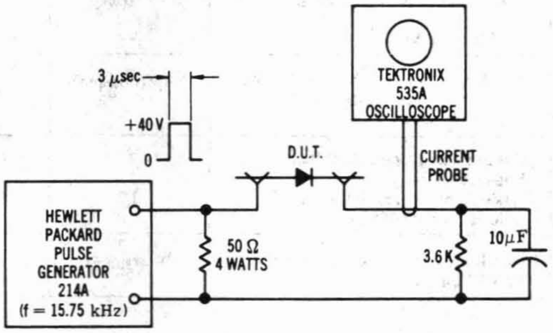


MAXIMUM ALLOWABLE DC OUTPUT

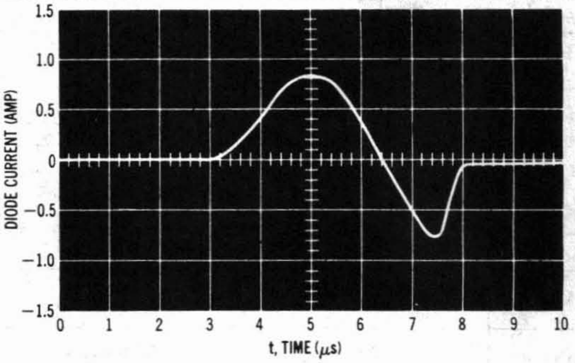
(Sine Wave Operation, Resistive or Inductive Load)



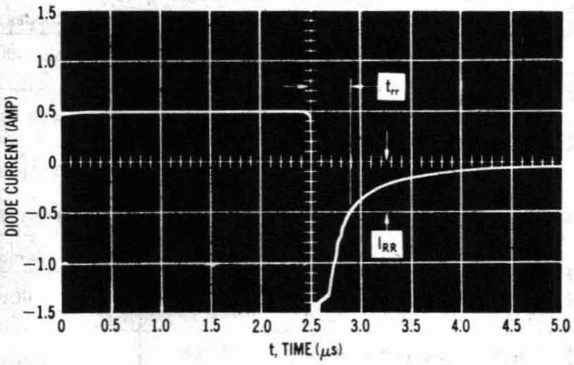
RECOVERY TIME TEST CIRCUIT


3 μsec
+40 V
0
TEKTRONIX
535A
OSCILLOSCOPE
D.U.T.
CURRENT
PROBE
HEWLETT
PACKARD
PULSE
GENERATOR
214A
(f = 15.75 kHz)
50 Ω
4 WATTS
3.6 K
10μF

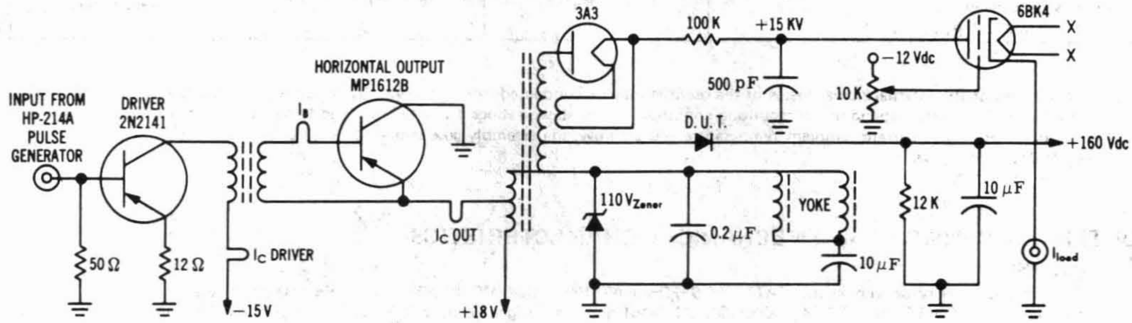
DIODE CURRENT WAVEFORM IN VIDEO SUPPLY OPERATION



TYPICAL RECOVERY WAVEFORM IN CIRCUIT



LOW VOLTAGE HORIZONTAL DEFLECTION TEST CIRCUIT


3A3
100 K
+15 KV
6BK4
X
X
−12 Vdc
500 pF
10 K
HORIZONTAL OUTPUT
MP1612B
INPUT FROM
HP-214A
PULSE
GENERATOR
DRIVER
2N2141
I_B
D. U. T.
+160 Vdc
110 V_{Zener}
YOKE
12 K
10 μF
0.2 μF
10 μF
I_C OUT
I_C DRIVER
50 Ω
12 Ω
−15 V
+18 V
I_{load}

MR2273

For Specifications, See MR2266 Data.

MRA130 (SILICON)
thru
MRA134

V_R = 50–400 V
I_{DC} = 300 A

Multi-Cell II, power rectifier diode circuits designed for high-current rectifier service. The MRA130 series are air-cooled, integral rectifier assemblies engineered for optimum diode/heatsink utilization.

MAXIMUM DIODE RATINGS PER CIRCUIT LEG

Rating	Symbol	MRA130	MRA131	MRA132	MRA133	MRA134	Units
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	200	300	400	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single-phase, 60 cycle peak)	$V_{RM(non\text{-}rep)}$	75	150	300	400	500	Volts
Continuous Average Rectified Forward Current (single-phase, resistive load, 60 Hz, $T_C = 150^\circ C$)	I_O	150					Amperes
Non-Repetitive Surge Currents at Rated Conditions	$I_{FM(surge)}$	3000 for 1/2 cycle 1800 for 6 cycles					Peak Amperes

MAXIMUM CIRCUIT RATINGS (All Types, $T_C \leq 150^\circ C$, See Figure 1)

Circuit Configuration	Total Diodes Required	Max Total Circuit DC Output Current
Single-Phase, Center Tap (2-1-1-C)	1 Diode Assembly Either Polarity	300 Amperes
Single-Phase Bridge (4-1-1-B)	2 Diode Assemblies, One Each Polarity	300 Amperes

Maximum Operating and Storage Temperature: $-65^\circ C$ to $+150^\circ C$ (All Types)

ELECTRICAL CHARACTERISTICS PER CIRCUIT LEG (All Types)

Characteristic And Conditions	Symbol	Maximum Limit	Units
Full-Cycle Average Forward Voltage Drop at Rated Load, $T_C = 150^\circ C$	$V_{F(AV)}$	0.5	Volts
Full-Cycle Average Reverse Current at Rated Load, $T_C = 150^\circ C$	$I_{R(AV)}$	20	Milliamperes
DC Reverse Current at Rated Reverse Voltage, V_R, $T_C = 25^\circ C$	I_R	1.5	Milliamperes

NOTE: A portion of the internal power losses of the rectifier may be conducted from the device by the connecting bus-bar or cables and can vary depending on mounting conditions. The above ratings are based on conditions where at any rating point of output current, ambient temperature and air flow, the assembly case temperature is not allowed to exceed 150°C. (See Figure 1).

OUTLINE DIMENSIONS AND MECHANICAL CHARACTERISTICS

POLARITY:

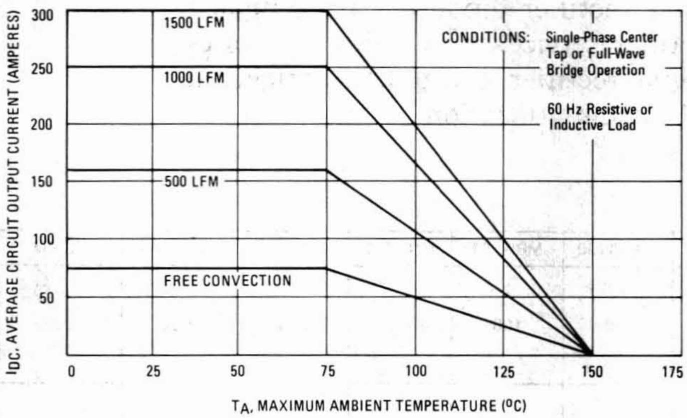
Standard polarity assemblies are CATHODES-TO-HEATSINK, (COMMON CATHODE). Reverse polarity assemblies are ANODES-TO-HEATSINK (COMMON ANODE) and are designated by an "R" suffix, i.e., MRA131R. (See Figure 2.)

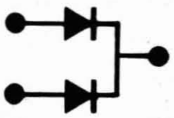
MOUNTING POSITION: Diode legs vertical for convection cooling or parallel to forced air flow.

FULL-WAVE BRIDGE ASSEMBLIES are available completely assembled with electrically insulated hardware suitable for easy mounting. The bridge assembly is designated by a "B" suffix, i.e., MRA132B. The bridges are composed of one common cathode and one common anode assembly. (See Figure 3)

CUSTOM RECTIFIER ASSEMBLIES are available in a variety of current and voltage ranges using the basic MULTI-CELL II construction techniques.

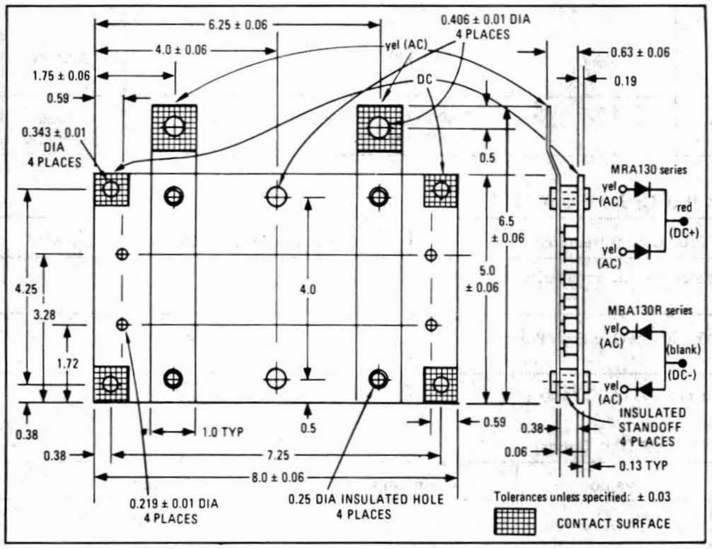
FIGURE 1 – MAXIMUM CIRCUIT RATINGS

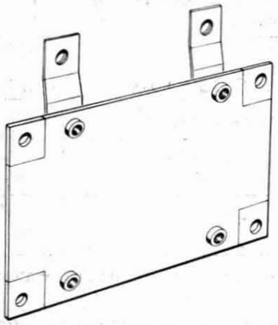




"C" CIRCUIT FOR SINGLE-PHASE OPERATION

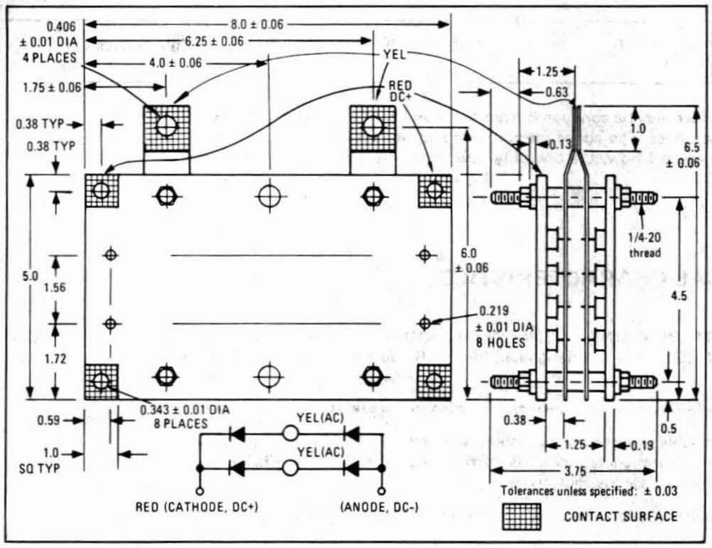
FIGURE 2 – MRA130 ("C" CIRCUIT)

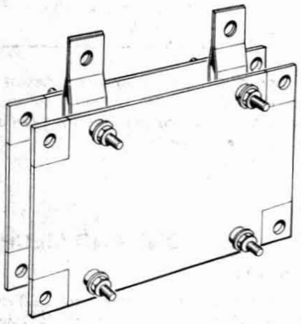

6.25 ± 0.06
4.0 ± 0.06
1.75 ± 0.06
0.59
0.343 ± 0.01 DIA 4 PLACES
0.406 ± 0.01 DIA 4 PLACES
yel (AC)
DC
0.63 ± 0.06
0.19
0.5
6.5 ± 0.06
5.0 ± 0.06
4.0
4.25
3.28
1.72
0.38
0.38
1.0 TYP
0.5
7.25
8.0 ± 0.06
0.59
0.38
0.06
0.13 TYP
0.219 ± 0.01 DIA 4 PLACES
0.25 DIA INSULATED HOLE 4 PLACES
MRA130 series
yel (AC)
red (DC+)
yel (AC)
MRA130R series
yel (AC)
(blank) (DC-)
yel (AC)
INSULATED STANDOFF 4 PLACES
Tolerances unless specified: ± 0.03
CONTACT SURFACE



CASE 154A

FIGURE 3 – MRA130B (BRIDGE CIRCUIT)


0.406 ± 0.01 DIA 4 PLACES
8.0 ± 0.06
6.25 ± 0.06
4.0 ± 0.06
1.75 ± 0.06
0.38 TYP
0.38 TYP
YEL
RED DC+
1.25
0.63
0.13
1.0
6.5 ± 0.06
6.0 ± 0.06
1/4-20 thread
4.5
5.0
1.56
1.72
0.219 ± 0.01 DIA 8 HOLES
0.343 ± 0.01 DIA 8 PLACES
0.59
1.0 SQ TYP
YEL(AC)
YEL(AC)
RED (CATHODE, DC+)
(ANODE, DC-)
0.38
1.25
0.19
0.5
3.75
Tolerances unless specified: ± 0.03
CONTACT SURFACE



CASE 155A

MRA160 (SILICON)
thru
MRA164

V_R = 50–400 V
I_{DC} = 600 A

Multi-Cell II, power rectifier diode circuits designed for high-current rectifier service. The MRA160 series are air-cooled, integral rectifier assemblies engineered for optimum diode/heatsink utilization.

MAXIMUM DIODE RATINGS PER CIRCUIT LEG

Rating	Symbol	MRA160	MRA161	MRA162	MRA163	MRA164	Units
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	200	300	400	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single-phase, 60 cycle peak)	$V_{RM(non-rep)}$	75	150	300	400	500	Volts
Continuous Average Rectified Forward Current (single-phase, resistive load, 60 Hz, T_C = 150°C)	I_o	300					Amperes
Non-Repetitive Surge Currents at Rated Conditions	$I_{FM(surge)}$	6000 for 1/2 cycle 3600 for 6 cycles					Peak Amperes

MAXIMUM CIRCUIT RATINGS (All Types, $T_C \leq 150°C$, See Figure 1)

Circuit Configuration	Total Diodes Required	Max Total Circuit DC Output Current
Single-Phase, Center Tap (2-1-1-C)	1 Diode Assembly Either Polarity	600 Amperes
Single-Phase Bridge (4-1-1-B)	2 Diode Assemblies One Each Polarity	600 Amperes

Maximum Operating and Storage Temperature: −65°C to +150°C (All Types)

ELECTRICAL CHARACTERISTICS PER CIRCUIT LEG (All Types)

Characteristic And Conditions	Symbol	Maximum Limit	Units
Full-Cycle Average Forward Voltage Drop at Rated Load, T_C = 150°C	$V_{F(AV)}$	0.5	Volts
Full-Cycle Average Reverse Current at Rated Load, T_C = 150°C	$I_{R(AV)}$	40	Milliamperes
DC Reverse Current at Rated Reverse Voltage, V_R, T_C = 25°C	I_R	3.0	Milliamperes

NOTE: A portion of the internal power losses of the rectifier may be conducted from the device by the connecting bus-bar or cables and can vary depending on mounting conditions. The above ratings are based on conditions where at any rating point of output current, ambient temperature and air flow, the assembly case temperature is not allowed to exceed 150°C. (See Figure 1).

OUTLINE DIMENSIONS AND MECHANICAL CHARACTERISTICS

POLARITY:

Standard polarity assemblies are CATHODES-TO-HEATSINK, (COMMON CATHODE). Reverse polarity assemblies are ANODES-TO-HEATSINK (COMMON ANODE) and are designated by an "R" suffix, i.e.,MRA161R. (See Figure 2.)

MOUNTING POSITION: Cooling fins and diode legs vertical for convection cooling or parallel to forced air flow.

FULL-WAVE BRIDGE ASSEMBLIES are available completely assembled with electrically insulated hardware suitable for easy mounting. The bridge assembly is designated by a "B" suffix, i.e.,MRA162B. The bridges are composed of one common cathode and one common anode assembly. (See Figure 3)

CUSTOM RECTIFIER ASSEMBLIES are available in a variety of current and voltage ranges using the basic MULTI-CELL II construction techniques.

FIGURE 1 – MAXIMUM CIRCUIT RATINGS

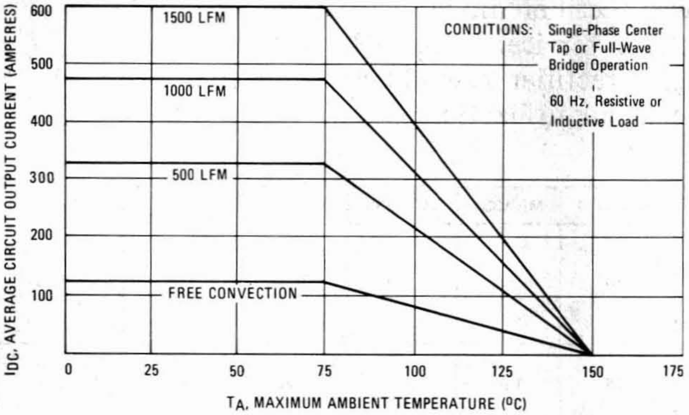


FIGURE 2 – MRA160 ("C" CIRCUIT)

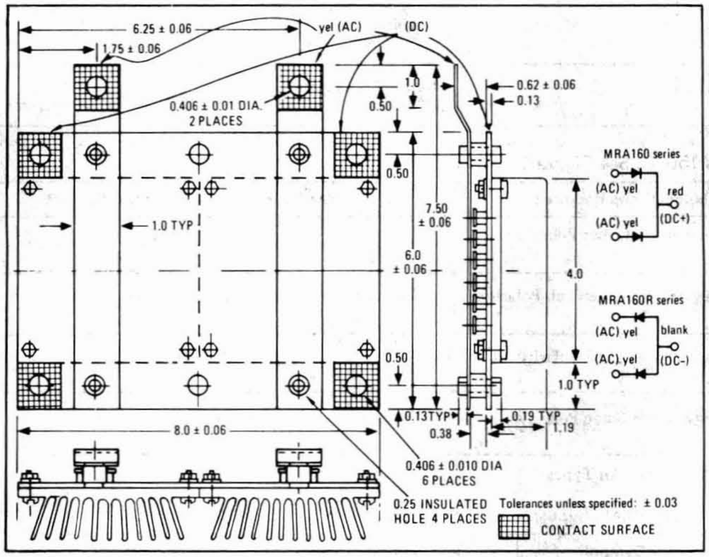
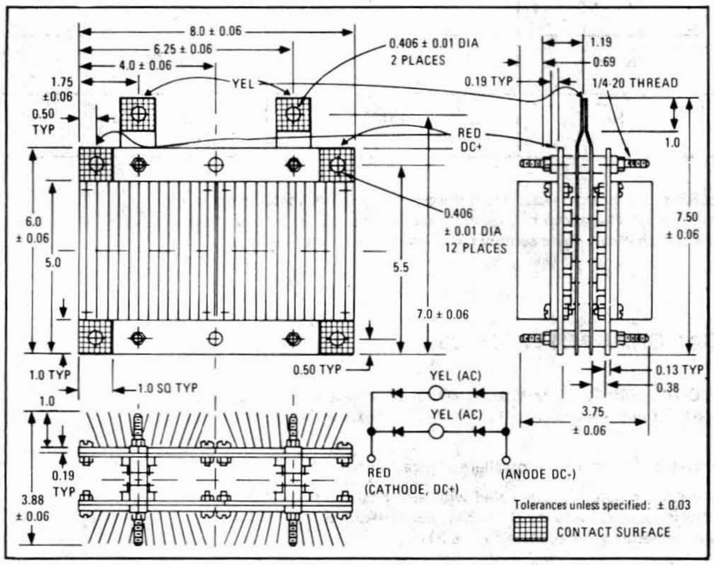
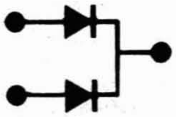
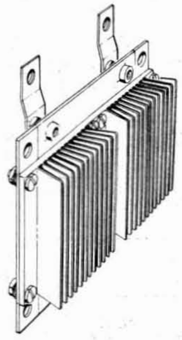

6.25 ± 0.06
1.75 ± 0.06
yel (AC)
(DC)
0.406 ± 0.01 DIA.
2 PLACES
1.0
0.50
0.62 ± 0.06
0.13
0.50
7.50
± 0.06
6.0
± 0.06
4.0
1.0 TYP
0.50
1.0 TYP
0.13TYP
0.38
0.19 TYP
1.19
8.0 ± 0.06
0.406 ± 0.010 DIA
6 PLACES
0.25 INSULATED
HOLE 4 PLACES
MRA160 series
(AC) yel
red
(AC) yel
(DC+)
MRA160R series
(AC) yel
blank
(AC) yel
(DC-)
Tolerances unless specified: ± 0.03
CONTACT SURFACE

FIGURE 3 – MRA160B (BRIDGE CIRCUIT)

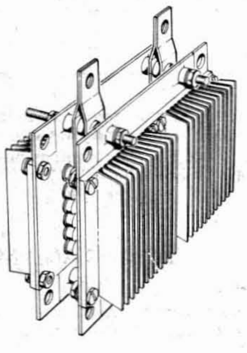

8.0 ± 0.06
6.25 ± 0.06
4.0 ± 0.06
1.75
±0.06
0.50
TYP
YEL
0.406 ± 0.01 DIA
2 PLACES
1.19
0.69
0.19 TYP
1/4-20 THREAD
1.0
RED
DC+
0.406
± 0.01 DIA
12 PLACES
6.0
± 0.06
5.0
5.5
7.0 ± 0.06
7.50
± 0.06
1.0 TYP
1.0 SQ TYP
0.50 TYP
0.13 TYP
0.38
3.75
± 0.06
1.0
0.19
TYP
3.88
± 0.06
YEL (AC)
YEL (AC)
RED
(CATHODE, DC+)
(ANODE DC-)
Tolerances unless specified: ± 0.03
CONTACT SURFACE



"C" CIRCUIT FOR SINGLE-PHASE OPERATION



CASE 156A



CASE 157A

MRA330 (SILICON)
thru
MRA334

V_R = 50–400 V
I_{DC} = 300 A

Multi-Cell II, power rectifier diode circuits designed for high-current rectifier service. The MRA330 series are air-cooled, integral rectifier assemblies engineered for optimum diode/heatsink utilization.

MAXIMUM DIODE RATINGS PER CIRCUIT LEG

Rating	Symbol	MRA330	MRA331	MRA332	MRA333	MRA334	Units
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	200	300	400	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single-phase, 60 cycle peak)	$V_{RM(non\text{-}rep)}$	75	150	300	400	500	Volts
Continuous Average Rectified Forward Current (three-phase, resistive load, 60 Hz, T_C = 150°C)	$I_{F(AV)}$	100					Amperes
Non-Repetitive Surge Currents at Rated Conditions	$I_{FM(surge)}$	2000 for 1/2 cycle 1200 for 6 cycles					Peak Amperes

MAXIMUM CIRCUIT RATINGS (All Types, $T_C \leqslant 150°C$, See Figure 1)

Circuit Configuration	Total Diodes Required	Max Total Circuit DC Output Current
Three-Phase Half-Wave (3-1-1-Y)	1 Diode Assembly, Either Polarity	300 Amperes
Three-Phase Full-Wave (6-1-1-B)	2 Diode Assemblies, One Each Polarity	300 Amperes
Six-Phase Star (6-1-1-S)	2 Diode Assemblies Same Polarity	400 Amperes
Six-Phase with Interphase, 3Φ Double WYE (6-1-1-Y)	2 Diode Assemblies Same Polarity	600 Amperes

Maximum Operating and Storage Temperature: −65°C to +150°C (All Types)

ELECTRICAL CHARACTERISTICS PER CIRCUIT LEG (All Types)

Characteristic And Conditions	Symbol	Maximum Limit	Units
Full-Cycle Average Forward Voltage Drop at Rated Load, T_C = 150°C	$V_{F(AV)}$	0.5	Volts
Full-Cycle Average Reverse Current at Rated Load, T_C = 150°C	$I_{R(AV)}$	15	Milliamperes
DC Reverse Current at Rated Reverse Voltage, V_R, T_C = 25°C	I_R	1.0	Milliamperes

NOTE: A portion of the internal power losses of the rectifier may be conducted from the device by the connecting bus-bar or cables and can vary depending on mounting conditions. The above ratings are based on conditions where at any rating point of output current, ambient temperature and air flow, the assembly case temperature is not allowed to exceed 150°C. (See Figure 1).

OUTLINE DIMENSIONS AND MECHANICAL CHARACTERISTICS

POLARITY:

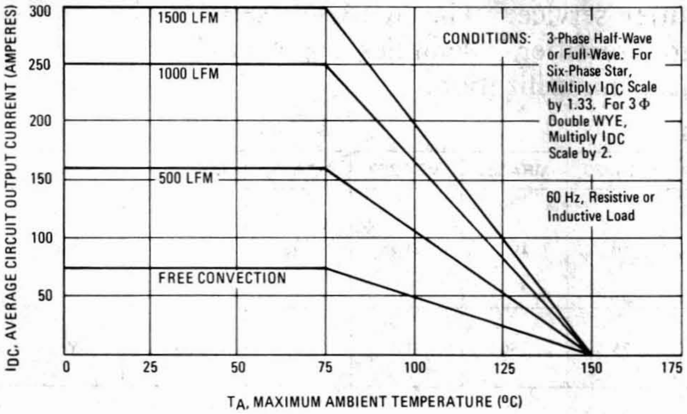
Standard polarity assemblies are CATHODES–TO–HEATSINK, (COMMON CATHODE). Reverse polarity assemblies are ANODES–TO–HEATSINK (COMMON ANODE) and are designated by an "R" suffix, i.e., MRA331R. (See Figure 2.)

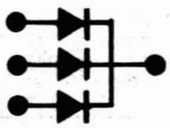
MOUNTING POSITION: Diode legs vertical for convection cooling or parallel to forced air flow.

FULL–WAVE BRIDGE ASSEMBLIES are available completely assembled with electrically insulated hardware suitable for easy mounting. The bridge assembly is designated by a "B" suffix, i.e., MRA332B. The bridges are composed of one common cathode and one common anode assembly. (See Figure 3)

CUSTOM RECTIFIER ASSEMBLIES are available in a variety of current and voltage ranges using the basic MULTI-CELL II construction techniques.

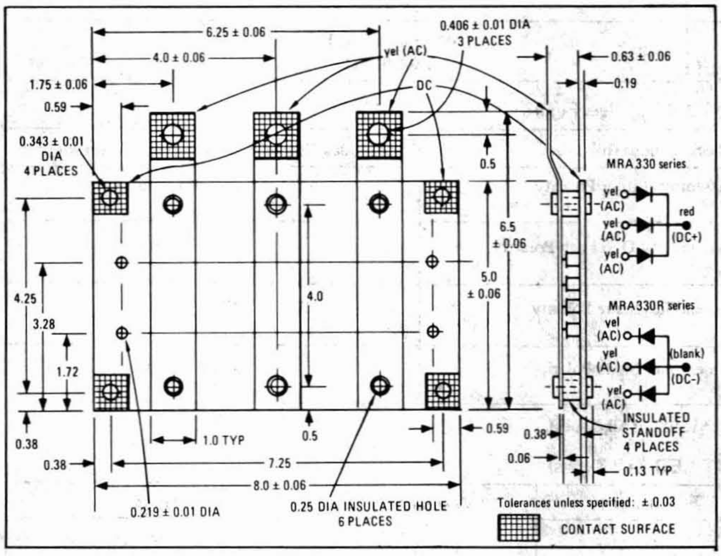
FIGURE 1 – MAXIMUM CIRCUIT RATINGS

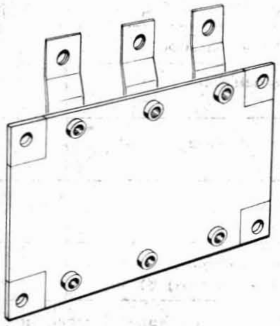




"Y" CIRCUIT FOR POLYPHASE OPERATION

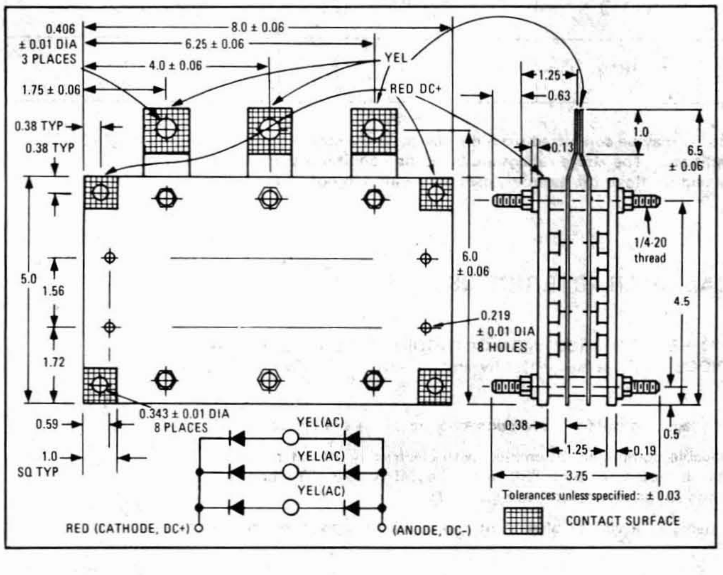
FIGURE 2 – MRA330 ("Y" CIRCUIT)

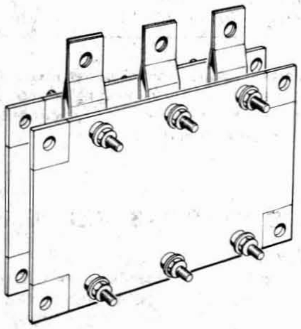

6.25 ± 0.06
4.0 ± 0.06
1.75 ± 0.06
0.59
0.343 ± 0.01 DIA 4 PLACES
0.406 ± 0.01 DIA 3 PLACES
yel (AC)
DC
0.63 ± 0.06
0.19
0.5
MRA330 series
yel (AC)
red (DC+)
6.5 ± 0.06
5.0 ± 0.06
4.0
4.25
3.28
1.72
MRA330R series
yel (AC)
(blank) (DC-)
INSULATED STANDOFF 4 PLACES
0.38
1.0 TYP
0.5
0.59
0.06
0.13 TYP
7.25
8.0 ± 0.06
0.219 ± 0.01 DIA
0.25 DIA INSULATED HOLE 6 PLACES
Tolerances unless specified: ± 0.03
CONTACT SURFACE



CASE 154

FIGURE 3 – MRA330B (BRIDGE CIRCUIT)


0.406 ± 0.01 DIA 3 PLACES
8.0 ± 0.06
6.25 ± 0.06
4.0 ± 0.06
1.75 ± 0.06
YEL
RED DC+
0.38 TYP
0.38 TYP
1.25
0.63
0.13
1.0
6.5 ± 0.06
6.0 ± 0.06
1/4-20 thread
4.5
5.0
1.56
1.72
0.219 ± 0.01 DIA 8 HOLES
0.343 ± 0.01 DIA 8 PLACES
0.59
1.0 SQ TYP
YEL(AC)
YEL(AC)
YEL(AC)
RED (CATHODE, DC+)
(ANODE, DC-)
0.38
1.25
0.19
0.5
3.75
Tolerances unless specified: ± 0.03
CONTACT SURFACE



CASE 155

MRA360 (SILICON)
thru
MRA364

$V_R = 50\text{–}400$ V
$I_{DC} = 650$ A

Multi-Cell II, power rectifier diode circuits designed for high-current rectifier service. The MRA360 series are air-cooled, integral rectifier assemblies engineered for optimum diode/heatsink utilization.

MAXIMUM DIODE RATINGS PER CIRCUIT LEG

Rating	Symbol	MRA360	MRA361	MRA362	MRA363	MRA364	Units
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	$V_{RM(rep)}$ $V_{RM(wkg)}$ V_R	50	100	200	300	400	Volts
Non-Repetitive Peak Reverse Voltage (one half-wave, single-phase, 60 cycle peak)	$V_{RM(non\text{-}rep)}$	75	150	300	400	500	Volts
Continuous Average Rectified Forward Current (three-phase, resistive load, 60 Hz, $T_C = 150^\circ C$)	$I_{F(AV)}$	220					Amperes
Non-Repetitive Surge Currents at Rated Conditions	$I_{FM(surge)}$	5000 for 1/2 cycle 3000 for 6 cycles					Peak Amperes

MAXIMUM CIRCUIT RATINGS (All Types, $T_C \leqslant 150^\circ C$, See Figure 1).

Circuit Configuration	Total Diodes Required	Max Total Circuit DC Output Current
Three-Phase Half-Wave (3-1-1-Y)	1 Diode Assembly Either Polarity	650 Amperes
Three-Phase Full-Wave (6-1-1-B)	2 Diode Assemblies, One Each Polarity	650 Amperes
Six-Phase Star (6-1-1-S)	2 Diode Assemblies Same Polarity	870 Amperes
Six-Phase with Interphase, 3Φ Double WYE (6-1-1-Y)	2 Diode Assemblies Same Polarity	1300 Amperes

Maximum Operating and Storage Temperature: $-65^\circ C$ to $+150^\circ C$ (All Types)

ELECTRICAL CHARACTERISTICS PER CIRCUIT LEG (All Types)

Characteristic And Conditions	Symbol	Maximum Limit	Units
Full-Cycle Average Forward Voltage Drop at Rated Load, $T_C = 150^\circ C$	$V_{F(AV)}$	0.5	Volts
Full-Cycle Average Reverse Current at Rated Load, $T_C = 150^\circ C$	$I_{R(AV)}$	40	Milliamperes
DC Reverse Current at Rated Reverse Voltage, V_R, $T_C = 25^\circ C$	I_R	3.0	Milliamperes

NOTE: A portion of the internal power losses of the rectifier may be conducted from the device by the connecting bus-bar or cables and can vary depending on mounting conditions. The above ratings are based on conditions where at any rating point of output current, ambient temperature and air flow, the assembly case temperature is not allowed to exceed 150°C. (See Figure 1).

OUTLINE DIMENSIONS AND MECHANICAL CHARACTERISTICS

POLARITY:
Standard polarity assemblies are CATHODES-TO-HEATSINK, (COMMON CATHODE). Reverse polarity assemblies are ANODES-TO-HEATSINK (COMMON ANODE) and are designated by an "R" suffix, i.e., MRA361R. (See Figure 2)

MOUNTING POSITION: Cooling fins and diode legs vertical for convection cooling or parallel to forced air flow.

FULL–WAVE BRIDGE ASSEMBLIES are available completely assembled with electrically insulated hardware suitable for easy mounting. The bridge assembly is designated by a "B" suffix, i.e., MRA362B. The bridges are composed of one common cathode and one common anode assembly. (See Figure 3)

CUSTOM RECTIFIER ASSEMBLIES are available in a variety of current and voltage ranges using the basic MULTI-CELL II construction techniques.

FIGURE 1 – MAXIMUM CIRCUIT RATINGS

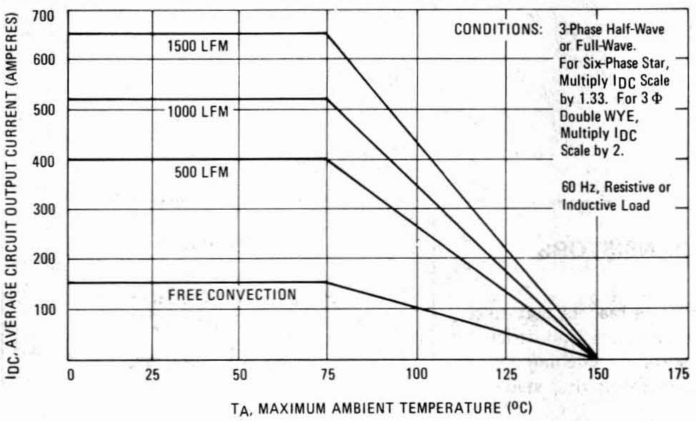
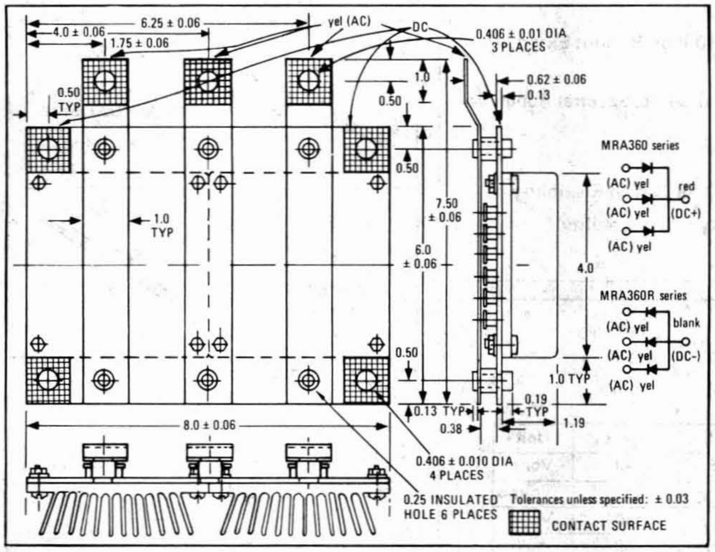
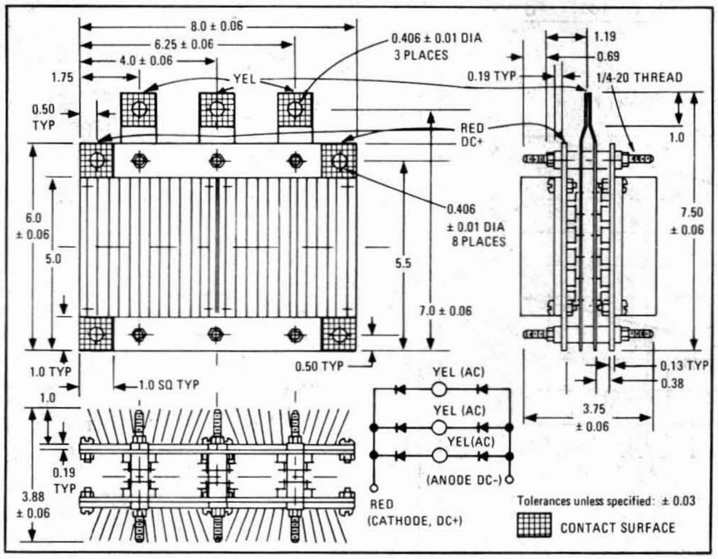


FIGURE 2 – MRA360 ("Y" CIRCUIT)

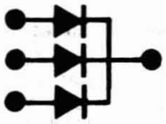


6.25 ± 0.06
4.0 ± 0.06
1.75 ± 0.06
yel (AC)
DC
0.406 ± 0.01 DIA 3 PLACES
0.50 TYP
1.0
0.50
0.62 ± 0.06
0.13
0.50
7.50 ± 0.06
6.0 ± 0.06
1.0 TYP
4.0
MRA360 series
(AC) yel
(AC) yel
(AC) yel
red
(DC+)
MRA360R series
(AC) yel
(AC) yel
(AC) yel
blank
(DC-)
0.50
1.0 TYP
0.13 TYP
0.19 TYP
0.38
1.19
8.0 ± 0.06
0.406 ± 0.010 DIA 4 PLACES
0.25 INSULATED HOLE 6 PLACES
Tolerances unless specified: ± 0.03
CONTACT SURFACE

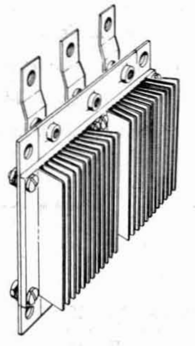
FIGURE 3 – MRA360B (BRIDGE CIRCUIT)



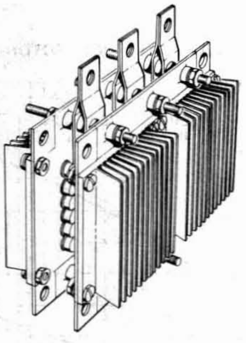
8.0 ± 0.06
6.25 ± 0.06
4.0 ± 0.06
1.75
YEL
0.406 ± 0.01 DIA 3 PLACES
1.19
0.69
0.19 TYP
1/4-20 THREAD
0.50 TYP
RED
DC+
1.0
6.0 ± 0.06
5.0
0.406 ± 0.01 DIA 8 PLACES
5.5
7.0 ± 0.06
7.50 ± 0.06
1.0 TYP
0.50 TYP
1.0 SQ TYP
1.0
0.19 TYP
3.88 ± 0.06
YEL (AC)
YEL (AC)
YEL(AC)
(ANODE DC-)
RED (CATHODE, DC+)
0.13 TYP
0.38
3.75 ± 0.06
Tolerances unless specified: ± 0.03
CONTACT SURFACE



"Y" CIRCUIT
FOR POLYPHASE OPERATION



CASE 156



CASE 157

MRD 100
MRD 150

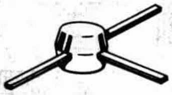
PLASTIC NPN SILICON PHOTO TRANSISTORS

. . . designed for application in punched card and tape readers, pattern and character recognition equipment, shaft encoders, industrial inspection processing and control, counters, sorters, switching and logic circuits, or any design requiring radiation sensitivity, stable characteristics and high-density mounting.

- Economical Plastic Package
- Available With External Base Lead (MRD100) or Without External Base Lead (MRD150)
- Sensitive Throughout Visible and Near Infra-Red Spectral Range for Wide Application
- Small Size for High-Density Mounting
- Minimum Sensitivity (0.04 mA/mW/cm^2) for Design Flexibility
- Annular Passivated Structure for Stability and Reliability

40 VOLT
MICRO-T
PHOTO TRANSISTORS
NPN SILICON

50 MILLIWATTS

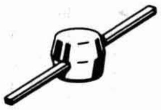


ACTUAL SIZE

MRD100
CASE 172

ACTUAL SIZE

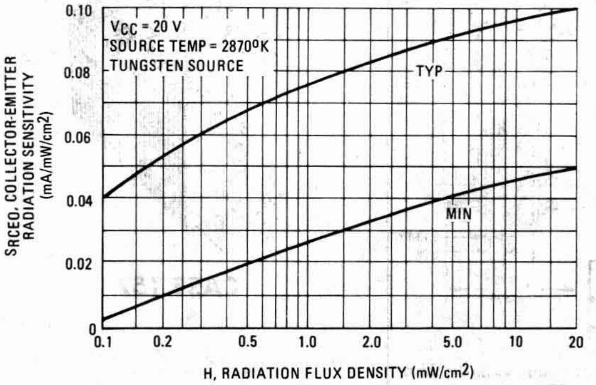
MRD150
CASE 173

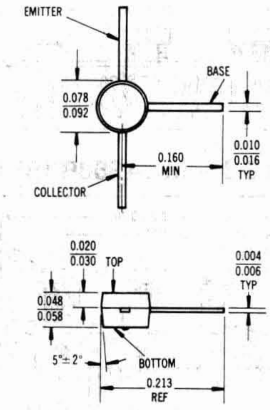


MAXIMUM RATINGS

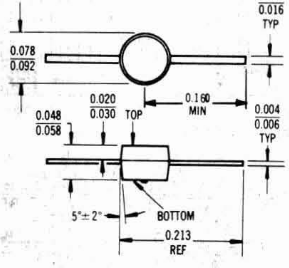
Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Volts
Emitter-Collector Voltage	V_{ECO}	6.0	Volts
Collector-Base Voltage	V_{CBO}	80	Volts
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	50 0.7	mW mW/°C
Operating Junction Temperature Range Storage Temperature Range	T_J T_{stg}	-40 to +85 -40 to +100	°C °C

FIGURE 1 – COLLECTOR-EMITTER SENSITIVITY




EMITTER
BASE
COLLECTOR
0.078/0.092
0.010/0.016 TYP
0.160 MIN
0.020/0.030
TOP
0.004/0.006 TYP
0.048/0.058
5°± 2°
BOTTOM
0.213 REF

CASE 172


0.010/0.016 TYP
0.078/0.092
0.160 MIN
0.020/0.030
TOP
0.048/0.058
0.004/0.006 TYP
5°± 2°
BOTTOM
0.213 REF

CASE 173

Collector indicated by arrow on bottom of device.

STATIC ELECTRICAL CHARACTERISTICS (T_A = 25°C unless noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Units
Collector Dark Current (V_{CC} = 20 V; R_L = 100 ohms; Base Open) (Note 2) T_A = 25°C T_A = 85°C	–	I_{CEO}	 – –	 – 5.0	 0.10 –	µA
Collector-Base Breakdown Voltage (I_C = 100 µA; Emitter Open; Note 2 and 4)	–	BV_{CBO}	80	–	–	Volts
Collector-Emitter Breakdown Voltage (I_C = 100 µA; Base Open; Note 2)	–	BV_{CEO}	40	–	–	Volts
Emitter-Collector Breakdown Voltage (I_E = 100 µA; Base Open; Note 2)	–	BV_{ECO}	6.0	–	–	Volts

OPTICAL CHARACTERISTICS (T_A = 25°C unless noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Units
Collector-Emitter Radiation Sensitivity (V_{CC} = 20 V; R_L = 100 ohms; Base Open) (Note 1)	1	S_{RCEO}	0.04	0.09	–	mA/mW/cm^2
Collector-Base Radiation Sensitivity (V_{CC} = 20 V; R_L = 100 ohms; Emitter Open) (Notes 1 and 4)	–	S_{RCBO}	0.3	0.4	–	µA/mW/cm^2
Photo Current Rise Time (Note 3)	2 and 3	t_r	–	–	2.5	µs
Photo Current Fall Time (Note 3)	2 and 3	t_f	–	–	4.0	µs
Wavelength of Maximum Sensitivity	9	$\lambda_{s(typ)}$	–	0.8	–	µm

NOTES:

1. Radiation Flux Density (H) equal to 5.0 mW/cm^2 emitted from a tungsten source at a color temperature of 2870°K.
2. Measured under dark conditions. ($H \approx 0$).
3. For unsaturated rise time measurements, radiation is provided by a pulsed GaAs (gallium-arsenide) light-emitting diode (λ = 0.9 µm) with a pulse width equal to or greater than 10 microseconds (see Figure 2 and Figure 3).
4. This characteristic applies only to the MRD100 since no base lead is available on the MRD150.

FIGURE 2 – PULSE RESPONSE TEST CIRCUIT

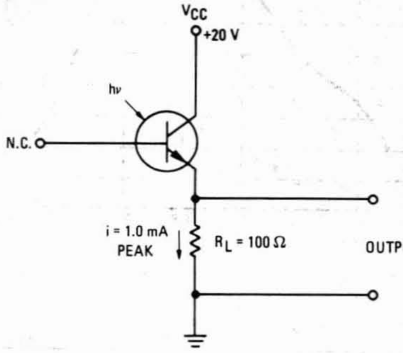
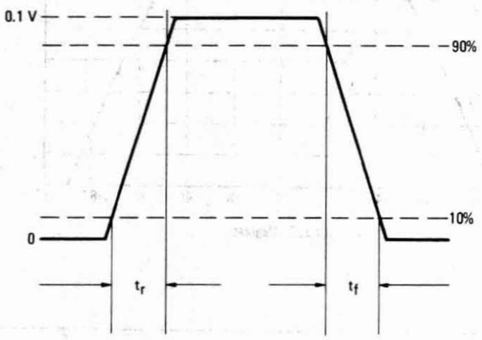


FIGURE 3 – PULSE RESPONSE TEST WAVEFORM



TYPICAL ELECTRICAL CHARACTERISTICS

FIGURE 4 – COLLECTOR-EMITTER CHARACTERISTICS

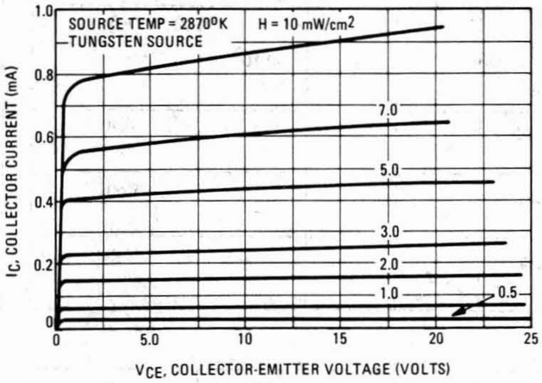


FIGURE 5 – COLLECTOR SATURATION CHARACTERISTICS

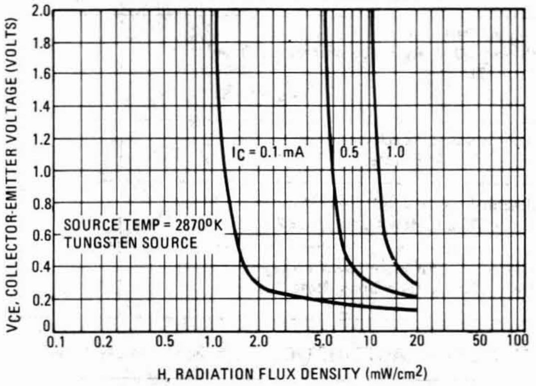


FIGURE 6 – DARK CURRENT versus TEMPERATURE

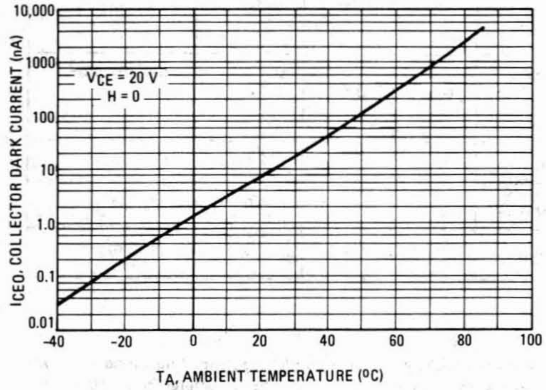


FIGURE 7 – DARK CURRENT versus VOLTAGE

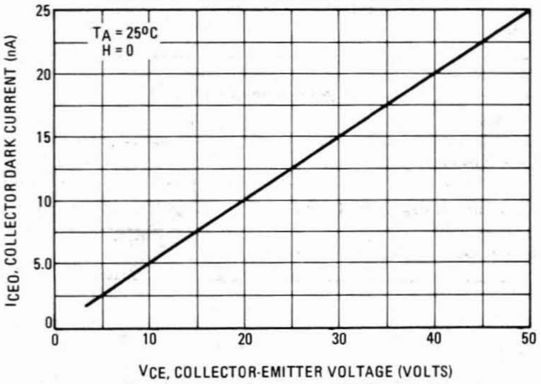


FIGURE 8 – ANGULAR RESPONSE

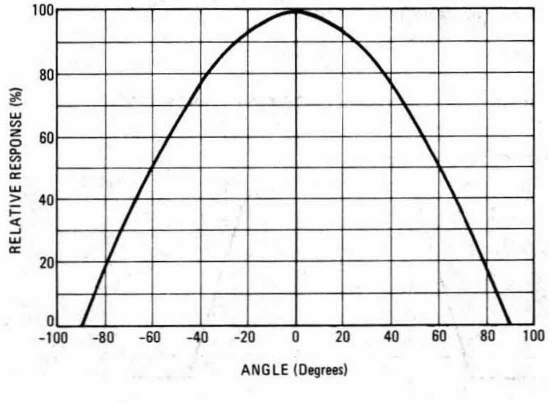
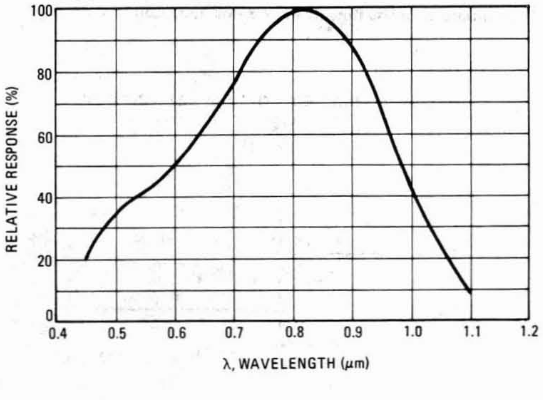


FIGURE 9 – CONSTANT ENERGY SPECTRAL RESPONSE



MRD100 AND MRD150

OPTOELECTRONIC DEFINITIONS, CHARACTERISTICS, AND RATINGS

BV_{CBO}	Collector-Base Breakdown Voltage – The minimum dc breakdown voltage, collector to base, at stated collector current and ambient temperature. (Emitter open and $H \approx 0$)
BV_{CEO}	Collector-Emitter Breakdown Voltage – The minimum dc breakdown voltage, collector to emitter, at stated collector current and ambient temperature. (Base open and $H \approx 0$)
BV_{ECO}	Emitter-Collector Breakdown Voltage – The minimum dc breakdown voltage, emitter to collector, at stated emitter current and ambient temperature. (Base open and $H \approx 0$)
E	Luminous Flux Density (Illuminance) [lumens/ft.^{2} = ft. candles] – The radiation flux density of wavelength within the band of visible light.
H	Radiation Flux Density (Irradiance) [mW/cm^2] – The total incident radiation energy measured in power per unit area.
I_{CEO}	Collector Dark Current – The maximum current through the collector terminal of the device measured under dark conditions, ($H \approx 0$), with a stated collector voltage, load resistance, and ambient temperature. (Base open)
P_D	Power Dissipation
S_{RCBO}	Collector-Base Radiation Sensitivity (μA/mW/cm^2) – The ratio of photo-induced collector-base current to the incident radiant energy measured at the plane of the lens of the photo device under stated conditions of radiation flux density (H), collector voltage, base load resistance, and ambient temperature. (Emitter open)
S_{RCEO}	Collector-Emitter Radiation Sensitivity (mA/mW/cm^2) – The ratio of photo-induced, collector-emitter current to the incident radiant energy measured at the plane of the lens of the photodevice under stated conditions of radiation flux density (H), collector voltage, load resistance, and ambient temperature. (Base open)
T_A	Ambient Temperature
t_f	Photo Current Fall Time – The response time for the photo-induced current to fall from the 90% point to the 10% point after removal of the GaAs (gallium-arsenide) source pulse under stated conditions of collector voltage, load resistance and ambient temperature. (See Note 3 and Figures 2 and 3)
T_J	Junction Temperature
t_r	Photo Current Rise Time – The response time for the photo-induced current to rise from the 10% point to the 90% point when pulsed with the stated GaAs (gallium-arsenide) source under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 3 and Figures 2 and 3)
T_{stg}	Storage Temperature
V_{CBO}	Collector-Base Voltage – The maximum allowable value of the collector-base voltage which can be applied to the device at the rated temperature. (Base open)
V_{CEO}	Collector-Emitter Voltage – The maximum allowable value of collector-emitter voltage which can be applied to the device at the rated temperature. (Base open)
V_{ECO}	Emitter-Collector Voltage – The maximum allowable value of emitter-collector voltage which can be applied to the device at the rated temperature. (Base open)
λ_s(μm)	Wavelength of maximum sensitivity in micrometers.

CUSTOM OPTOELECTRONIC ARRAYS

The MRD100/150 is also available in custom designed arrays or matrices as well as in discrete form.

These arrays can be designed to meet customer requirements for punched card and tape readers, position indicators, pattern and character recognition, shaft encoders, and many other special applications.

The arrays are pre-assembled and tested, ready for installation into the system eliminating the special handling and testing problems associated with the small photo detectors.

The custom arrays can be manufactured in almost any shape to allow maximum design flexibility; they can also be matched for sensitivity to assure more uniform output.

Specifying optoelectronic arrays is easy; all that is required is a print of the array and the desired specifications; or your representative will assist in developing specifications for your special applications.

MRD200 (SILICON)

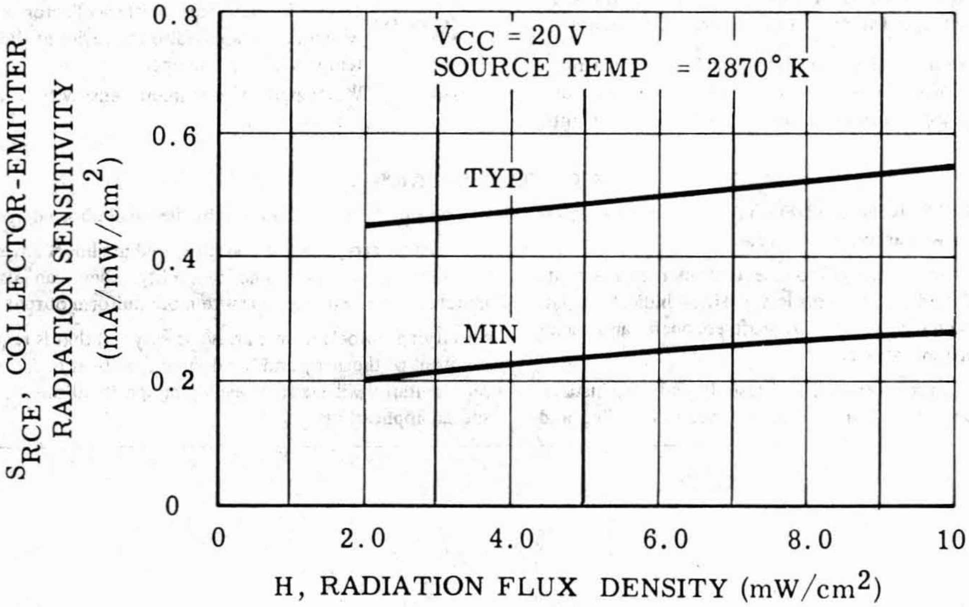
CASE 81
(DO-31)

NPN silicon high sensitivity photo detector designed for application in card and tape readers, pattern and character recognition, and shaft encoders, or any design requiring high radiation sensitivity, stable characteristics, and high-density mounting.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating (NOTE 1)	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Volts
Emitter-Collector Voltage	V_{ECO}	7.0	Volts
Total Device Dissipation @ $T_A = 25°C$	P_D	50	mW
Derate above 25°C		0.5	mW/°C
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

FIGURE 1 – COLLECTOR-EMITTER SENSITIVITY



STATIC ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristics (NOTE 1)	Fig. No.	Symbol	Min	Typ	Max	Units
Collector Dark Current (V_{CC} = 20 V; R_L = 100 ohms) (Note 3) $T_A = 25^oC$ $T_A = 100^oC$	—	I_{CEO}	— —	— 10	0.025 —	μA
Collector-Emitter Breakdown Voltage (I_C = 100 μA) (Note 3)	—	BV_{CEO}	50	—	—	Volts
Emitter-Collector Breakdown Voltage (I_E = 100 μA) (Note 3)	—	BV_{ECO}	7.0	—	—	Volts

OPTICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristics (NOTE 1)	Fig. No.	Symbol	Min	Typ	Max	Units
Collector-Emitter Radiation Sensitivity (V_{CC} = 20 V; R_L = 100 ohms)(Note 2)	1	S_{RCE}	0.25	0.5	—	$mA/mW/cm^2$
Collector-Emitter Illumination Sensitivity (V_{CC} = 20 V; R_L = 100 ohms)(Note 4)	—	S_{ICE}	2.0	5.0		$\mu A/lum/ft^2$
Photo Current Saturated Rise Time (Note 5)	4	$t_{r(sat)}$	—	1.0	—	μs
Photo Current Saturated Fall Time (Note 5)	4	$t_{f(sat)}$	—	10	—	μs
Photo Current Rise Time (Note 6)	4	t_r	—	—	2.5	μs
Photo Current Fall Time (Note 6)	4	t_f	—	—	4.0	μs
Wavelength of Maximum Sensitivity	—	λS(typ)	—	0.8	—	Microns

NOTES:

1. No base terminal available.
2. Radiation flux density (H) equal to 5.0 mW/cm^2 emitted from a tungsten source at a color temperature of 2870^oK.
3. Measured under dark conditions. ($H \approx 0$)
4. Luminous flux density (E) equal to 100 $lumens/ft^2$. (100 ft. -candles) measured through two Corning CS1-69 filters.
5. For saturated rise time measurements, radiation is provided by a pulsed xenon arc lamp with a pulse width of approximately 1.0 microsecond (see Figure 4).
6. For unsaturated rise time measurements, radiation is provided by a pulsed GaAs (gallium-arsenide) light-emitting diode ($\lambda \approx 0.9$ microns) with a pulse width equal or greater than 10 microseconds (see Figure 4).

TYPICAL ELECTRICAL CHARACTERISTICS

FIGURE 2 — COLLECTOR-EMITTER CHARACTERISTICS

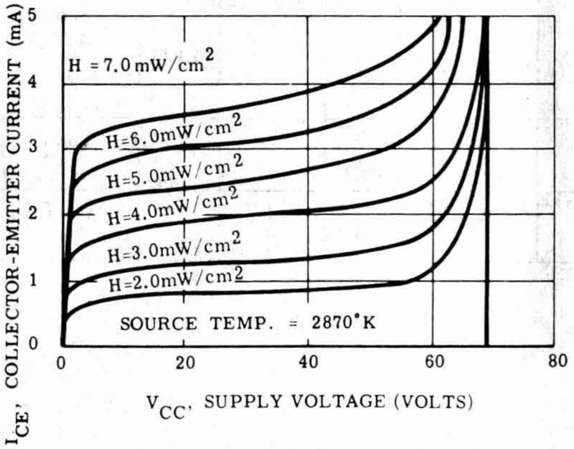


FIGURE 3 — PHOTO CURRENT vs TEMPERATURE

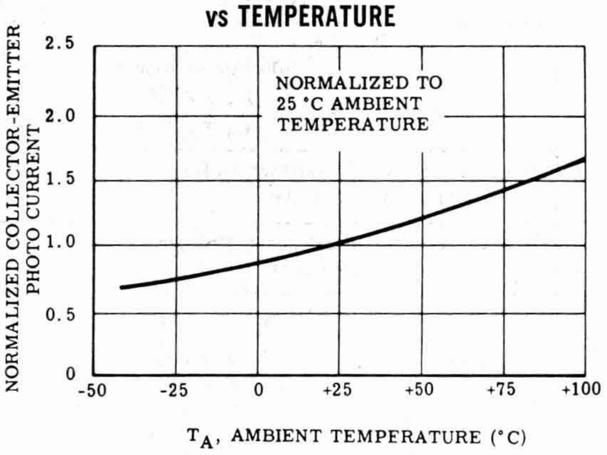
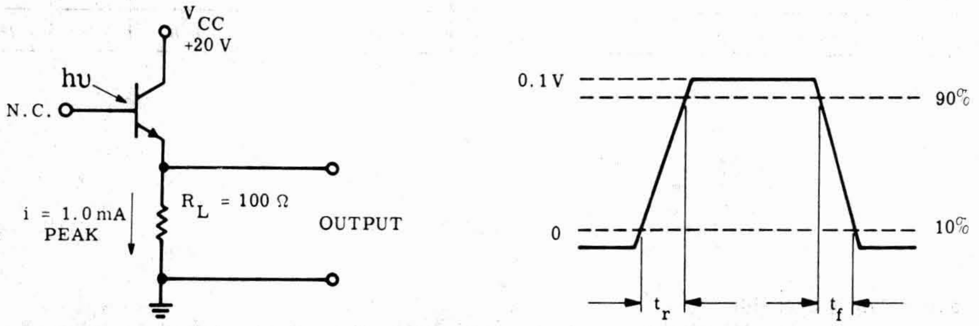


FIGURE 4 — PULSE RESPONSE TEST CIRCUIT



V_{CC}
+20 V
hυ
N.C.
i = 1.0 mA
PEAK
R_L = 100 Ω
OUTPUT
0.1 V
90%
0
10%
t_r
t_f

TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

MRD210 (SILICON)

CASE 81
(DO-31)

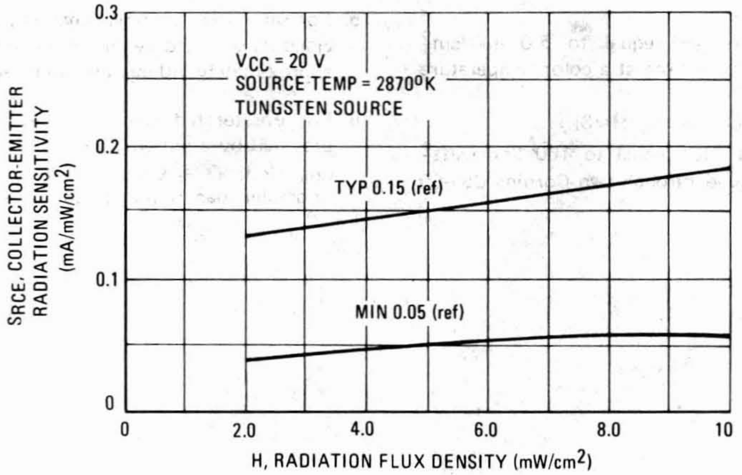
Actual Size

NPN silicon photo detector designed for application in card and tape readers, pattern and character recognition, and shaft encoders, or any design requiring radiation sensitivity, stable characteristics, and high-density mounting.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating (Note 1)	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Volts
Emitter-Collector Voltage	V_{ECO}	7.0	Volts
Total Device Dissipation @ T_A = 25°C	P_D	50	mW
Derate above 25°C		0.5	mW/°C
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

FIGURE 1 – COLLECTOR-EMITTER SENSITIVITY



STATIC ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic (Note 1)	Symbol	Min	Typ	Max	Unit
Collector Dark Current (V_{CC} = 20 V, R_L = 100 ohms, Note 3)	I_{CEO}				μA
T_A = 25°C		-	-	0.025	
T_A = 100°C		-	10	-	
Collector-Emitter Breakdown Voltage (I_C = 100 μA)	BV_{CEO}	50	-	-	Volts
Emitter-Collector Breakdown Voltage (I_E = 100 μA)	BV_{ECO}	7.0	-	-	Volts

OPTICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic (Note 1)	Fig. No.	Symbol	Min	Typ	Max	Unit
Collector-Emitter Radiation Sensitivity (V_{CC} = 20 V, R_L = 100 ohms, Note 2)	1	S_{RCE}	0.05	0.15	-	mA/mW/cm^2
Collector-Emitter Illumination Sensitivity (V_{CC} = 20 V, R_L = 100 ohms, Note 4)	-	S_{ICE}	0.4	1.2	-	μA/lum/ft^2
Photo Current Saturated Rise Time (Note 5)	4	$t_{r(sat)}$	-	1.0	-	μs
Photo Current Saturated Fall Time (Note 5)	4	$t_{f(sat)}$	-	10	-	μs
Photo Current Rise Time (Note 6)	4	t_r	-	-	2.5	μs
Photo Current Fall Time (Note 6)	4	t_f	-	-	4.0	μs
Wavelength of Maximum Sensitivity	-	λ_s	-	0.8	-	μm

NOTES:

1. No base terminal available.
2. Radiation flux density (H) equal to 5.0 mW/cm^2 emitted from a tungsten source at a color temperature of 2870°K.
3. Measured under dark conditions. (H≈0).
4. Luminous flux density (E) equal to 100 lumens/ft^2 (100 ft-candles) measured through two Corning CS1-69 filters.
5. For saturated rise time measurements, radiation is provided by a pulsed xenon arc lamp with a pulse width of approximately 1.0 microsecond (see Figure 4).
6. For unsaturated rise time measurements, radiation is provided by a pulsed GaAs (gallium-arsenide) light-emitting diode ($\lambda \approx 0.9\ \mu$m) with a pulse width equal to or greater than 10 microseconds (see Figure 4).

TYPICAL ELECTRICAL CHARACTERISTICS

FIGURE 2 – COLLECTOR-EMITTER CHARACTERISTICS

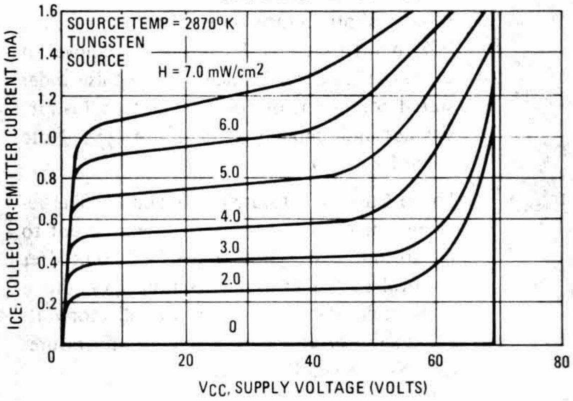


FIGURE 3 – PHOTO CURRENT versus TEMPERATURE

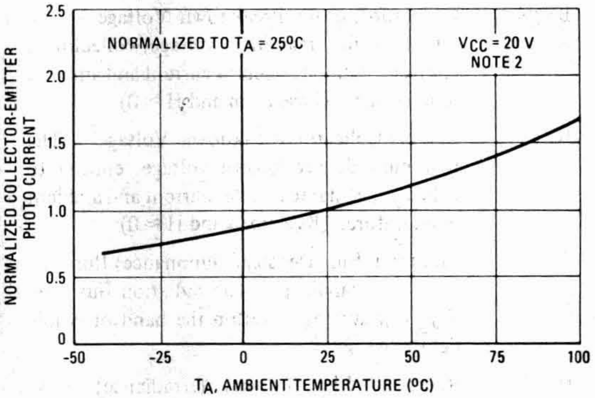
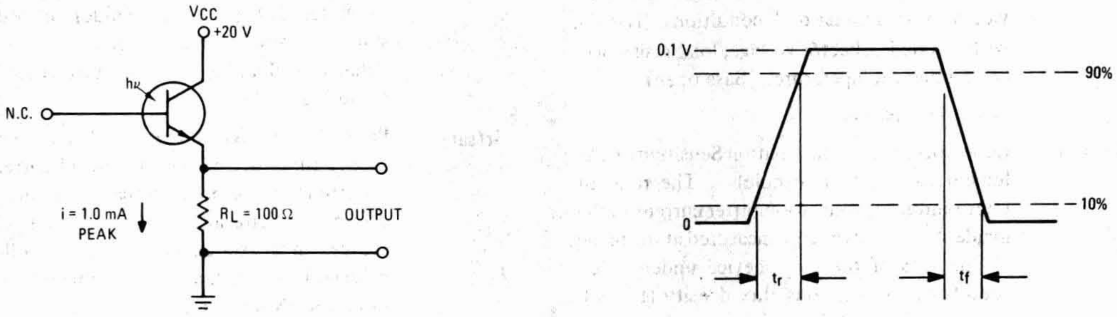


FIGURE 4 – PULSE RESPONSE TEST CIRCUIT AND WAVEFORM



CUSTOM OPTOELECTRONIC ARRAYS

The MRD 210 is also available in custom designed arrays or matrices as well as in discrete form.

These arrays can be designed to meet customer requirements for punched card and tape readers, position indicators, pattern and character recognition, shaft encoders, and many other special applications.

The arrays are pre-assembled and tested, ready for installation into the system eliminating the special handling and testing problems associated with the small photo detectors.

The custom arrays can be manufactured in almost any shape to allow maximum design flexibility; they can also be matched for sensitivity to assure more uniform output.

Specifying optoelectronic arrays is easy; all that is required is a print of the array and the desired specifications; or our representative will assist in developing specifications for your special application.

MRD210

OPTOELECTRONIC DEFINITIONS, CHARACTERISTICS, AND RATINGS

BV_{CEO}	Collector-Emitter Breakdown Voltage – The minimum dc breakdown voltage, collector to emitter, at stated collector current and ambient temperature. (Base open and $H \approx 0$)
BV_{ECO}	Emitter-Collector Breakdown Voltage – The minimum dc breakdown voltage, emitter to collector, at stated emitter current and ambient temperature. (Base open and $H \approx 0$)
E	Luminous Flux Density (Illuminance) [lumens/ft.^{2} = ft. candles] – The radiation flux density of wavelength within the band of visible light.
H	Radiation Flux Density (Irradiance) [mW/cm^2] – The total incident radiation energy measured in power per unit area.
I_{CEO}	Collector Dark Current – The maximum current through the collector terminal of the device measured under dark conditions, ($H \approx 0$), with a stated collector voltage, load resistance, and ambient temperature. (Base open)
P_D	Power Dissipation
S_{ICEO}	Collector-Emitter Illumination Sensitivity (μA/lumen/ft.^{2} = μA/ft. candle) – The ratio of photo-induced, collector-emitter current to the incident luminous energy measured at the plane of the lens of the photodevice under stated conditions of luminous flux density (E), collector voltage, load resistance, and ambient temperature. (Base open)
S_{RCEO}	Collector-Emitter Radiation Sensitivity (mA/mW/cm^2) – The ratio of photo-induced, collector-emitter current to the incident radiant energy measured at the plane of the lens of the photodevice under stated conditions of radiation flux density (H), collector voltage, load resistance, and ambient temperature. (Base open)
T_A	Ambient Temperature
t_f	Photo Current Fall Time – The response time for the photo-induced current to fall from the 90% point to the 10% point after removal of the GaAs (gallium-arsenide) source pulse under stated conditions of collector voltage, load resistance and ambient temperature. (See Note 6 and Figure 4)
$t_{f(sat)}$	Photo Current Saturated Fall Time – The response time for the photo-induced current to fall from the 90% point to the 10% point after removal of the saturating xenon light source pulse under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 5 and Figure 4)
T_J	Junction Temperature
t_r	Photo Current Rise Time – The response time for the photo-induced current to rise from the 10% point to the 90% point when pulsed with the stated GaAs (gallium-arsenide) source under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 6 and Figure 4)
$t_{r(sat)}$	Photo Current Saturated Rise Time – The response time for the photo-induced current to rise from the 10% point to the 90% point when driven into saturation by the stated xenon source under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 5 and Figure 4)
T_{stg}	Storage Temperature
V_{CEO}	Collector-Emitter Voltage – The maximum allowable value of collector-emitter voltage which can be applied to the device at the rated temperature. (Base open)
V_{ECO}	Emitter-Collector Voltage – The maximum allowable value of emitter-collector voltage which can be applied to the device at the rated temperature. (Base open)
$\lambda_s(\mu m)$	Wavelength of maximum sensitivity in micro meters.

MRD250 (SILICON)

CASE 81A-01

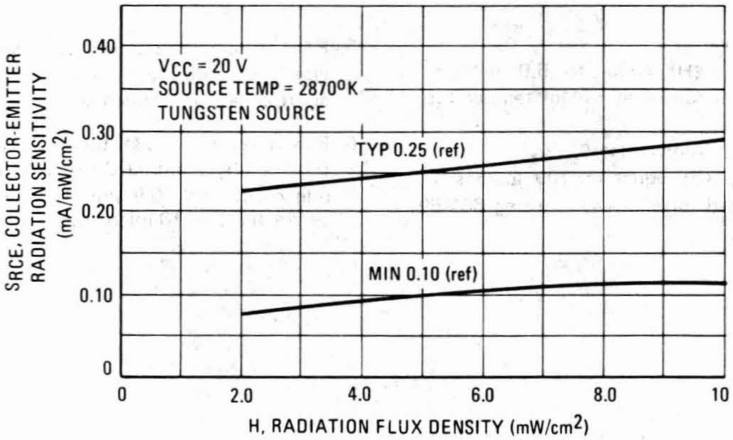
Actual Size

NPN silicon photo detector designed for application in card and tape readers, pattern and character recognition, and shaft encoders, or any design requiring radiation sensitivity, stable characteristics, and high-density mounting.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating (Note 1)	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Volts
Emitter-Collector Voltage	V_{ECO}	7.0	Volts
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	50 0.5	mW mW/°C
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

FIGURE 1 — COLLECTOR-EMITTER SENSITIVITY



STATIC ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic (Note 1)	Symbol	Min	Typ	Max	Unit
Collector Dark Current (V_{CC} = 20 V, R_L = 100 ohms, Note 3)	I_{CEO}				μA
T_A = 25°C		-	-	0.025	
T_A = 100°C		-	10	-	
Collector-Emitter Breakdown Voltage (I_C = 100 μA)	BV_{CEO}	50	-	-	Volts
Emitter-Collector Breakdown Voltage (I_E = 100 μA)	BV_{ECO}	7.0	-	-	Volts

OPTICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic (Note 1)	Fig. No.	Symbol	Min	Typ	Max	Unit
Collector-Emitter Radiation Sensitivity (V_{CC} = 20 V, R_L = 100 ohms, Note 2)	1	S_{RCE}	0.10	0.25	-	mA/mW/cm^2
Collector-Emitter Illumination Sensitivity (V_{CC} = 20 V, R_L = 100 ohms, Note 4)	-	S_{ICE}	0.8	2.5	-	μA/lum/ft^2
Photo Current Saturated Rise Time (Note 5)	4	$t_{r(sat)}$	-	1.0	-	μs
Photo Current Saturated Fall Time (Note 5)	4	$t_{f(sat)}$	-	10	-	μs
Photo Current Rise Time (Note 6)	4	t_r	-	-	2.5	μs
Photo Current Fall Time (Note 6)	4	t_f	-	-	4.0	μs
Wavelength of Maximum Sensitivity	-	λ_s	-	0.8	-	μm

NOTES:

1. No base terminal available.
2. Radiation flux density (H) equal to 5.0 mW/cm^2 emitted from a tungsten source at a color temperature of 2870°K.
3. Measured under dark conditions. (H≈0).
4. Luminous flux density (E) equal to 100 lumens/ft^2 (100 ft-candles) measured through two Corning CS1-69 filters.
5. For saturated rise time measurements, radiation is provided by a pulsed xenon arc lamp with a pulse width of approximately 1.0 microsecond (see Figure 4).
6. For unsaturated rise time measurements, radiation is provided by a pulsed GaAs (gallium-arsenide) light-emitting diode (λ ≈ 0.9 μm) with a pulse width equal to or greater than 10 microseconds (see Figure 4).

TYPICAL ELECTRICAL CHARACTERISTICS

FIGURE 2 – COLLECTOR-EMITTER CHARACTERISTICS

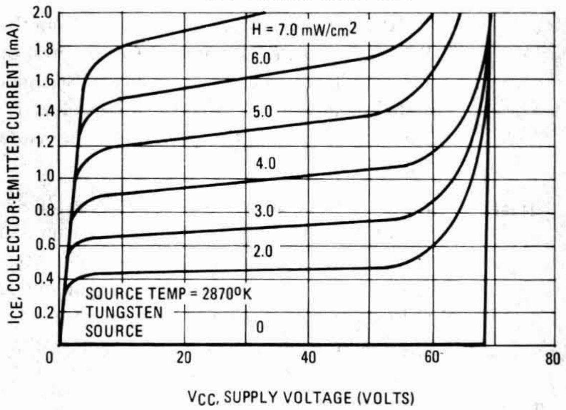


FIGURE 3 – PHOTO CURRENT versus TEMPERATURE

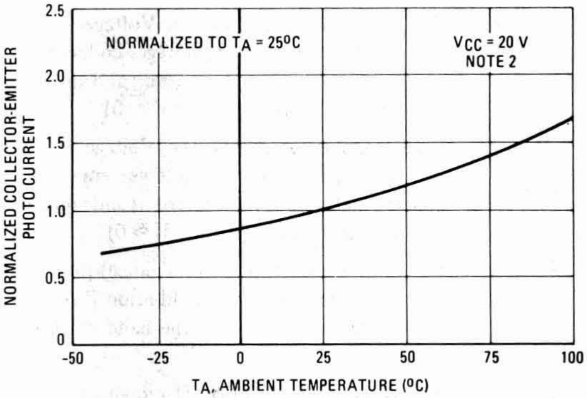
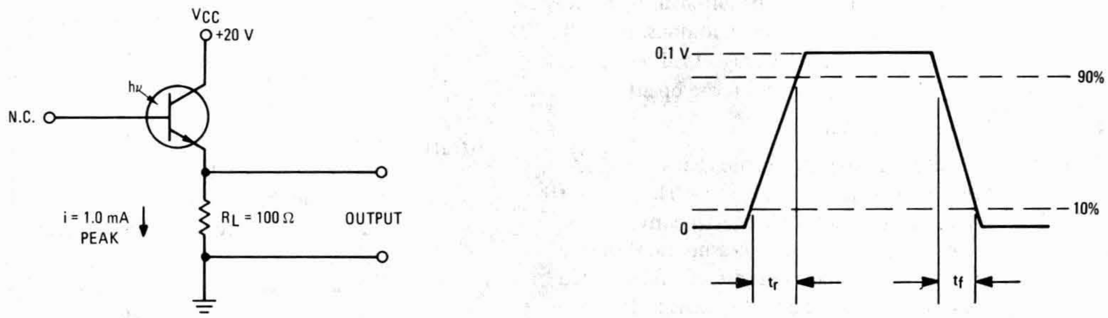


FIGURE 4 – PULSE RESPONSE TEST CIRCUIT AND WAVEFORM



CUSTOM OPTOELECTRONIC ARRAYS

The MRD 250 is also available in custom designed arrays or matrices as well as in discrete form.

These arrays can be designed to meet customer requirements for punched card and tape readers, position indicators, pattern and character recognition, shaft encoders, and many other special applications.

The arrays are pre-assembled and tested, ready for installation into the system eliminating the special handling and testing problems associated with the small photo detectors.

The custom arrays can be manufactured in almost any shape to allow maximum design flexibility; they can also be matched for sensitivity to assure more uniform output.

Specifying optoelectronic arrays is easy; all that is required is a print of the array and the desired specifications; or our representative will assist in developing specifications for your special application.

MRD250

OPTOELECTRONIC DEFINITIONS, CHARACTERISTICS, AND RATINGS

BV_{CEO}	Collector-Emitter Breakdown Voltage – The minimum dc breakdown voltage, collector to emitter, at stated collector current and ambient temperature. **(Base open and H ≈ 0)**
BV_{ECO}	Emitter-Collector Breakdown Voltage – The minimum dc breakdown voltage, emitter to collector, at stated emitter current and ambient temperature. **(Base open and H ≈ 0)**
E	Luminous Flux Density (Illuminance) [lumens/ft.^{2} = ft. candles] – The radiation flux density of wavelength within the band of visible light.
H	Radiation Flux Density (Irradiance) [mW/cm^2] – The total incident radiation energy measured in power per unit area.
I_{CEO}	Collector Dark Current – The maximum current through the collector terminal of the device measured under dark conditions, (H ≈ 0), with a stated collector voltage, load resistance, and ambient temperature. (Base open)
P_D	Power Dissipation
S_{ICEO}	Collector-Emitter Illumination Sensitivity (μA/lumen/ft.^{2} = μA/ft. candle) – The ratio of photo-induced, collector-emitter current to the incident luminous energy measured at the plane of the lens of the photodevice under stated conditions of luminous flux density (E), collector voltage, load resistance, and ambient temperature. (Base open)
S_{RCEO}	Collector-Emitter Radiation Sensitivity (mA/mW/cm^2) – The ratio of photo-induced, collector-emitter current to the incident radiant energy measured at the plane of the lens of the photodevice under stated conditions of radiation flux density (H), collector voltage, load resistance, and ambient temperature. (Base open)
T_A	Ambient Temperature
t_f	Photo Current Fall Time – The response time for the photo-induced current to fall from the 90% point to the 10% point after removal of the GaAs (gallium-arsenide) source pulse under stated conditions of collector voltage, load resistance and ambient temperature. (See Note 6 and Figure 4)
$t_{f(sat)}$	Photo Current Saturated Fall Time – The response time for the photo-induced current to fall from the 90% point to the 10% point after removal of the saturating xenon light source pulse under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 5 and Figure 4)
T_J	Junction Temperature
t_r	Photo Current Rise Time – The response time for the photo-induced current to rise from the 10% point to the 90% point when pulsed with the stated GaAs (gallium-arsenide) source under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 6 and Figure 4)
$t_{r(sat)}$	Photo Current Saturated Rise Time – The response time for the photo-induced current to rise from the 10% point to the 90% point when driven into saturation by the stated xenon source under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 5 and Figure 4)
T_{stg}	Storage Temperature
V_{CEO}	Collector-Emitter Voltage – The maximum allowable value of collector-emitter voltage which can be applied to the device at the rated temperature. (Base open)
V_{ECO}	Emitter-Collector Voltage – The maximum allowable value of emitter-collector voltage which can be applied to the device at the rated temperature. (Base open)
$\lambda_s(\mu m)$	Wavelength of maximum sensitivity in micro meters.

MRD300 (SILICON)

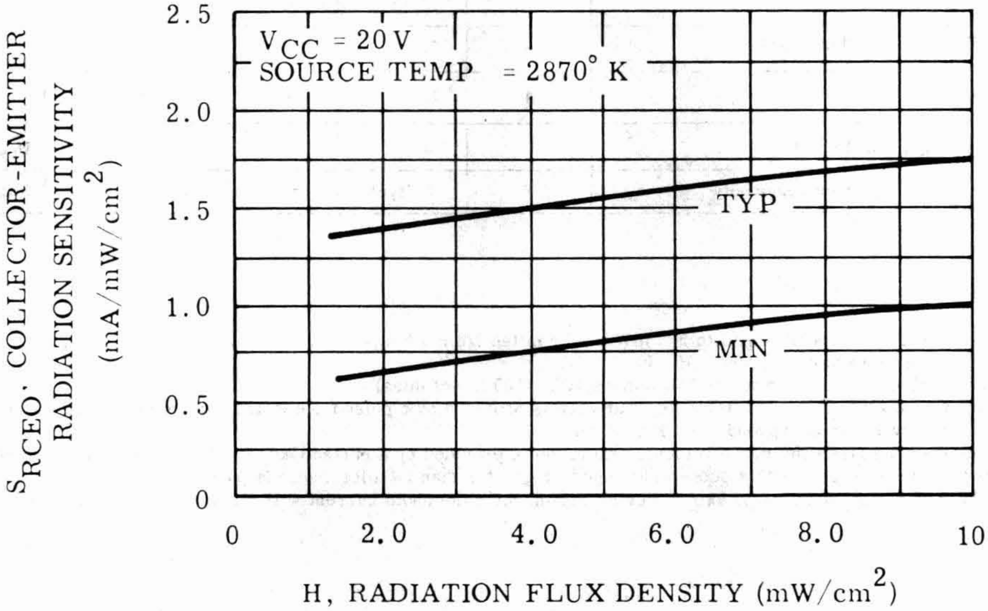
CASE 82

NPN silicon high sensitivity photo transistor designed for application in industrial inspection, processing and control, counters, sorters, switching and logic circuits or any design requiring high radiation sensitivity, and stable characteristics.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating (NOTE 2)	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Volts
Emitter-Collector Voltage	V_{ECO}	7.0	Volts
Collector-Base Voltage	V_{CB}	80	Volts
Total Device Dissipation @ T_A = 25 °C Derate above 25 °C	P_D	0.25 1.43	Watt mW/ °C
Operating Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +200	°C

FIGURE 1 — COLLECTOR-EMITTER SENSITIVITY



MRD300 (continued)

STATIC ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Units
Collector Dark Current (V_{CC} = 20 V; R_L = 100 ohms; Base Open) (Note 2) T_A = 25°C	—	I_{CEO}	—	—	0.025	μA
T_A = 100°C			—	10	—	
Collector-Base Breakdown Voltage (I_C = 100 μA; Emitter Open) (Note 2)	—	BV_{CBO}	80	—	—	Volts
Collector-Emitter Breakdown Voltage (I_C = 100 μA; Base Open) (Note 2)	—	BV_{CEO}	50	—	—	Volts
Emitter-Collector Breakdown Voltage (I_E = 100 μA; Base Open) (Note 2)	—	BV_{ECO}	7.0	—	—	Volts

OPTICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Units
Collector-Emitter Radiation Sensitivity (V_{CC} = 20V; R_L = 100 ohms; Base Open) (Note 1)	—	S_{RCEO}	0.8	1.6	—	mA/mW/cm^2
Collector-Base Radiation Sensitivity (V_{CC} = 20V; R_L = 100 ohms; Emitter Open) (Note 1)	—	S_{RCBO}	1.4	—	—	μA/mW/cm^2
Collector-Emitter Illumination Sensitivity (V_{CC} = 20V; R_L = 100 ohms; Base Open) (Note 3)	—	S_{ICEO}	4.0	10	—	μA/lum/ft^2
Collector-Base Illumination Sensitivity (V_{CC} = 20V; R_L = 100 ohms; Emitter Open) (Note 3)	—	S_{ICBO}	0.01	—	—	μA/lum/ft^2
Photo Current Saturated Rise Time (Note 4)	4	$t_{r(sat)}$	—	1.0	—	μs
Photo Current Saturated Fall Time (Note 4)	4	$t_{f(sat)}$	—	10	—	μs
Photo Current Rise Time (Note 5)	4	t_r	—	—	2.5	μs
Photo Current Fall Time (Note 5)	4	t_f	—	—	4.0	μs
Angular Alignment (Note 6)	6	θ	—	—	10	Degrees
Wavelength of Maximum Sensitivity	—	λS(typ)	—	0.8	—	Microns

NOTES:

1. Radiation Flux Density (H) equal to 5.0 mW/cm^2 emitted from a tungsten source at a color temperature of 2870°K.
2. Measured under dark conditions. (H ≈ 0)
3. Luminous flux density (E) equal to 100 lumens/ft^2. (100 ft.-candles)
4. For saturated rise time measurements, radiation is provided by a pulsed xenon arc lamp with a pulse width of approximately 1.0 microsecond (see Figure 4).
5. For unsaturated rise time measurements, radiation is provided by a pulsed GaAs (gallium-arsenide) light-emitting diode (λ ≃ 0.9 microns) with a pulse width equal or greater than 10 microseconds (see Figure 4).
6. Angular deviation from central axis of device within which the photo current will reach a maximum value.

TYPICAL ELECTRICAL CHARACTERISTICS

FIGURE 2 — COLLECTOR-EMITTER CHARACTERISTICS

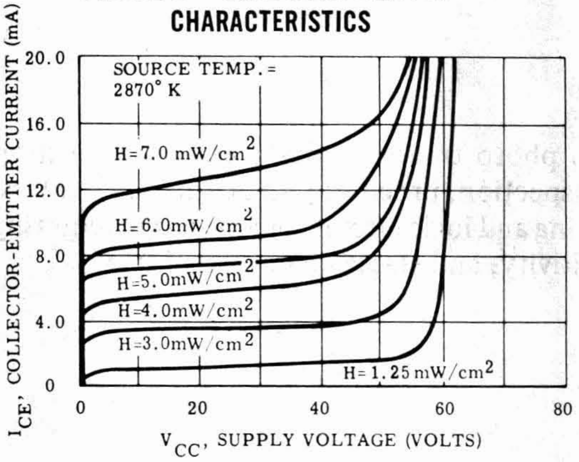


FIGURE 3 — PHOTO CURRENT vs TEMPERATURE

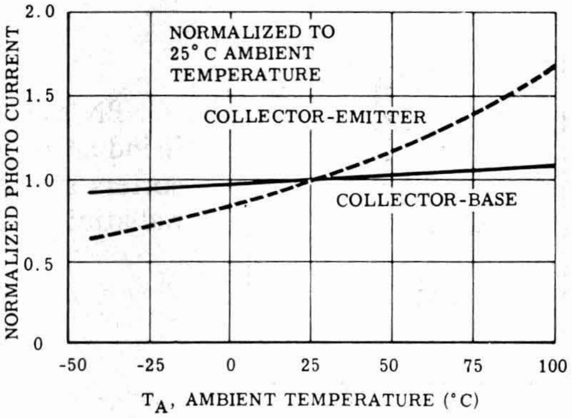
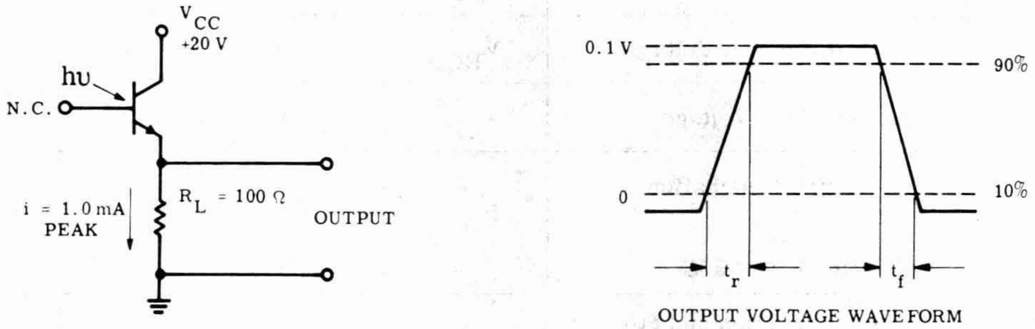


FIGURE 4 — PULSE RESPONSE TEST CIRCUIT


V_CC
+20 V
hυ
N.C.
i = 1.0 mA PEAK
R_L = 100 Ω
OUTPUT
0.1 V
0
90%
10%
t_r
t_f

TEST CIRCUIT

OUTPUT VOLTAGE WAVEFORM

FIGURE 5 — BASE CURRENT vs RADIATION EQUIVALENT

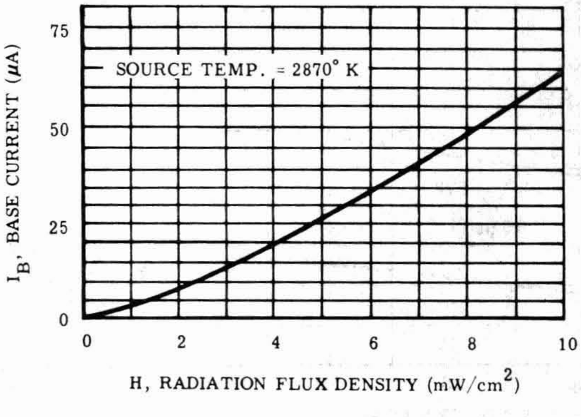
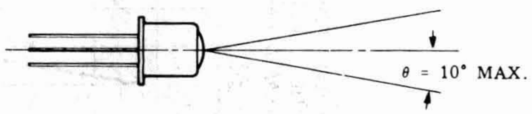


FIGURE 6 — ANGULAR ALIGNMENT



MRD310 (SILICON)

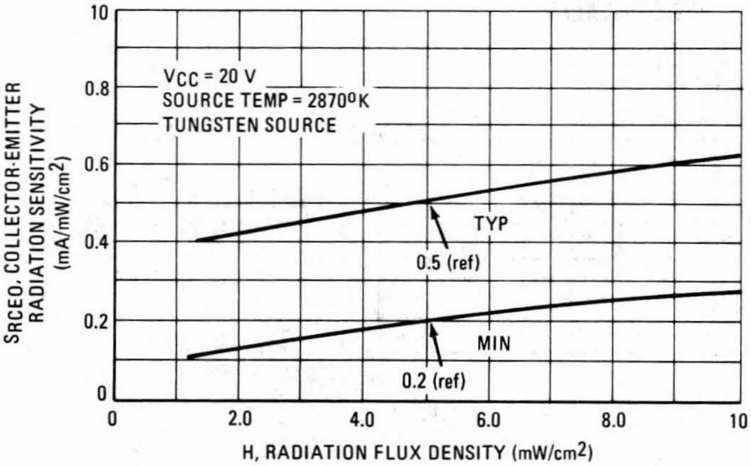
CASE 82

NPN silicon photo transistor designed for application in industrial inspection, processing and control, counters, sorters, switching and logic circuits or any design requiring radiation sensitivity, and stable characteristics.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating (Note 1)	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Volts
Emitter-Collector Voltage	V_{ECO}	7.0	Volts
Collector-Base Voltage	V_{CB}	80	Volts
Total Device Dissipation @ T_A = 25 °C Derate above 25 °C	P_D	250 1.43	mW mW/°C
Operating Junction and Storage Temperature Range	T_J, T_{stg}	-65 to +200	°C

FIGURE 1 — COLLECTOR-EMITTER SENSITIVITY



STATIC ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector Dark Current (V_{CC} = 20 V, R_L = 100 ohms, Note 2) T_A = 25°C T_A = 100°C	I_{CEO}	 - -	 - 10	 0.025 -	μA
Collector-Base Breakdown Voltage (I_C = 100 μA)	BV_{CBO}	80	-	-	Volts
Collector-Emitter Breakdown Voltage (I_C = 100 μA)	BV_{CEO}	50	-	-	Volts
Emitter-Collector Breakdown Voltage (I_E = 100 μA)	BV_{ECO}	7.0	-	-	Volts

OPTICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit
Collector-Emitter Radiation Sensitivity (V_{CC} = 20 V, R_L = 100 ohms, Note 1)	1	S_{RCEO}	0.2	0.5	-	mA/mW/cm^2
Collector-Base Radiation Sensitivity (V_{CC} = 20 V, R_L = 100 ohms, Note 1)	-	S_{RCBO}	1.4	-	-	μA/mW/cm^2
Collector-Emitter Illumination Sensitivity (V_{CC} = 20 V, R_L = 100 ohms, Note 3)	-	S_{ICEO}	1.0	2.5	-	μA/lum/ft^2
Collector-Base Illumination Sensitivity (V_{CC} = 20 V, R_L = 100 ohms, Note 3)	-	S_{ICBO}	0.01	-	-	μA/lum/ft^2
Photo Current Saturated Rise Time (Note 4)	4	$t_{r(sat)}$	-	1.0	-	μs
Photo Current Saturated Fall Time (Note 4)	4	$t_{f(sat)}$	-	10	-	μs
Photo Current Rise Time (Note 5)	4	t_r	-	-	2.5	μs
Photo Current Fall Time (Note 5)	4	t_f	-	-	4.0	μs
Angular Alignment (Note 6)	6	θ	-	-	10	Degrees
Wavelength of Maximum Sensitivity	-	λ_s	-	0.8	-	μm

NOTES:

1. Radiation flux density (H) equal to 5.0 mW/cm^2 emitted from a tungsten source at a color temperature of 2870°K.
2. Measured under dark conditions. (H≈0).
3. Luminous flux density (E) equal to 100 lumens/ft^2 (100 ft-candles) measured through two Corning CS1-69 filters.
4. For saturated rise time measurements, radiation is provided by a pulsed xenon arc lamp with a pulse width of approximately 1.0 microsecond (see Figure 4).
5. For unsaturated rise time measurements, radiation is provided by a pulsed GaAs (gallium-arsenide) light-emitting diode (λ≈0.9 μm) with a pulse width equal to or greater than 10 microseconds (see Figure 4).
6. The axis of maximum sensitivity shall be within a 10° cone with reference to the central axis of the device. The photo-induced current will reach a maximum within this cone.

TYPICAL ELECTRICAL CHARACTERISTICS

FIGURE 2 – COLLECTOR-EMITTER CHARACTERISTICS

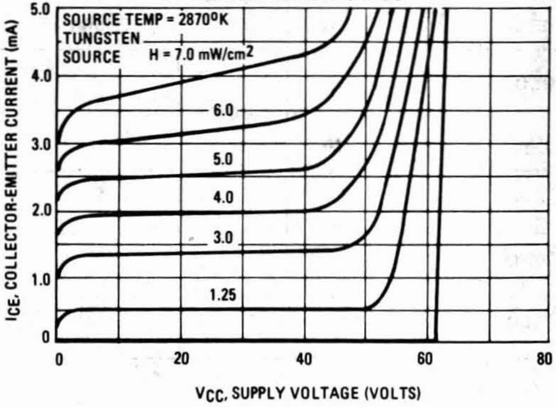


FIGURE 3 – PHOTO CURRENT versus TEMPERATURE

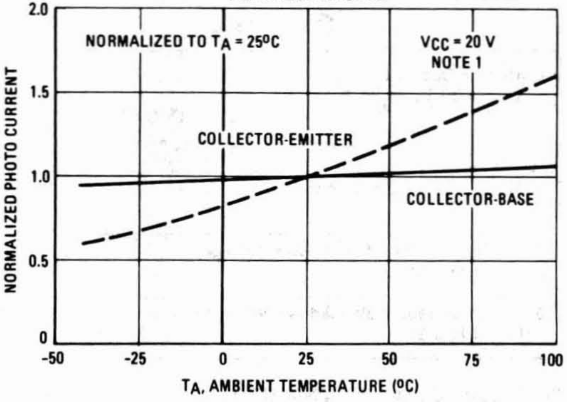


FIGURE 4 – PULSE RESPONSE TEST CIRCUIT AND WAVEFORM

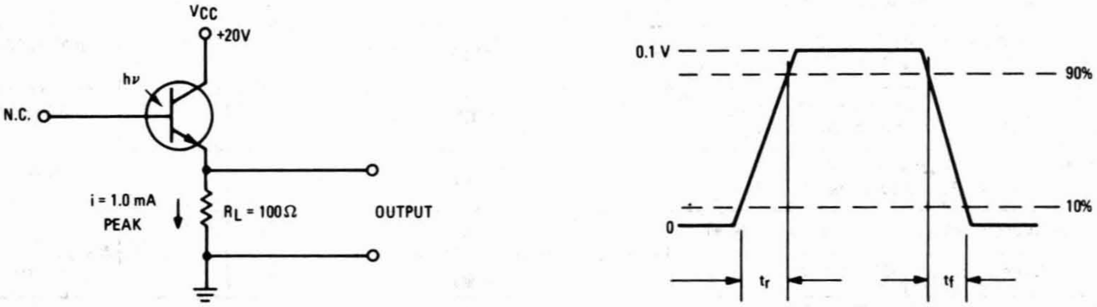

V_{CC}
+20V
hν
N.C.
i = 1.0 mA PEAK
R_L = 100Ω
OUTPUT
0.1 V
90%
10%
0
t_r
t_f

FIGURE 5 – BASE CURRENT versus RADIATION EQUIVALENCE

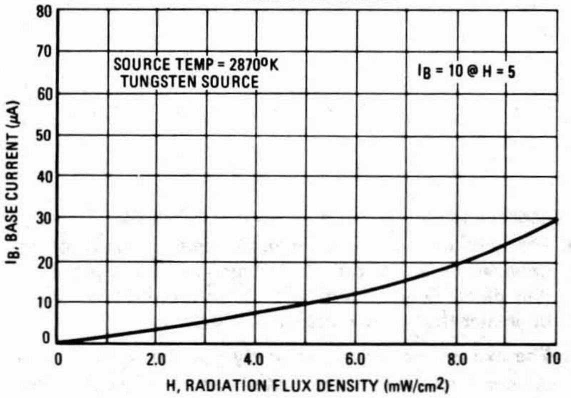
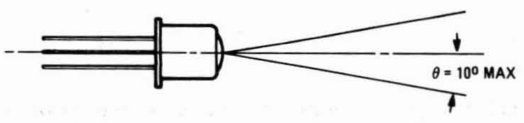


FIGURE 6 – ANGULAR ALIGNMENT



MRD310

OPTOELECTRONIC DEFINITIONS, CHARACTERISTICS, AND RATINGS

BV_{CBO}	Collector-Base Breakdown Voltage – The minimum dc breakdown voltage, collector to base, at stated collector current and ambient temperature. (Emitter open and $H \approx 0$)
BV_{CEO}	Collector-Emitter Breakdown Voltage – The minimum dc breakdown voltage, collector to emitter, at stated collector current and ambient temperature. (Base open and $H \approx 0$)
BV_{ECO}	Emitter-Collector Breakdown Voltage – The minimum dc breakdown voltage, emitter to collector, at stated emitter current and ambient temperature. (Base open and $H \approx 0$)
E	Luminous Flux Density (Illuminance) [lumens/ft.^{2} = ft. candles] – The radiation flux density of wavelength within the band of visible light.
H	Radiation Flux Density (Irradiance) [mW/cm^2] – The total incident radiation energy measured in power per unit area.
I_{CEO}	Collector Dark Current – The maximum current through the collector terminal of the device measured under dark conditions, ($H \approx 0$), with a stated collector voltage, load resistance, and ambient temperature. (Base open)
P_D	Power Dissipation
S_{ICBO}	Collector-Base Illumination Sensitivity (μA/lumen/ft.^{2} = μA/ft. candle) – The ratio of photo-induced collector-base current to the incident luminous energy measured at the plane of the lens of the photo device under stated conditions of luminous flux density (E), collector voltage, base load resistance, and ambient temperature. (Emitter open)
S_{ICEO}	Collector-Emitter Illumination Sensitivity (μA/lumen/ft.^{2} = μA/ft. candle) – The ratio of photo-induced, collector-emitter current to the incident luminous energy measured at the plane of the lens of the photodevice under stated conditions of luminous flux density (E), collector voltage, load resistance, and ambient temperature. (Base open)
S_{RCBO}	Collector-Base Radiation Sensitivity (μA/mW/cm^2) – The ratio of photo-induced collector-base current to the incident radiant energy measured at the plane of the lens of the photo device under stated conditions of radiation flux density (H), collector voltage, base load resistance, and ambient temperature. (Emitter open)
S_{RCEO}	Collector-Emitter Radiation Sensitivity (mA/mW/cm^2) – The ratio of photo-induced, collector-emitter current to the incident radiant energy measured at the plane of the lens of the photodevice under stated conditions of radiation flux density (H), collector voltage, load resistance, and ambient temperature. (Base open)
T_A	Ambient Temperature
t_f	Photo Current Fall Time – The response time for the photo-induced current to fall from the 90% point to the 10% point after removal of the GaAs (gallium-arsenide) source pulse under stated conditions of collector voltage, load resistance and ambient temperature. (See Note 5 and Figure 4)
$t_{f(sat)}$	Photo Current Saturated Fall Time – The response time for the photo-induced current to fall from the 90% point to the 10% point after removal of the saturating xenon light source pulse under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 4 and Figure 4)
T_J	Junction Temperature
t_r	Photo Current Rise Time – The response time for the photo-induced current to rise from the 10% point to the 90% point when pulsed with the stated GaAs (gallium-arsenide) source under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 5 and Figure 4)
$t_{r(sat)}$	Photo Current Saturated Rise Time – The response time for the photo-induced current to rise from the 10% point to the 90% point when driven into saturation by the stated xenon source under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 4 and Figure 4)
T_{stg}	Storage Temperature
V_{CBO}	Collector-Base Voltage – The maximum allowable value of the collector-base voltage which can be applied to the device at the rated temperature. (Base open)
V_{CEO}	Collector-Emitter Voltage – The maximum allowable value of collector-emitter voltage which can be applied to the device at the rated temperature. (Base open)
V_{ECO}	Emitter-Collector Voltage – The maximum allowable value of emitter-collector voltage which can be applied to the device at the rated temperature. (Base open)
θ	Angular Alignment – The axis of maximum sensitivity shall lie within a cone of this angle with reference to the central axis of the device. (See Note 6 and Figure 6)
$\lambda_s (\mu m)$	Wavelength of maximum sensitivity in micro meters.

MRD 450

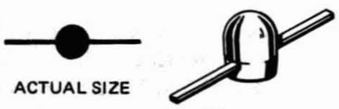
PLASTIC NPN SILICON PHOTO TRANSISTOR

. . . designed for application in industrial inspection, processing and control, counters, sorters, switching and logic circuits or any design requiring radiation sensitivity, and stable characteristics.

- Economical Plastic Package
- Sensitive Throughout Visible and Near Infra-Red Spectral Range for Wide Application
- Minimum Sensitivity (0.2 mA/mW/cm^2) for Design Flexibility
- Unique Molded Lens for High, Uniform Sensitivity
- Annular† Passivated Structure for Stability and Reliability

40 VOLT
PHOTO TRANSISTOR
NPN SILICON

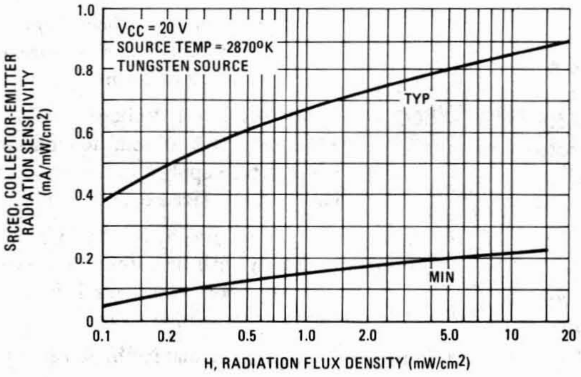
100 MILLIWATTS

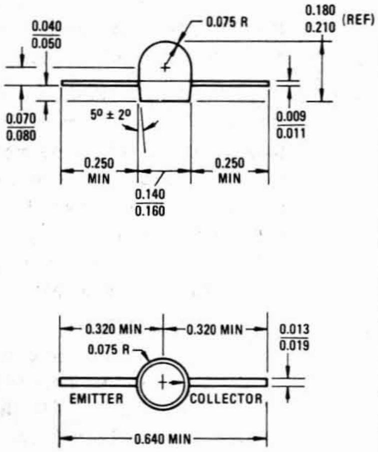

ACTUAL SIZE

MAXIMUM RATINGS

Rating (Note 1)	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	40	Volts
Emitter-Collector Voltage	V_{ECO}	6.0	Volts
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	100 1.3	mW mW/°C
Operating Junction Temperature Range	T_J	-40 to +85	°C
Storage Temperature Range	T_{stg}	-40 to +100	°C

FIGURE 1 – COLLECTOR-EMITTER SENSITIVITY




0.040
0.050
0.075 R
0.180
0.210
(REF)
0.070
0.080
5° ± 2°
0.009
0.011
0.250 MIN
0.250 MIN
0.140
0.160
0.320 MIN
0.320 MIN
0.013
0.019
0.075 R
EMITTER
COLLECTOR
0.640 MIN

CASE 171

Collector indicated by arrow on bottom of device.

STATIC ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Collector Dark Current (V_{CC} = 20 V, R_L = 100 ohms, Note 2)	I_{CEO}				μA
T_A = 25°C		–	–	0.10	
T_A = 85°C		–	5.0	–	
Collector-Emitter Breakdown Voltage (I_C = 100 μA; Note 2)	BV_{CEO}	40	–	–	Volts
Emitter-Collector Breakdown Voltage (I_E = 100 μA; Note 2)	BV_{ECO}	6.0	–	–	Volts

OPTICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit
Collector-Emitter Radiation Sensitivity (V_{CC} = 20 V, R_L = 100 ohms, Note 1)	1	S_{RCEO}	0.2	0.8	–	mA/mW/cm^2
Photo Current Rise Time (Note 3)	2 and 3	t_r	–	–	2.5	μs
Photo Current Fall Time (Note 3)	2 and 3	t_f	–	–	4.0	μs
Angular Alignment (Note 4)	8	θ	–	–	10	Degrees
Wavelength of Maximum Sensitivity	9	λ_s	–	0.8	–	μm

NOTES:

1. Radiation Flux Density (H) equal to 5.0 mW/cm^2 emitted from a tungsten source at a color temperature of 2870°K.
2. Measured under dark conditions. (H≈0).
3. For unsaturated rise time measurements, radiation is provided by a pulsed GaAs (gallium-arsenide) light-emitting diode (λ ≈ 0.9 μm) with a pulse width equal to or greater than 10 microseconds (see Figures 2 and 3).
4. The axis of maximum sensitivity shall be within a 10° cone with reference to the central axis of the device. The photo-induced current will reach a maximum within this cone.

FIGURE 2 – PULSE RESPONSE TEST CIRCUIT

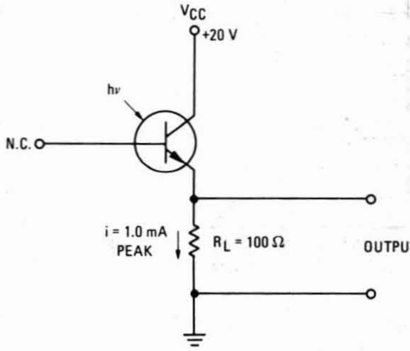
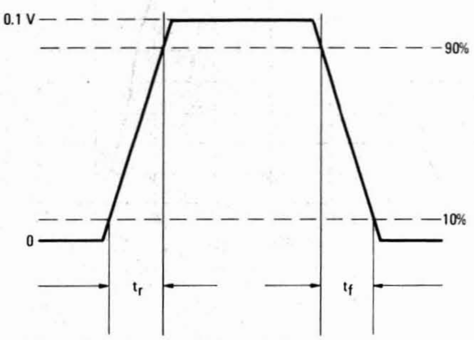


FIGURE 3 – PULSE RESPONSE TEST WAVEFORM



TYPICAL ELECTRICAL CHARACTERISTICS

FIGURE 4 – COLLECTOR-EMITTER CHARACTERISTICS

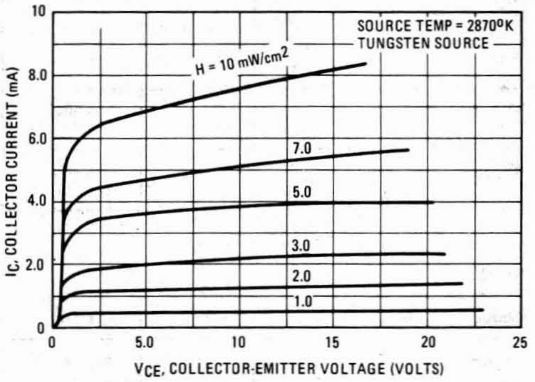


FIGURE 5 – COLLECTOR SATURATION CHARACTERISTICS

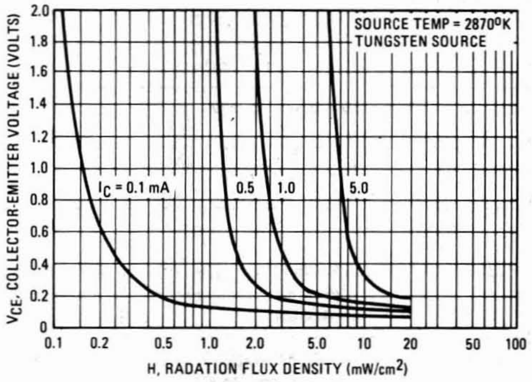


FIGURE 6 – DARK CURRENT versus TEMPERATURE

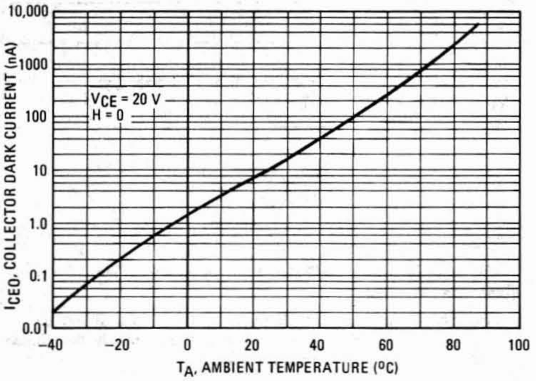


FIGURE 7 – DARK CURRENT versus VOLTAGE

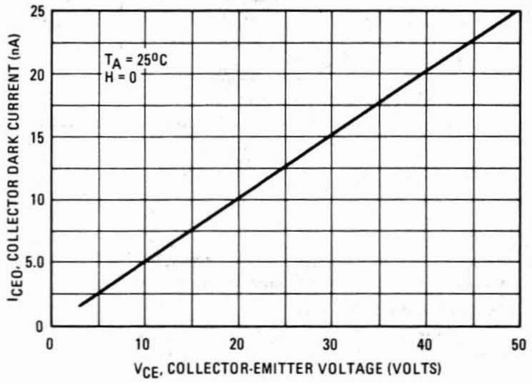


FIGURE 8 – ANGULAR RESPONSE

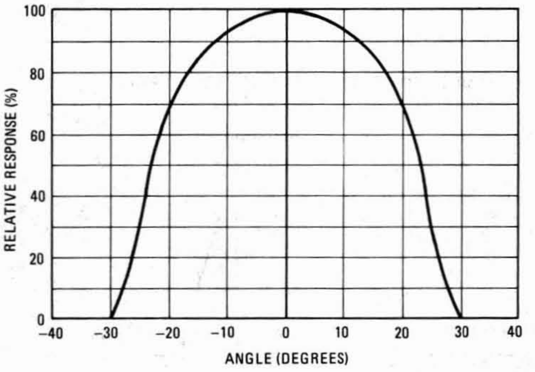
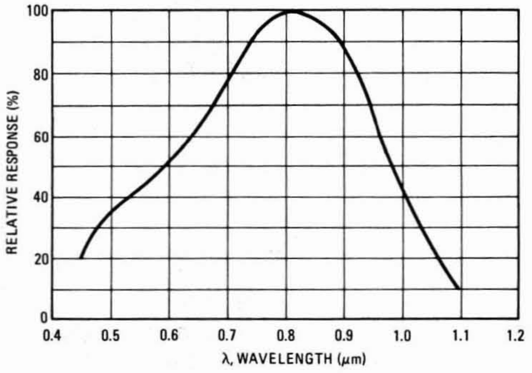


FIGURE 9 – CONSTANT ENERGY SPECTRAL RESPONSE



MRD450

OPTOELECTRONIC DEFINITIONS, CHARACTERISTICS, AND RATINGS

BV_{CEO}	Collector-Emitter Breakdown Voltage – The minimum dc breakdown voltage, collector to emitter, at stated collector current and ambient temperature. (Base open and $H \approx 0$)
BV_{ECO}	Emitter-Collector Breakdown Voltage – The minimum dc breakdown voltage, emitter to collector, at stated emitter current and ambient temperature. (Base open and $H \approx 0$)
E	Luminous Flux Density (Illuminance) [lumens/ft.^{2} = ft. candles] – The radiation flux density of wavelength within the band of visible light.
H	Radiation Flux Density (Irradiance) [mW/cm^2] – The total incident radiation energy measured in power per unit area.
I_{CEO}	Collector Dark Current – The maximum current through the collector terminal of the device measured under dark conditions, ($H \approx 0$), with a stated collector voltage, load resistance, and ambient temperature. (Base open)
P_D	Power Dissipation
S_{RCEO}	Collector-Emitter Radiation Sensitivity (mA/mW/cm^2) – The ratio of photo-induced, collector-emitter current to the incident radiant energy measured at the plane of the lens of the photodevice under stated conditions of radiation flux density (H), collector voltage, load resistance, and ambient temperature. (Base open)
T_A	Ambient Temperature
t_f	Photo Current Fall Time – The response time for the photo-induced current to fall from the 90% point to the 10% point after removal of the GaAs (gallium-arsenide) source pulse under stated conditions of collector voltage, load resistance and ambient temperature. (See Note 3 and Figures 2 and 3)
T_J	Junction Temperature
t_r	Photo Current Rise Time – The response time for the photo-induced current to rise from the 10% point to the 90% point when pulsed with the stated GaAs (gallium-arsenide) source under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 3 and Figures 2 and 3)
V_{CEO}	Collector-Emitter Voltage – The maximum allowable value of collector-emitter voltage which can be applied to the device at the rated temperature. (Base open)
V_{ECO}	Emitter-Collector Voltage – The maximum allowable value of emitter-collector voltage which can be applied to the device at the rated temperature. (Base open)
θ	Angular Alignment – The axis of maximum sensitivity shall lie within a cone of this angle with reference to the central axis of the device. (See Note 4 and Figure 8)
$\lambda_s(\mu m)$	Wavelength of maximum sensitivity in micro meters.

CUSTOM OPTOELECTRONIC ARRAYS

Optoelectronic devices are also available in custom designed arrays or matrices as well as in discrete form.

These arrays can be designed to meet customer requirements for punched card and tape readers, position indicators, pattern and character recognition, shaft encoders, and many other special applications.

The arrays are pre-assembled and tested, ready for installation into the system eliminating the special handling and testing problems associated with the small photo detectors.

The custom arrays can be manufactured in almost any shape to allow maximum design flexibility; they can also be matched for sensitivity to assure more uniform output.

Specifying optoelectronic arrays is easy; all that is required is a print of the array and the desired specifications; or your representative will assist in developing specifications for your special application.

MRD600

NPN SILICON PHOTO DETECTOR

. . . designed for application in card and tape readers, pattern and character recognition, equipment, and shaft encoders, or any design requiring radiation sensitivity, stable characteristics, and high-density mounting.

- Small Size for High Density Mounting
- Sensitive Throughout Visible and Near Infra-Red Spectral Range for Wide Application
- Minimum Sensitivity (0.04 mA/mW/cm^2) for Design Flexibility
- Pill Package Allows Printed Circuit Board Assembly
- Annular Passivated Structure for Stability and Reliability

50 VOLT
PHOTO DETECTOR
NPN SILICON

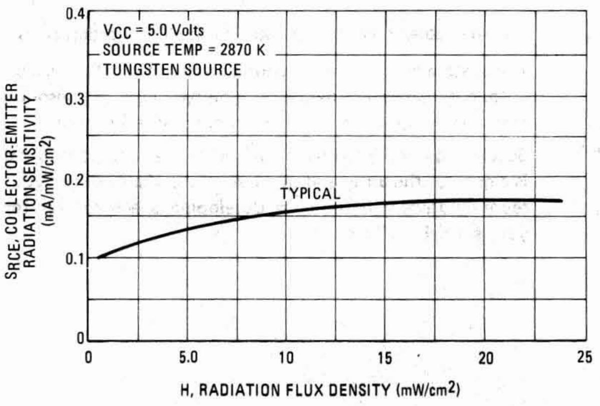
50 MILLIWATTS

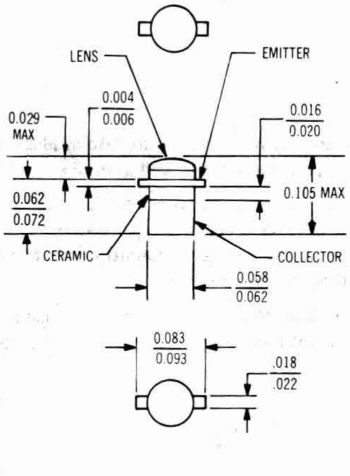
MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CEO}	50	Volts
Emitter-Collector Voltage	V_{ECO}	7.0	Volts
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	50 0.5	mW mW/°C
Operating Junction Temperature Range	T_J	-65 to +125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

Actual Size

FIGURE 1 – COLLECTOR-EMITTER SENSITIVITY




LENS
EMITTER
0.004
0.006
0.029 MAX
0.016
0.020
0.062
0.072
0.105 MAX
CERAMIC
COLLECTOR
0.058
0.062
0.083
0.093
.018
.022

CASE 81A - 02

MRD600 (continued)

STATIC ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic (Note 1)	Symbol	Min	Typ	Max	Unit
Collector Dark Current (V_{CC} = 30 V, R_L = 1.0 megohm, Note 3)	I_{CEO}				μA
T_A = 25°C		–	0.010	0.025	
T_A = 100°C		–	10	–	
Collector-Emitter Breakdown Voltage (I_C = 100 μA, Note 3)	BV_{CEO}	50	–	–	Volts
Emitter-Collector Breakdown Voltage (I_E = 100 μA, Note 3)	BV_{ECO}	7.0	–	–	Volts
Collector-Emitter Saturation Voltage (I_C = 0.4 mA, Note 2)	$V_{CE(sat)}$	–	0.3	–	Volt

OPTICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic (Note 1)	Fig. No.	Symbol	Min	Typ	Max	Unit
Collector-Emitter Radiation Sensitivity (V_{CC} = 5.0 V, R_L = 100 ohms, Note 2)	1	S_{RCE}	0.04	0.17	–	mA/mW/cm^2
Collector Light Current (V_{CC} = 5.0 V, R_L = 100 ohms, Note 2)	–	I_L	0.8	3.4	–	mA
Photo Current Saturated Rise Time (Note 4)	4	$t_{r(sat)}$	–	1.5	–	μs
Photo Current Saturated Fall Time (Note 4)	4	$t_{f(sat)}$	–	15	–	μs
Wavelength of Maximum Sensitivity	6	λ_s	–	0.8	–	μm

NOTES:

1. No base terminal available.
2. Radiation flux density (H) equal to 20 mW/cm^2 emitted from a tungsten source at a color temperature of 2870 K.
3. Measured under dark conditions. ($H \approx 0$).
4. For saturated rise time measurements, radiation is provided by a pulsed xenon arc lamp with a pulse width of approximately 1.0 microsecond (see Figure 4). Radiation flux density is adjusted for I_L = 800 μA peak.

TYPICAL ELECTRICAL CHARACTERISTICS

FIGURE 2 – COLLECTOR-EMITTER CHARACTERISTICS

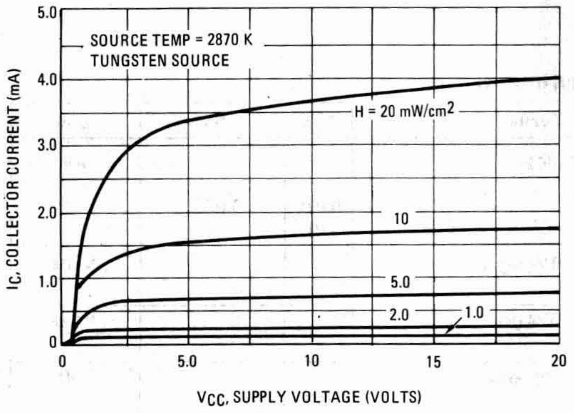


FIGURE 3 – PHOTO CURRENT versus TEMPERATURE

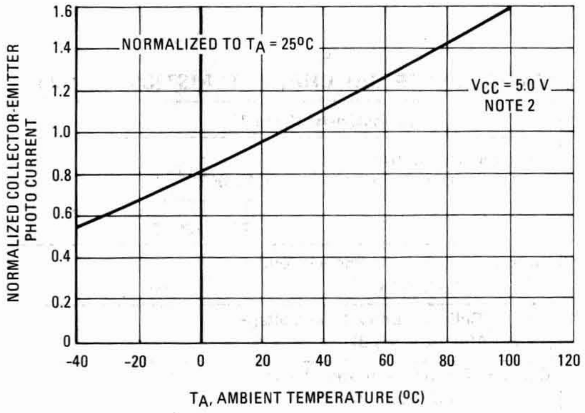


FIGURE 4 – PULSE RESPONSE TEST CIRCUIT AND WAVEFORM

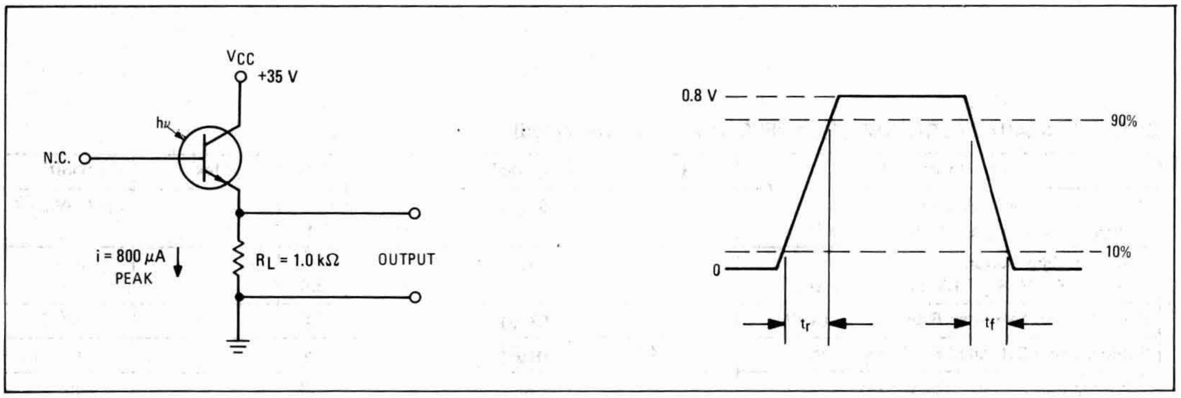

VCC
+35 V
hν
N.C.
i = 800 μA
PEAK
RL = 1.0 kΩ
OUTPUT
0.8 V
90%
10%
0
tr
tf

FIGURE 5 – DARK CURRENT versus VOLTAGE

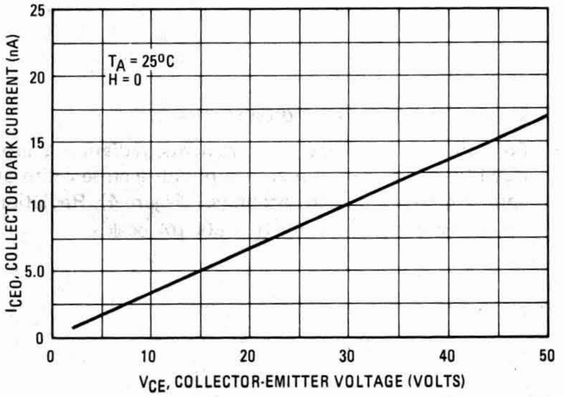
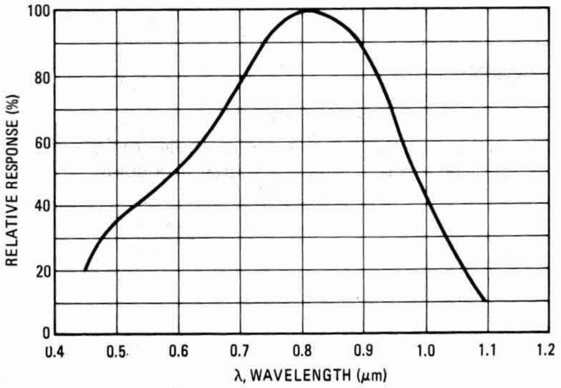


FIGURE 6 – CONSTANT ENERGY SPECTRAL RESPONSE



OPTOELECTRONIC DEFINITIONS, CHARACTERISTICS, AND RATINGS

BV_{CEO}	Collector-Emitter Breakdown Voltage – The dc breakdown voltage, collector to emitter, at stated collector current and ambient temperature. (Base open and $H \approx 0$)
BV_{CEO}	Emitter-Collector Breakdown Voltage – The dc breakdown voltage, emitter to collector, at stated emitter current and ambient temperature. (Base open and $H \approx 0$)
E	Luminous Flux Density (Illuminance) [lumens/ft.^{2} = ft. candles] – The radiation flux density of wavelength within the band of visible light.
H	Radiation Flux Density (Irradiance) [mW/cm^2] – The total incident radiation energy measured in power per unit area.
I_{CEO}	Collector Dark Current – The current through the collector terminal of the device measured under dark conditions, ($H \approx 0$), with a stated collector voltage, load resistance, and ambient temperature. (Base open)
I_L	Collector Light Current (mA) – The current through the collector terminal of the device measured under stated conditions of radiation flux density (H), collector voltage, load resistance, and ambient temperature. (Base open)
P_D	Power Dissipation
S_{RCEO}	Collector-Emitter Radiation Sensitivity (mA/mW/cm^2) The ratio of photo-induced, collector-emitter current to the incident radiant energy measured at the plane of the lens of the photodevice under stated conditions of radiation flux density (H), collector voltage, load resistance, and ambient temperature. (Base open)
T_A	Ambient Temperature
$t_{f(sat)}$	Photo Current Saturated Fall Time – The response time for the photo-induced current to fall from the 90% point to the 10% point after removal of the saturating xenon light source pulse under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 4 and Figure 4)
T_J	Junction Temperature
$t_{r(sat)}$	Photo Current Saturated Rise Time – The response time for the photo-induced current to rise from the 10% point to the 90% point when driven into saturation by the stated xenon source under stated conditions of collector voltage, load resistance, and ambient temperature. (See Note 4 and Figure 4)
T_{stg}	Storage Temperature
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage
V_{CEO}	Collector-Emitter Voltage – The maximum allowable value of collector-emitter voltage which can be applied to the device at the rated temperature. (Base open and $H \approx 0$)
V_{ECO}	Emitter-Collector Voltage – The maximum allowable value of emitter-collector voltage which can be applied to the device at the rated temperature. (Base open and $H \approx 0$)
$\lambda_s(\mu m)$	Wavelength of maximum sensitivity in micro meters.

CUSTOM OPTOELECTRONIC ARRAYS

The MRD 600 is also available in custom designed arrays or matrices as well as in discrete form.

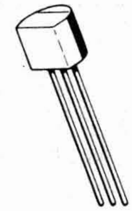
These arrays can be designed to meet customer requirements for punched card and tape readers, position indicators, pattern and character recognition, shaft encoders, and many other special applications.

The arrays are pre-assembled and tested, ready for installation into the system eliminating the special handling and testing problems associated with the small photo detectors.

The custom arrays can be manufactured in almost any shape to allow maximum design flexibility; they can also be matched for sensitivity to assure more uniform output.

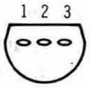
Specifying Motorola optoelectronic arrays is easy; all that is required is a print of the array and the desired specifications; or your Motorola representative will assist in developing specifications for your special application.

MSD6100



Silicon epitaxial dual switching diode, designed for use in high speed switching applications, features high breakdown voltage, low capacitance, one-piece injection-molded unibloc package, and space saving common-cathode configuration.

CASE 29(3)
(TO-92)



PIN 1. ANODE
2. ANODE
3. CATHODE

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	100	Vdc
Recurrent Peak Forward Current	I_F	200	mA
Peak Forward Surge Current (Pulse Width = 10 μsec)	$I_{FM(surge)}$	500	mA
Power Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.82	mW mW/°C
Operating Junction Temperature	T_J	135	°C
Storage Temperature Range	T_{stg}	-55 to +135	°C

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
Breakdown Voltage ($I_{(BR)}$ = 100 μAdc)	—	$V_{(BR)}$	100	—	Vdc
Reverse Current (V_R = 100 Vdc) (V_R = 50 Vdc) (V_R = 50 Vdc, T_A = 125°C)	2	I_R	 — — —	 5 0.1 20	μAdc
Forward Voltage (I_F = 1 mAdc) (I_F = 10 mAdc) (I_F = 100 mAdc)	1	V_F	 0.55 0.67 0.75	 0.7 0.82 1.1	Vdc
Capacitance (V_R = 0)	3	C	—	1.5	pF
Reverse Recovery Time (I_F = I_R = 10 mAdc, V_R = 5 Vdc, i_{rr} = 1.0 mAdc)	4,5	t_{rr}	—	4.0	ns

FIGURE 1 — FORWARD CHARACTERISTICS

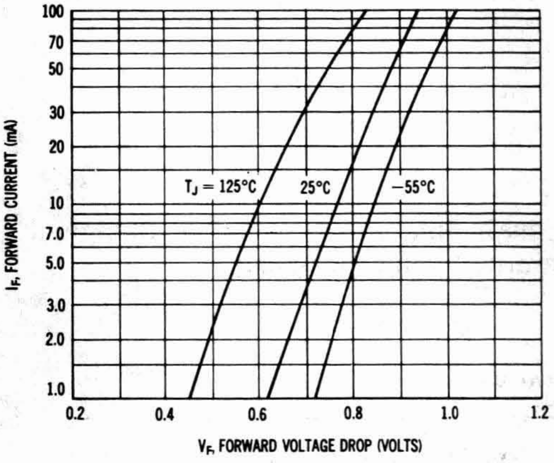


FIGURE 2 — REVERSE LEAKAGE CURRENT

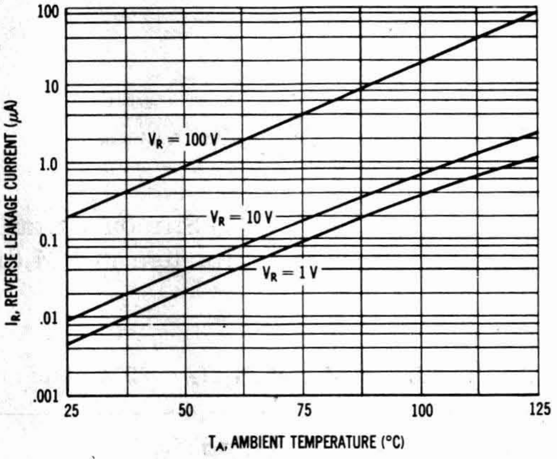


FIGURE 3 — CAPACITANCE

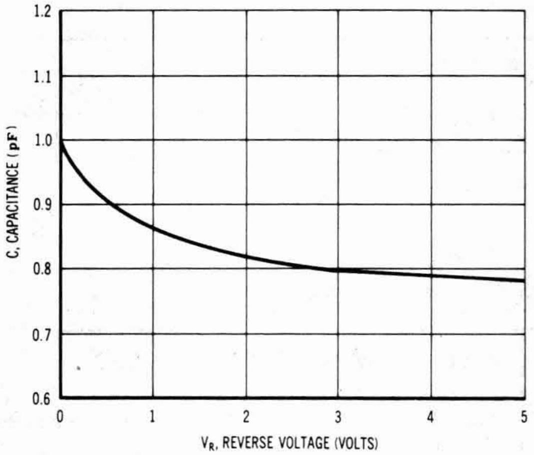


FIGURE 4 — REVERSE RECOVERY TIME

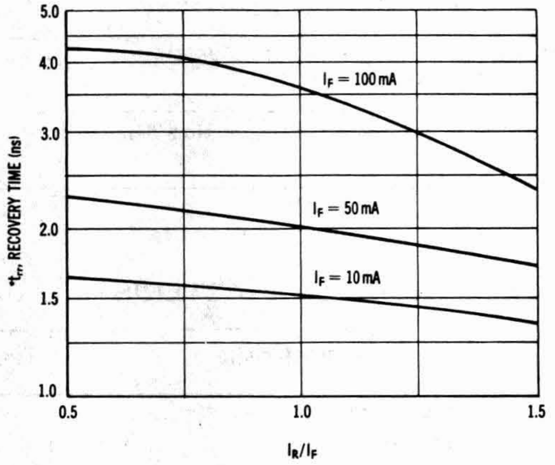
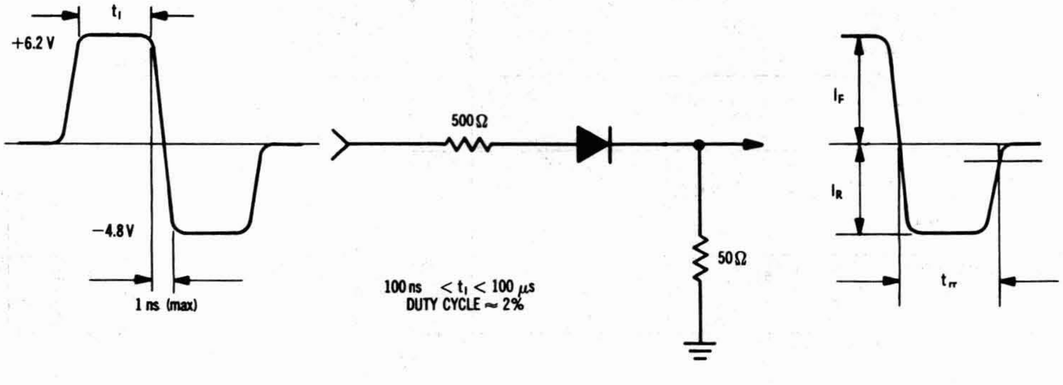
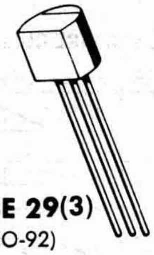


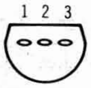
FIGURE 5 — RECOVERY TIME EQUIVALENT TEST CIRCUIT


t_l
+6.2 V
−4.8 V
1 ns (max)
500 Ω
50 Ω
100 ns < t_l < 100 μs
DUTY CYCLE ≈ 2%
I_F
I_R
t_{rr}

MSD6101



CASE 29(3)
(TO-92)



PIN 1. ANODE
2. ANODE
3. CATHODE

Silicon epitaxial dual discriminator diode designed for use in FM discriminator applications.

MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	50	Vdc
Peak Forward Recurrent Current	I_F	200	mA
Peak Forward Surge Current (Pulse Width = 10 µs)	$I_{FM(surge)}$	500	mA
Power Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	310 2.82	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Max	Unit
Breakdown Voltage ($I_{(BR)} = 100$ µAdc)	-	$V_{(BR)}$	50	-	Vdc
Reverse Current	2	I_R			µAdc
($V_R = 40$ Vdc)			-	0.1	
($V_R = 40$ Vdc, $T_A = 125°C$)			-	100	
Forward Voltage	1	V_F			Vdc
($I_F = 0.1$ mAdc)			0.43	0.57	
($I_F = 10$ mAdc)			0.67	0.82	
Capacitance ($V_R = 0$)	3	C	-	2.0	pF
Reverse Recovery Time ($I_F = I_R = 10$ mAdc, $V_R = 5$ Vdc, $i_{rr} = 1.0$ mAdc)	4, 5	t_{rr}	-	10	ns
Forward Voltage Matching $\|V_{F1} - V_{F2}\|$ ($I_{F1} = I_{F2} = 0.1$ mAdc)	-	ΔV_F	-	0.003	Vdc

FIGURE 1 — FORWARD CHARACTERISTICS

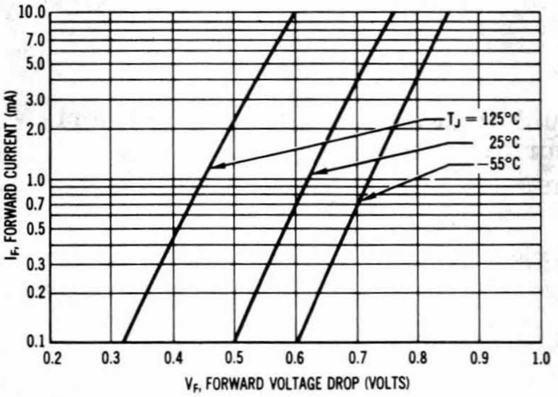


FIGURE 2 — REVERSE LEAKAGE CURRENT

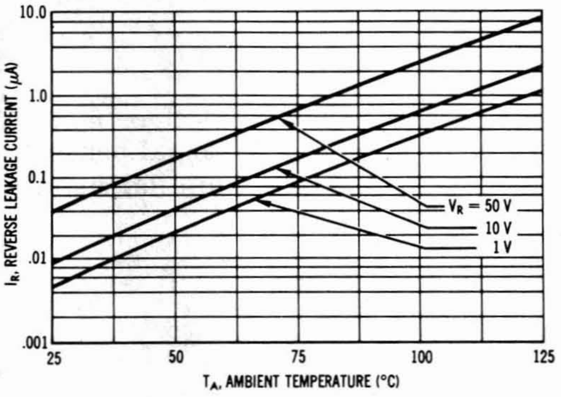


FIGURE 3 — CAPACITANCE

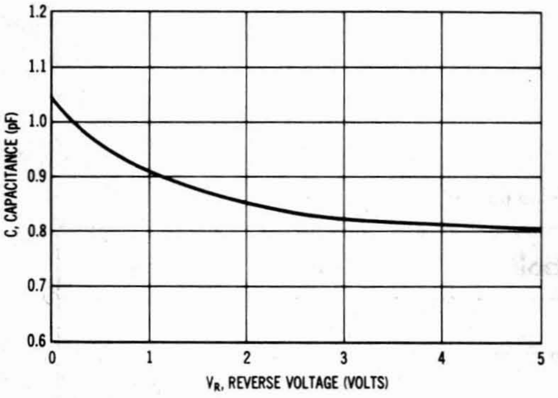


FIGURE 4 — REVERSE RECOVERY TIME

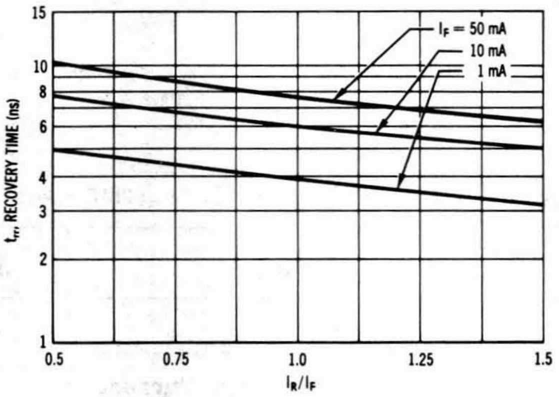
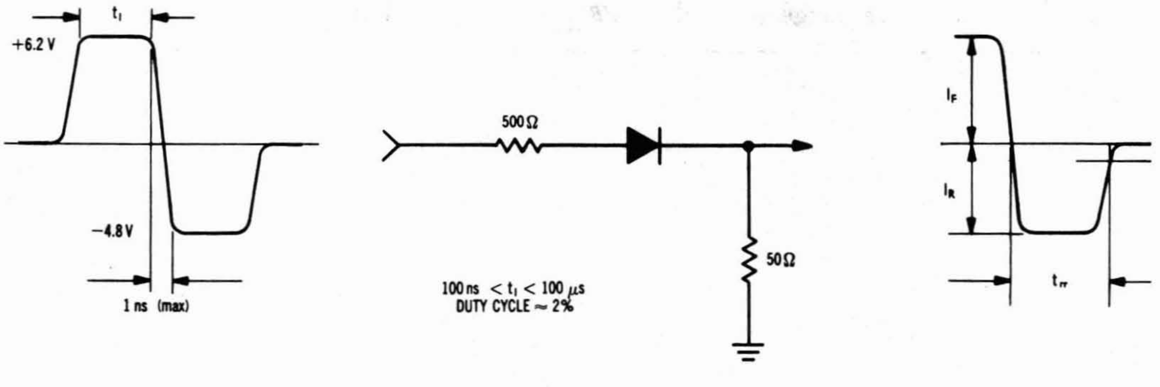
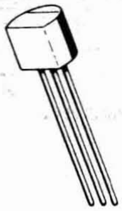


FIGURE 5 — RECOVERY TIME EQUIVALENT TEST CIRCUIT

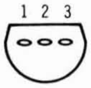

t_l
+6.2 V
−4.8 V
1 ns (max)
500 Ω
50 Ω
100 ns < t_l < 100 μs
DUTY CYCLE ≈ 2%
I_F
I_R
t_{rr}

MSD6102 (SILICON)

Silicon epitaxial dual diode designed for use as a horizontal phase detector for television receivers, and for similar applications.



CASE 29(3)
(TO-92)



PIN 1. ANODE
2. ANODE
3. CATHODE

MAXIMUM RATINGS (T$_A$ = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	70	Vdc
Recurrent Peak Forward Current	I_F	200	mA
Peak Forward Surge Current (Pulse Width = 10 μs)	$I_{FM(surge)}$	500	mA
Power Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.82	mW mW/°C
Operating Junction Temperature	T_J	135	°C
Storage Temperature Range	T_{stg}	-55 to +135	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Breakdown Voltage ($I_{(BR)} = 100\ \mu$Adc)	$V_{(BR)}$	70	—	Vdc
Reverse Current ($V_R = 50$ Vdc)	I_R	—	0.1	μAdc
Forward Voltage ($I_F = 10$ mAdc)	V_F	0.67	1.0	Vdc
Capacitance ($V_R = 0$)	C	—	3.0	pF
Reverse Recovery Time ($I_F = I_R = 10$ mAdc, $V_R = 5$ Vdc, $i_{rr} = 1.0$ mAdc)	t_{rr}	—	100	ns

FIGURE 1 — FORWARD CHARACTERISTICS

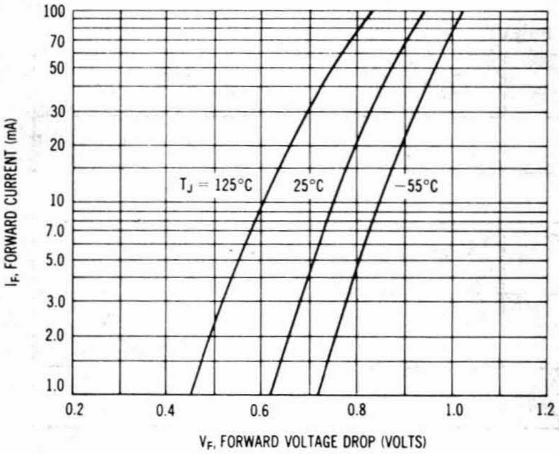


FIGURE 2 — REVERSE LEAKAGE CURRENT versus TEMPERATURE

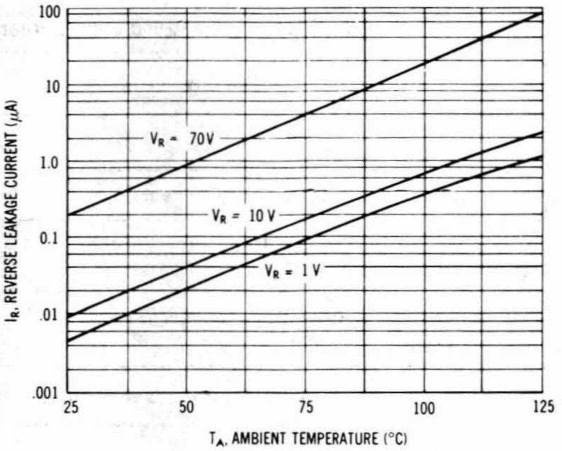
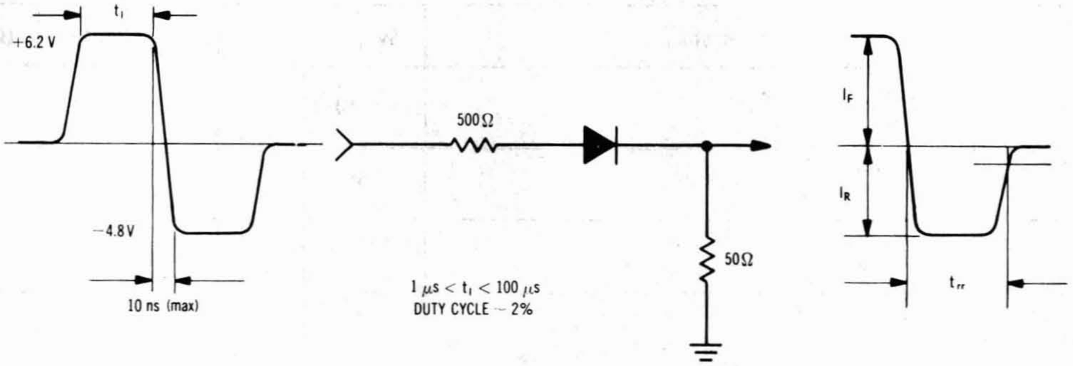
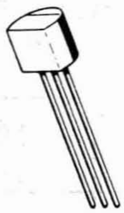


FIGURE 3 — RECOVERY TIME EQUIVALENT TEST CIRCUIT

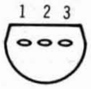

t_r
+6.2 V
−4.8 V
10 ns (max)
500 Ω
50 Ω
1 μs < t_r < 100 μs
DUTY CYCLE ~ 2%
I_F
I_R
t_rr

MSD6150 (SILICON)

Silicon epitaxial dual diode designed for general-purpose consumer applications.



CASE 29(4)
(TO-92)



PIN 1. CATHODE
2. CATHODE
3. ANODE

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	70	Vdc
Peak Forward Recurrent Current	I_F	200	mA
Peak Forward Surge Current (Pulse Width = 10 μs)	$I_{FM(surge)}$	500	mA
Power Dissipation @ T_A = 25°C Derate above 25°C	P_D	310 2.82	mW mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +135	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Breakdown Voltage ($I_{(BR)}$ = 100 μAdc)	$V_{(BR)}$	70	—	—	Vdc
Reverse Current (V_R = 50 Vdc)	I_R	—	—	0.1	μAdc
Forward Voltage (I_F = 10 mAdc)	V_F	—	0.80	1.0	Vdc
Capacitance (V_R = 0)	C	—	2.0	3.5	pF
Reverse Recovery Time (I_F = I_R = 10 mAdc, V_R = 5 Vdc, i_{rr} = 1.0 mAdc)	t_{rr}	—	—	100	ns

FIGURE 1 — FORWARD CHARACTERISTICS

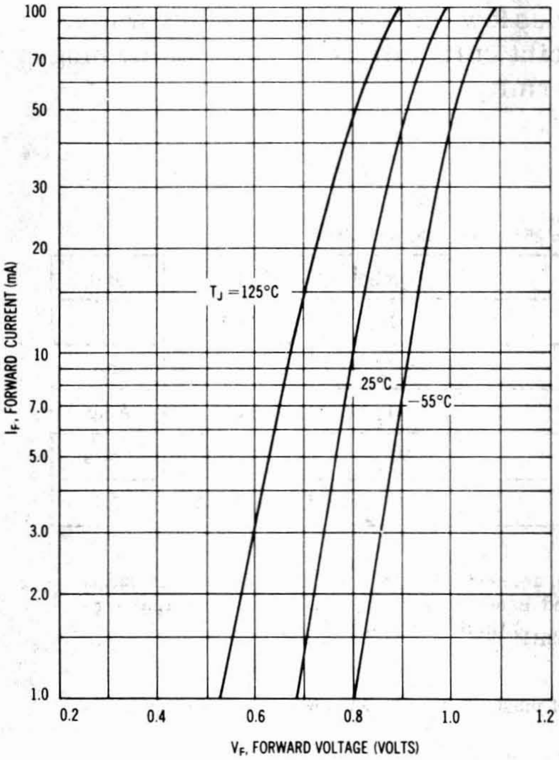


FIGURE 2 — REVERSE LEAKAGE CURRENT

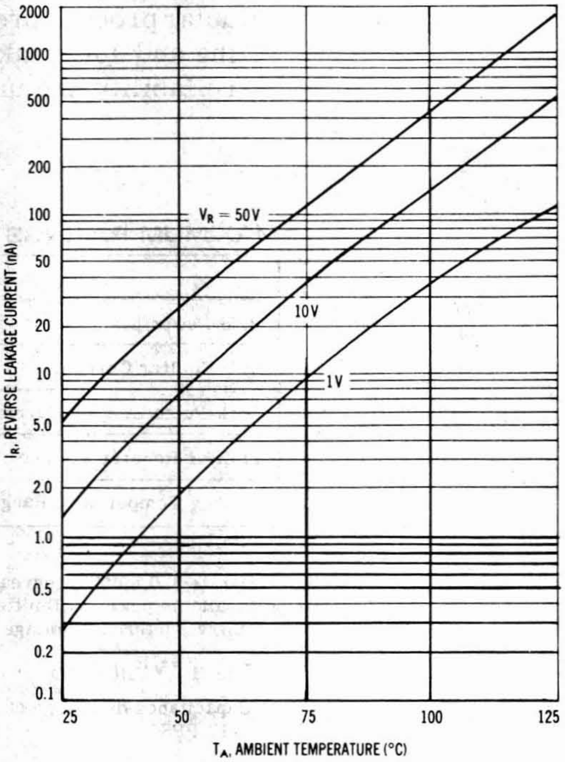
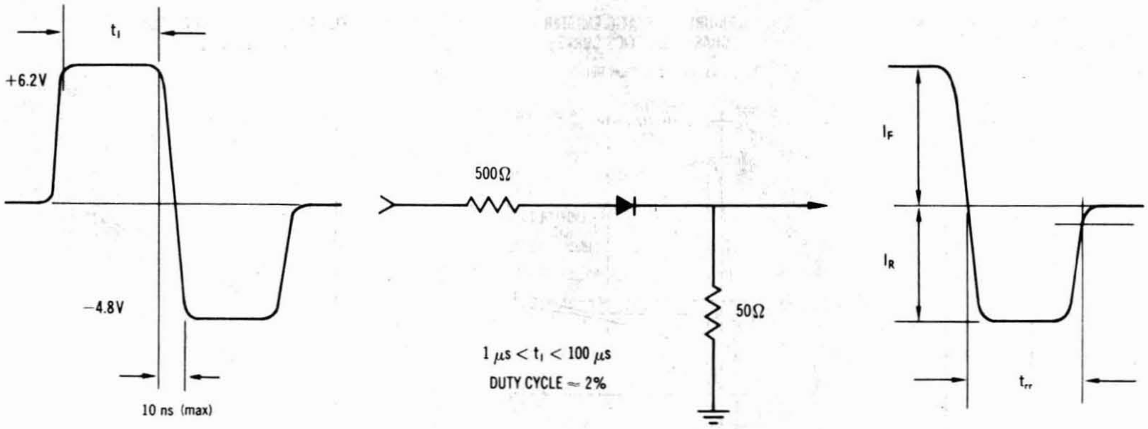
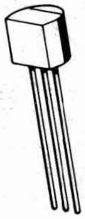


FIGURE 3 — RECOVERY TIME EQUIVALENT TEST CIRCUIT


t_1
+6.2 V
−4.8 V
10 ns (max)
500Ω
50Ω
1 μs < t_1 < 100 μs
DUTY CYCLE ≈ 2%
I_F
I_R
t_{rr}

MU4891 (SILICON)
thru
MU4894

Silicon annular plastic unijunction transistors designed for military and industrial use in pulse, timing, triggering, sensing, and oscillator circuits. The annular process provides low leakage current, fast switching and low peak-point currents as well as outstanding reliability and uniformity.



CASE 29 (9)
(TO-92)

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
RMS Power Dissipation*	P_D	300	mW
RMS Emitter Current	I_e	50	mA
Peak Pulse Emitter Current**	i_e	1.0**	Amp
Emitter Reverse Voltage	V_{B2E}	30	Volts
Storage Temperature Range	T_{stg}	-65 to +150	°C

* Derate 3.0 mW/°C increase in ambient temperature. Total power dissipation (available power to Emitter and Base-Two) must be limited by external circuitry. Interbase voltage (V_{B2B1}) limited by power dissipation,

$$V_{B2B1} = \sqrt{R_{BB} \cdot P_D}$$

** Capacitance discharge current must fall to 0.37 Amp within 3.0 ms and PRR $\leq$ 10 PPS.

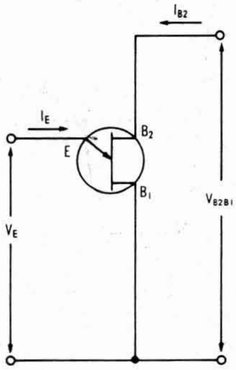


FIGURE 1 — UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

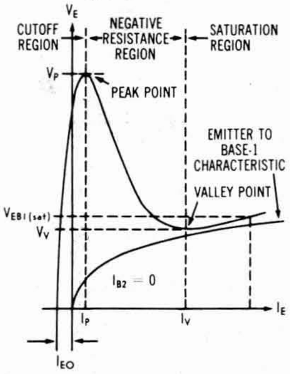


FIGURE 2 — STATIC EMITTER CHARACTERISTICS CURVES

(Exaggerated to Show Details)

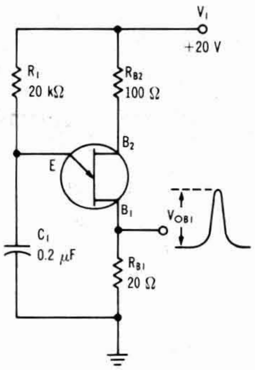


FIGURE 3 — V_{OB1} TEST CIRCUIT

(Typical Relaxation Oscillator)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Intrinsic Standoff Ratio (V_{B2B1} = 10 V) Note 1	MU4892	η	0.51	-	0.69	-
	MU4891, MU4893		0.55	-	0.82	
	MU4894		0.74	-	0.86	
Interbase Resistance (V_{B2B1} = 3.0 V, I_E = 0)	MU4891, MU4892	R_{BB}	4.0	7.0	9.1	k ohms
	MU4893, MU4894		4.0	7.0	12.0	
Interbase Resistance Temperature Coefficient (V_{B2B1} = 3.0 V, I_E = 0, T_A = -65°C to + 100°C)		αR_{BB}	0.1	-	0.9	%/°C
Emitter Saturation Voltage (V_{B2B1} = 10 V, I_E = 50 mA) Note 2		$V_{EB1(sat)}$	-	2.5	4.0	Volts
Modulated Interbase Current (V_{B2B1} = 10 V, I_E = 50 mA)		$I_{B2(mod)}$	10	15	-	mA
Emitter Reverse Current (V_{B2E} = 30 V, I_{B1} = 0)		I_{EB2O}	-	5.0	10	nA
Peak Point Emitter Current (V_{B2B1} = 25 V)	MU4891	I_P		0.6	5.0	μA
	MU4892, MU4893		-	0.6	2.0	
	MU4894		-	0.6	1.0	
Valley Point Current (V_{B2B1} = 20 V, R_{B2} = 100 ohms) Note 2	MU4891, MU4893, MU4894	I_V	2.0	4.0	-	mA
	MU4892		2.0	3.0	-	
Base-One Peak Pulse Voltage (Note 3, Figure 3)	MU4891, MU4892, MU4894	V_{OB1}	3.0	5.0	-	Volts
	MU4893		6.0	8.0	-	

NOTES

1. Intrinsic standoff ratio.
η,is defined by equation:

$$\eta = \frac{V_P - V_{(EB1)}}{V_{B2B1}}$$

Where V_P = Peak Point Emitter Voltage
V_{B2B1} = Interbase Voltage
$V_{(EB1)}$ = Emitter to Base-One Junction Diode Drop
(~0.5 V @ 10 μA)

2. Use pulse techniques: PW ≈ 300 μs duty cycle ≤2% to avoid internal heating due to interbase modulation which may result in erroneous readings.

3. Base-One Peak Pulse Voltage is measured in circuit of Figure 3. This specification is used to ensure minimum pulse amplitude for applications in SCR firing circuits and other types of pulse circuits.

MV830 thru MV840 (SILICON)

CASE 51
(DO-7)

Polarity band on
cathode end

Silicon voltage-variable capacitance diodes, designed for electronic-tuning applications from 15 to 100 pF.

MAXIMUM RATINGS (Tc = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	30	Vdc
Forward Current	I_F	250	mAdc
Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	400 2.67	mW mW/°C
Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	2 13.3	W mW/°C
Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

MV830 thru MV840 (continued)

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted) See Notes

Characteristic — All Types	Symbol	Test Conditions	Min	Typ	Max	Unit
Reverse Breakdown Voltage	BV_R	I_R = 10 μAdc	30	—	—	Vdc
Reverse Voltage Leakage Current	I_R	V_R = 25 Vdc	—	—	0.2	μAdc
Series Inductance	L_S	f = 250 MHz, L ≈ 1/16"	—	5	10	nH
Case Capacitance	C_C	f = 1 MHz, L = 0	—	0.25	0.3	pF

Device	C_T, Diode Capacitance V_R = 4 Vdc, f = 1 MHz pF			TR, Tuning Ratio f = 1 MHz C_4/C_{25}		Q, Figure of Merit V_R = 4 Vdc, f = 50 MHz		α	
	Min	Typ	Max	Min	Typ	Min	Typ	Min	Typ
MV830	13.5	15.0	16.5	1.8	2.00	30	35	0.32	0.375
MV831	16.2	18.0	19.8	1.8	2.00	25	30	0.32	0.375
MV832	19.8	22.0	24.2	1.8	2.10	25	30	0.32	0.40
MV833	24.3	27.0	29.7	1.8	2.10	25	30	0.32	0.40
MV834	29.7	33.0	36.3	1.9	2.12	20	25	0.35	0.41
MV835	35.1	39.0	42.9	1.9	2.12	20	25	0.35	0.41
MV836	42.3	47.0	51.7	1.9	2.15	15	20	0.35	0.415
MV837	50.4	56.0	61.6	1.9	2.15	15	20	0.35	0.415
MV838	61.2	68.0	74.8	2.0	2.18	15	20	0.375	0.425
MV839	73.8	82.0	90.2	2.0	2.18	10	15	0.375	0.425
MV840	90.0	100.0	110.0	2.0	2.18	10	15	0.375	0.425

PARAMETER TEST METHODS

1. L_S, SERIES INDUCTANCE

L_S is measured on a shorted package at 250 MHz using an impedance bridge (Boonton Radio Model 250A RX Meter). L = lead length.

2. C_C, CASE CAPACITANCE

C_C is measured on an open package at 1 MHz using a capacitance bridge (Boonton Electronics Model 75A).

3. C_T, DIODE CAPACITANCE

($C_T = C_C + C_J$). C_T is measured at 1 MHz using a capacitance bridge (Boonton Electronics Model 33AS8).

4. TR, TUNING RATIO

TR is the ratio of C_T measured at 4 Vdc divided by C_T measured at 25 Vdc.

5. Q, FIGURE OF MERIT

Q is calculated by taking the G and C readings of an admittance bridge at the specified frequency and substituting in the following equations:

$$Q = \frac{2\pi fC}{G}$$

(Boonton Electronics Model 33AS8).

6. α, DIODE CAPACITANCE REVERSE VOLTAGE SLOPE

The diode capacitance, C_T (as measured at $V_R = 4$ Vdc, f = 1 MHz) is compared to C_T (as measured at $V_R = 30$ Vdc, f = 1 MHz) by the following equation which defines α.

$$\alpha = \frac{\log C_T(4) - \log C_T(30)}{\log 30 - \log 4}$$

Note that a C_T versus V_R law is assumed as shown in the following equation where C_C is included.

$$C_T = \frac{K}{V^{\alpha}}$$

MV1620 thru MV1650 (SILICON)

CASE 51
(DO-7)

Silicon Epicap diodes, epitaxial passivated tuning diodes designed for AFC applications in radio, TV, and general electronic-tuning.

MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	20	Volts
Forward Current	I_F	250	mAdc
Device Dissipation @ $T_A = 25°C$	P_D	400	mW
Derate above 25°C		2.67	mW/°C
Device Dissipation @ $T_C = 25°C$	P_D	2	Watts
Derate above 25°C		13.3	mW/°C
Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic – All Types	Test Conditions	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage	$I_R = 10\ \mu$Adc	BV_R	20	–	–	Vdc
Reverse Voltage Leakage Current	$V_R = 15$ Vdc	I_R	–	–	0.1	μAdc
Series Inductance	f = 250 MHz, lead length ≈ 1/16"	L_S	–	5.0	10	nH
Case Capacitance	f = 1 MHz, lead length ≈ 1/16"	C_C	–	0.25	0.3	pF

Device	C_T, Diode Capacitance $V_R = 4$ Vdc, f = 1 MHz pF			Q, Figure of Merit $V_R = 4$ Vdc, f = 50 MHz	TR, Tuning Ratio * C_2/C_{20} f = 1 MHz	
	Min	Nom	Max	Min	Min	Max
MV1620	6.1	6.8	7.5	300	2.0	3.2
MV1622	7.4	8.2	9.0	300	2.0	3.2
MV1624	9.0	10.0	11.0	300	2.0	3.2
MV1626	10.8	12.0	13.2	300	2.0	3.2
MV1628	13.5	15.0	16.5	250	2.0	3.2
MV1630	16.2	18.0	19.8	250	2.0	3.2
MV1632	18.0	20.0	22.0	250	2.0	3.2
MV1634	19.8	22.0	24.2	250	2.0	3.2
MV1636	24.3	27.0	29.7	200	2.0	3.2
MV1638	29.7	33.0	36.3	200	2.0	3.2
MV1640	35.1	39.0	42.9	200	2.0	3.2
MV1642	42.3	47.0	51.7	200	2.0	3.2
MV1644	50.4	56.0	61.6	150	2.0	3.2
MV1646	61.2	68.0	74.8	150	2.0	3.2
MV1648	73.8	82.0	90.2	150	2.0	3.2
MV1650	90.0	100.0	110.0	150	2.0	3.2

* TR, Tuning Ratio, is the ratio of C_T measured at 2 Vdc divided by C_T measured at 20 Vdc.

MV1652 (SILICON)
MV1654
MV1656
MV1658
MV1660
MV1662
MV1664
MV1666

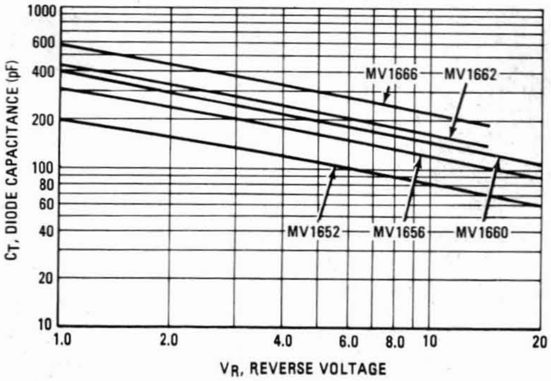
Silicon epicap epitaxial passivated tuning diodes designed for general tuning, trimming and AFC applications at low radio frequencies.

CASE 146

MAXIMUM RATINGS

Rating	Symbol	MV1652/ MV1660	MV1662/ MV1666	Unit
Reverse Voltage	V_R	20	15	Vdc
Forward Current	I_F	400		mAdc
Total Device Dissipation @ $T_A = 25°C$ Derate above 25°C	P_D	400 2.67		mW mW/°C
Junction Temperature	T_J	175		°C
Storage Temperature Range	T_{stg}	-65 to +200		°C

FIGURE 1 - DIODE CAPACITANCE versus REVERSE VOLTAGE



PARAMETER TEST METHODS

1. **L_S, SERIES INDUCTANCE**
   L_S, is determined from the self resonant frequency and the junction capacity of the device.

$$L_S = \frac{1}{\omega^2_{res}\ C_J}$$

2. **C_T, DIODE CAPACITANCE**
   ($C_T = C_C + C_J$). C_T is measured at 1.0 MHz using a capacitance bridge (Boonton Electronics Model 75A or equivalent).
3. **TR, TUNING RATIO**
   TR is the ratio of C_T measured at 2.0 Vdc divided by C_T measured at 20 Vdc or at 15 Vdc.
4. **Q, FIGURE OF MERIT**
   Q is calculated by taking the G and C readings of an admittance bridge at the specified frequency and substituting in the following equations:

$$Q = \frac{2\pi fC}{G}$$

(Boonton Electronics Model 33AS9 with range extender or equivalent).

MV1652, 54, 56, 58, 60, 62, 64, 66 (continued)

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage (I_R = 10 μAdc)	MV1652 thru MV1660 MV1662 thru MV1666	BV_R	20 15	- -	- -	Vdc
Reverse Current (V_R = 15 Vdc) (V_R = 10 Vdc)	MV1652 thru MV1660 MV1662 thru MV1666	I_R	- -	- -	0.1 0.1	μAdc
Series Inductance	MV1652 thru MV1666	L_S	-	5.0	-	nH

Device	C_T, Diode Capacitance V_R = 4.0 Vdc, f = 1.0 MHz (pF)			Q, Figure of Merit V_R = 4.0 Vdc, f = 20 MHz	Capacitance Ratio C_2/C_{20}
	Min	Nom	Max		Typical
MV1652	108	120	135	250	2.6
MV1654	132	150	165	250	2.6
MV1656	162	180	198	200	2.6
MV1658	180	200	220	200	2.6
MV1660	198	220	242	150	2.6
					C_2/C_{15}
MV1662	225	250	275	150	2.3
MV1664	243	270	300	100	2.3
MV1666	297	330	363	100	2.3

MV1804

For Specifications, See 1N4387 Data.

MV1805C

CASE 47

High-frequency step-recovery silicon power varactor for 100 MHz to 2.0 GHz harmonic-generation applications with output power up to 35 watts at 1.0 GHz.

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	80	Volts
Forward Current	I_F	5	Amps
RF Power Input	P_{in}	50	Watts
Total Device Dissipation @ T_A = 75°C	P_D	18	Watts
Derate above 75°C		0.14	W/°C
Junction Temperature	T_J	+200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Test Conditions	Min	Typ	Max	Unit
Reverse Breakdown Voltage	BV_R	I_R = 10 μAdc	80	95	—	Vdc
Reverse Current	I_R	V_R = 70 Vdc V_R = 70 Vdc, T_A = 150°C	— —	— —	2 100	μAdc
Diode Capacitance	C_T	V_R = 6 Vdc, f = 1.0 MHz	20	25	30	pF
Figure of Merit	Q	V_R = 6 Vdc, f = 50 MHz	—	500	—	—
Thermal Resistance	θ_{JC}		—	—	7	°C/W

FUNCTIONAL TEST

RF Power Output	P_{out}	Test Setup Figure 4 P_{in} = 40 Watts	26	—	—	Watts
Tripler Efficiency	η	f_{in} = 250 MHz f_{out} = 750 MHz	65	—	—	%

POWER OUTPUT versus OUTPUT FREQUENCY

FIGURE 1A – DOUBLING (X2)

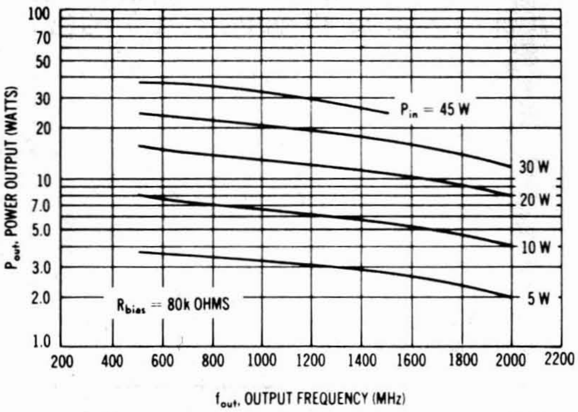


FIGURE 1B – TRIPLING (X3)

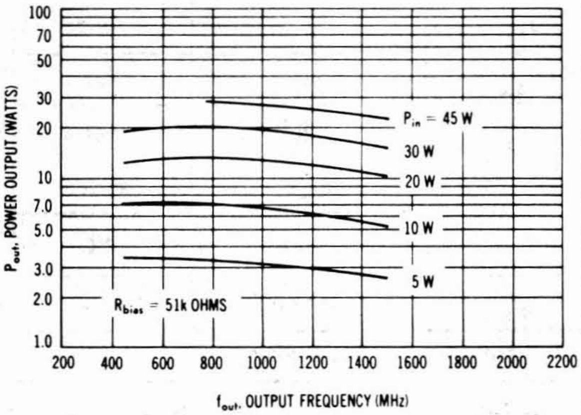


TABLE 1 – TYPICAL QUADRUPLING (X4)

f_{in} = 275 MHz, f_{out} = 1100 MHz, R_{bias} = 100k OHMS

INPUT POWER Watts	OUTPUT POWER Watts	EFFICIENCY %
5	2.6	52
10	5.4	54
20	10.6	53
30	14.4	48
40	19.0	47.5
45	20.6	45.8

TABLE 2 – TYPICAL ONE-STEP (X9)

f_{in} = 50 MHz, f_{out} = 450 MHz, R_{bias} = 5k OHMS

INPUT POWER Watts	OUTPUT POWER Watts	EFFICIENCY %
5	1.4	28
10	2.7	27

FIGURE 2 – TRIPLER LINEARITY CHARACTERISTICS

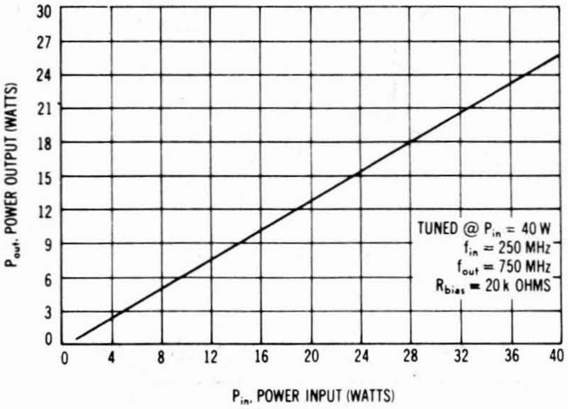


FIGURE 3 – CAPACITANCE versus REVERSE VOLTAGE

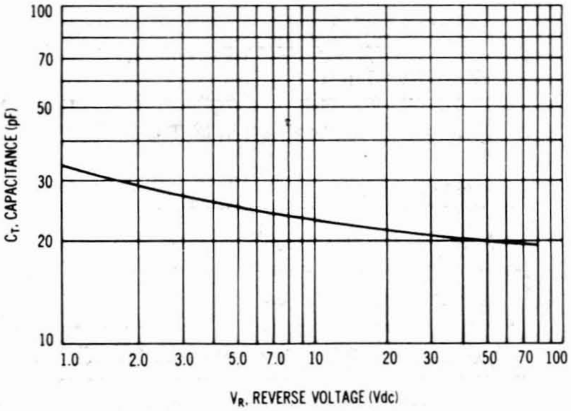
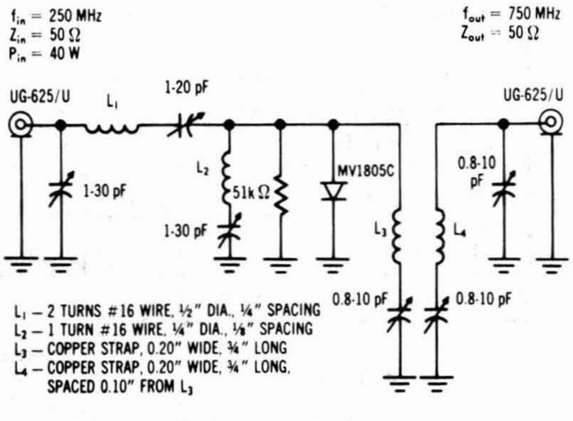


FIGURE 4 – HARMONIC TRIPLER – 250 MHz to 750 MHz


f_{in} = 250 MHz
Z_{in} = 50 Ω
P_{in} = 40 W
f_{out} = 750 MHz
Z_{out} = 50 Ω
UG-625/U
L_1
1-20 pF
UG-625/U
1-30 pF
L_2
51k Ω
MV1805C
0.8-10 pF
1-30 pF
L_3
L_4
0.8-10 pF
0.8-10 pF

L_1 – 2 TURNS #16 WIRE, ½" DIA., ¼" SPACING
L_2 – 1 TURN #16 WIRE, ¼" DIA., ⅛" SPACING
L_3 – COPPER STRAP, 0.20" WIDE, ¾" LONG
L_4 – COPPER STRAP, 0.20" WIDE, ¾" LONG, SPACED 0.10" FROM L_3

MV1806

For Specifications, See 1N4388 Data.

MV1806C, MV1807C

For Specifications, See 1N5149 Data.

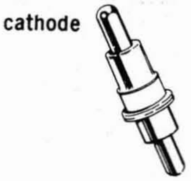
MV1807C1, MV1808B1, MV1808C1, MV1810B1

For Specifications, See 1N5150A Data.

MV1808A, MV1808B, MV1808C

For Specifications, See 1N5151 Data.

MV1809C (SILICON)
MV1809C1



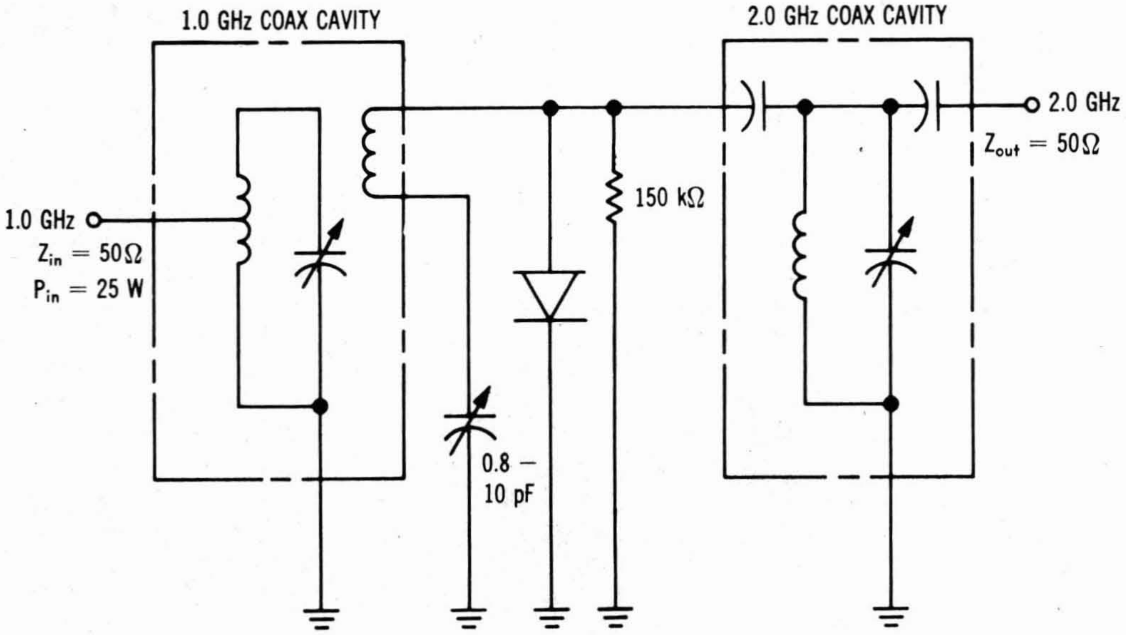
CASE 47

Silicon high-frequency step-recovery power varactors for 300 MHz to 3.0 GHz harmonic-generation applications with output power to 17 watts at 2.0 GHz.

MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Rating		Symbol	Value	Unit
Reverse Voltage		V_R	75	Vdc
Forward Current		I_F	5.0	Adc
RF Power Input	MV1809C MV1809C1	P_{in}	25 30	Watts
Total Device Dissipation @ T_C = 75°C	MV1809C MV1809C1	P_D	9.0 14	Watts
Derate above 75°C	MV1809C MV1809C1		0.07 0.11	mW/°C
Operating and Storage Junction Temperature Range		T_J, T_{stg}	-65 to +200	°C

FIGURE 1 — HARMONIC DOUBLER EFFICIENCY TEST CIRCUIT


1.0 GHz COAX CAVITY
2.0 GHz COAX CAVITY
1.0 GHz
Z_{in} = 50Ω
P_{in} = 25 W
150 kΩ
0.8 – 10 pF
2.0 GHz
Z_{out} = 50Ω

MV1809C, MV1809C1 (continued)

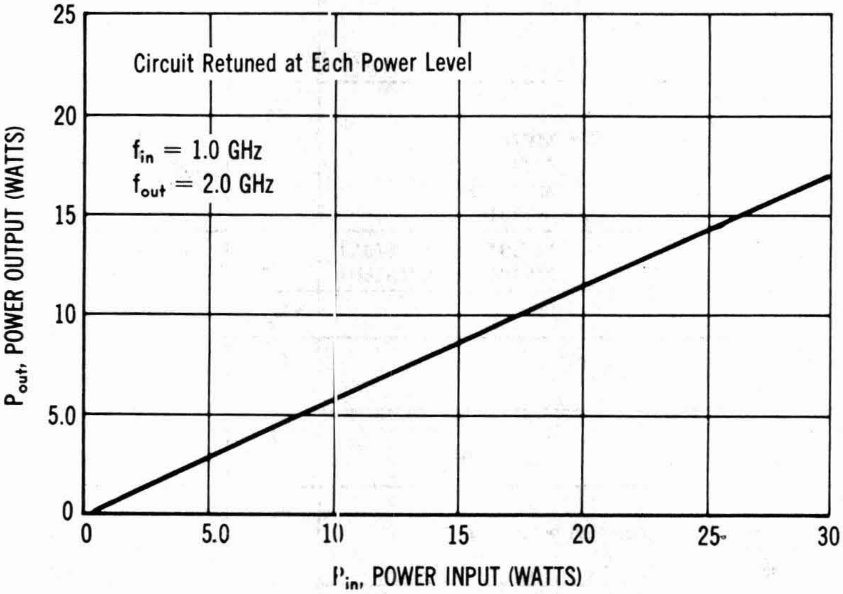
ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage (I_R = 10 μAdc)		BV_R	75	-	-	Vdc
Reverse Current (V_R = 70 Vdc)		I_R	-	-	2.0	μAdc
(V_R = 70 Vdc, T_A = 150°C)			-	-	100	
Diode Capacitance ($C_J + C_C$) (V_R = 6.0 Vdc, f = 1.0 MHz)	MV1809C	C_T	9.6	-	14.4	pF
	MV1809C1		10.8	-	13.2	
Case Capacitance		C_C	-	0.47	-	pF
Series Inductance		L_S	-	2.2	-	nH
Series Resistance (V_R = 6.0 Vdc)		R_S	-	0.35	0.5	Ohm
Thermal Resistance	MV1809C	θ_{JC}	-	-	14	°C/W
	MV1809C1		-	-	9.0	

FUNCTIONAL TESTS

MV1809C1 Power Output	Doubler Test Circuit (Figure 1) P_{in} = 25 W, f_{in} = 1.0 GHz, f_{out} = 2.0 GHz	P_{out}	14.5	-	-	Watt
Efficiency		η	58	-	-	%
MV1809C Power Output	Doubler Test Circuit (Figure 1) P_{in} = 20 W, f_{in} = 1.0 GHz, f_{out} = 2.0 GHz	P_{out}	10.4	-	-	Watt
Efficiency		η	52	-	-	%

FIGURE 2 — POWER OUTPUT versus POWER INPUT



MV1810A, MV1810B

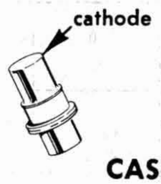
For Specifications, See 1N5154 Data.

MV1812A, MV1812B

For Specifications, See 1N5156 Data.

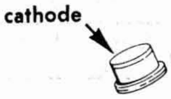
MV1816A, B (SILICON)
MV1816A1, B1

Silicon high-frequency power varactors designed for high efficiency in frequency multiplier applications. Permits ONE-STEP multiplication to frequencies as high as 3.0 GHz.



CASE 46

MV1816B
MV1816B1



CASE 48

MV1816A
MV1816A1

MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	75	Vdc
Forward Current	I_F	2.5	Adc
RF Power Input	P_{in}	10	Watts
Total Device Dissipation @ T_C = 25°C	P_D		
MV1816A, MV1816B		7.5	Watts
Derate above 25°C		43	mW/°C
MV1816A1, MV1816B1		11.5	Watts
Derate above 25°C		66	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage (I_R = 10 μAdc)		BV_R	75	103	-	Vdc
Reverse Current (V_R = 60 Vdc)		I_R	-	-	1.0	μAdc
(V_R = 60 Vdc, T_A = 150°C)			-	-	100	
Diode Capacitance ($C_J + C_C$) (V_R = 6.0 Vdc, f = 1.0 MHz)	MV1816A	C_T	2.5	-	3.7	pF
	MV1816A1		2.8	-	3.4	
	MV1816B		2.4	-	3.6	
	MV1816B1		2.7	-	3.3	
Case Capacitance	MV1816A, MV1816A1	C_C	-	0.25	-	pF
	MV1816B, MV1816B1		-	0.15	-	
Series Inductance		L_S	-	0.85	-	nH
Series Resistance (V_R = 6.0 Vdc)		R_S	-	0.57	-	Ohm
Minority Carrier Lifetime (I_F = 1.7 I_R, when I_F = 10 mA)	MV1816B1	τ	-	580	-	ns
Transition Time (I_F = 10 mA, Z_L = 50 ohms; measured between the 20% and 80% points)		t_t	-	1.25	-	ns
Thermal Resistance	MV1816A, MV1816B	θ_{JC}	-	-	23	°C/W
	MV1816A1, MV1816B1		-	8.5	15	

FUNCTIONAL TEST

Power Output	X 8 Test Circuit (Figure 1)	MV1816A, MV1816B	P_{out}	0.6	-	-	Watt
		MV1816A1, MV1816B1		0.75	-	-	
Efficiency	P_{in} = 3.0 W, f_{in} = 300 MHz, f_{out} = 2.4 GHz	MV1816A, MV1816B	η	20	-	-	%
		MV1816A1, MV1816B1		25	-	-	

FIGURE 1 — OCTUPLER TEST CIRCUIT

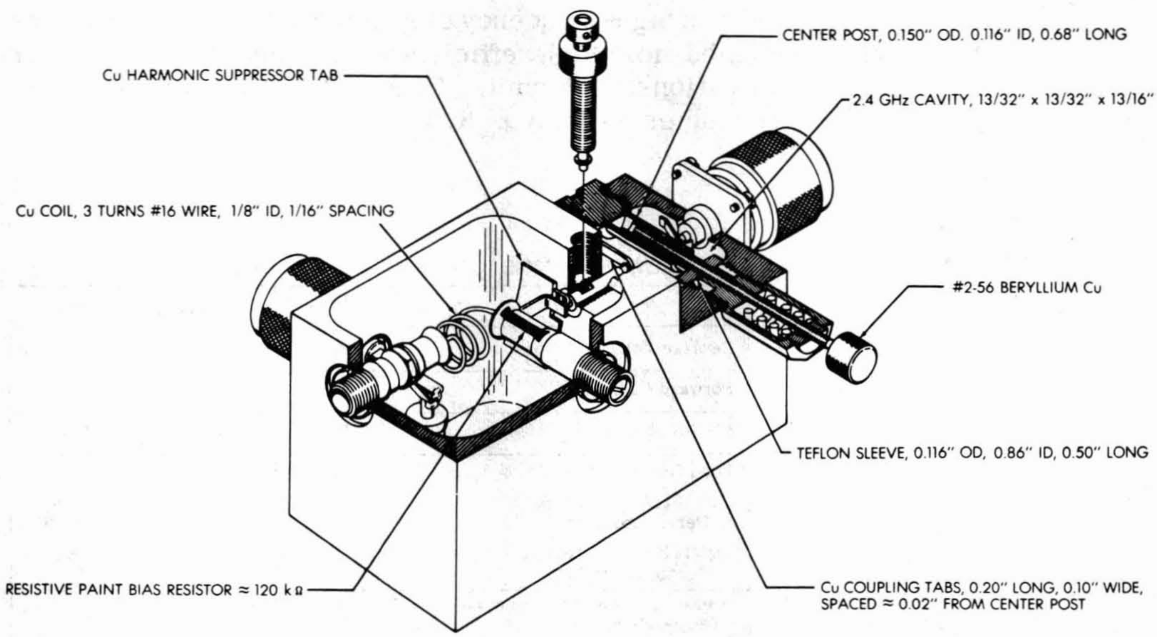

CENTER POST, 0.150" OD, 0.116" ID, 0.68" LONG
Cu HARMONIC SUPPRESSOR TAB
2.4 GHz CAVITY, 13/32" x 13/32" x 13/16"
Cu COIL, 3 TURNS #16 WIRE, 1/8" ID, 1/16" SPACING
#2-56 BERYLLIUM Cu
TEFLON SLEEVE, 0.116" OD, 0.86" ID, 0.50" LONG
RESISTIVE PAINT BIAS RESISTOR ≈ 120 k Ω
Cu COUPLING TABS, 0.20" LONG, 0.10" WIDE, SPACED ≈ 0.02" FROM CENTER POST

FIGURE 2 — CAPACITANCE versus REVERSE VOLTAGE

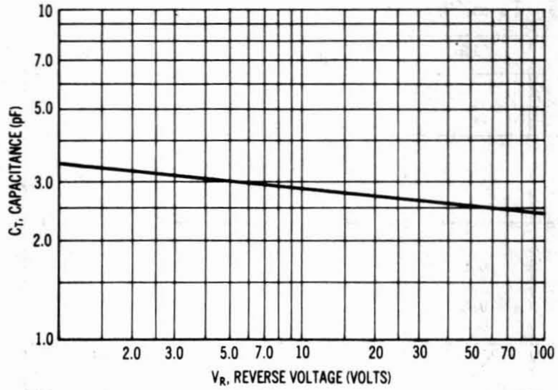


FIGURE 3 — OUTPUT POWER versus INPUT POWER

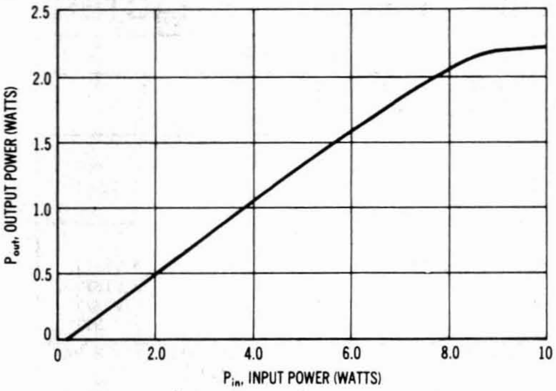
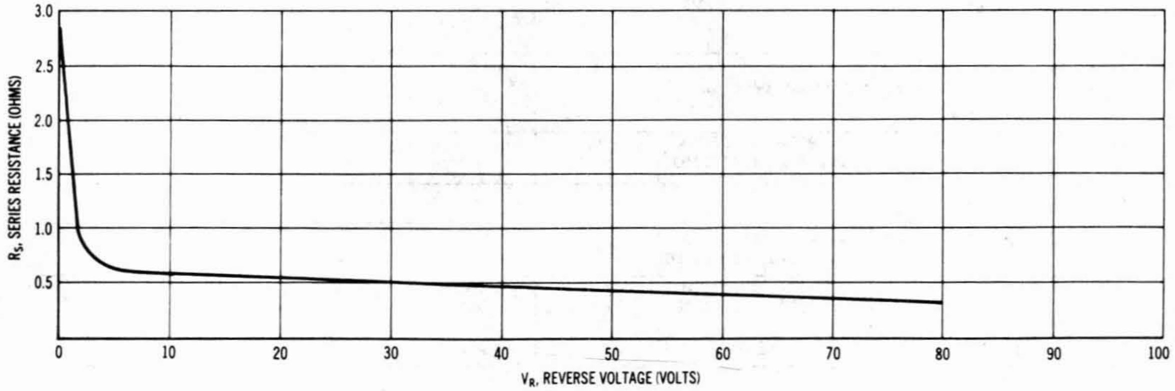
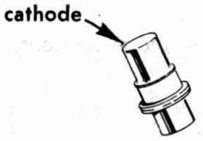


FIGURE 4 — SERIES RESISTANCE versus REVERSE VOLTAGE



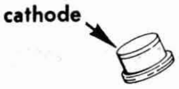
MV1817A, B (SILICON)
MV1817A1, B1



Silicon high-frequency step-recovery power varactors designed for high efficiency in frequency multiplier applications. Permits ONE-STEP multiplication to frequencies as high as 8.0 GHz.

CASE 46

MV1817B
MV1817B1



CASE 48

MV1817A
MV1817A1

MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	35	Vdc
Forward Current	I_F	0.80	Adc
RF Power Input	P_{in}	2.0	Watts
Total Device Dissipation @ T_C = 25°C	P_D		
MV1817A, MV1817B		5.0	Watts
Derate above 25°C		28	mW/°C
MV1817A1, MV1817B1		7.0	Watts
Derate above 25°C		40	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage (I_R = 10 μAdc)		BV_R	35	60	-	Vdc
Reverse Current (V_R = 60 Vdc)		I_R	-	-	1.0	μAdc
(V_R = 60 Vdc, T_A = 150°C)			-	-	100	
Diode Capacitance ($C_J + C_C$) (V_R = 6.0 Vdc, f = 1.0 MHz)	MV1817A	C_T	0.9	-	1.3	pF
	MV1817A1		1.0	-	1.2	
	MV1817B		0.8	-	1.2	
	MV1817B1		0.9	-	1.1	
Case Capacitance	MV1817A, MV1817A1	C_C	-	0.25	-	pF
	MV1817B, MV1817B1		-	0.15	-	
Series Inductance		L_S	-	0.85	-	nH
Series Resistance (V_R = 6.0 Vdc)		R_S	-	0.80	-	Ohm
Minority Carrier Lifetime ($I_F = 1.7\ I_R$, when I_F = 10 mA)		τ	-	120	-	ns
Transition Time (I_F = 10 mA, Z_L = 50 ohms; measured between the 20% and 80% points)		t_t	-	0.4	-	ns
Thermal Resistance	MV1817A, MV1817B,	θ_{JC}	-	-	35	°C/W
	MV1817A1 MV1817B1		-	12.5	25	

FUNCTIONAL TESTS

Power Output	X 8 Test Circuit (Figure 1) P_{in} = 1.0 W, f_{in} = 800 MHz, f_{out} = 6.4 GHz	MV1817A, MV1817B	P_{out}	0.2	-	-	Watt
		MV1817A1, MV1817B1		0.25	-	-	
Efficiency		MV1817A, MV1817B	η	20	-	-	%
		MV1817A1, MV1817B1		25	-	-	

FIGURE 1 — OCTUPLER TEST CIRCUIT

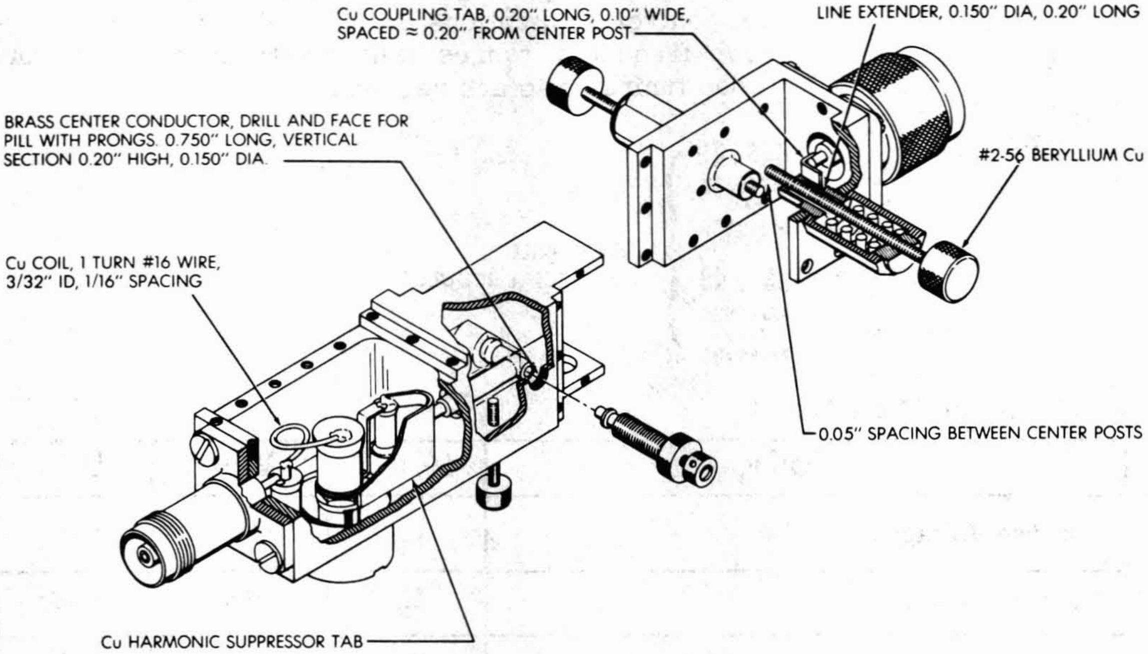

Cu COUPLING TAB, 0.20" LONG, 0.10" WIDE, SPACED ≈ 0.20" FROM CENTER POST
LINE EXTENDER, 0.150" DIA, 0.20" LONG
BRASS CENTER CONDUCTOR, DRILL AND FACE FOR PILL WITH PRONGS. 0.750" LONG, VERTICAL SECTION 0.20" HIGH, 0.150" DIA.
#2-56 BERYLLIUM Cu
Cu COIL, 1 TURN #16 WIRE, 3/32" ID, 1/16" SPACING
0.05" SPACING BETWEEN CENTER POSTS
Cu HARMONIC SUPPRESSOR TAB

FIGURE 2 — CAPACITANCE versus REVERSE VOLTAGE

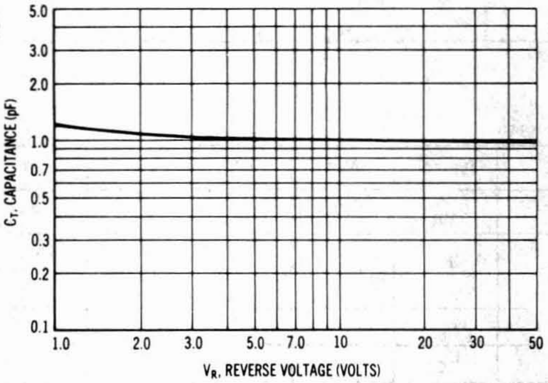


FIGURE 3 — OUTPUT POWER versus INPUT POWER

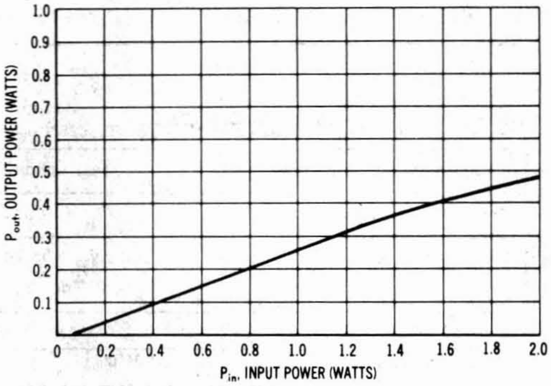
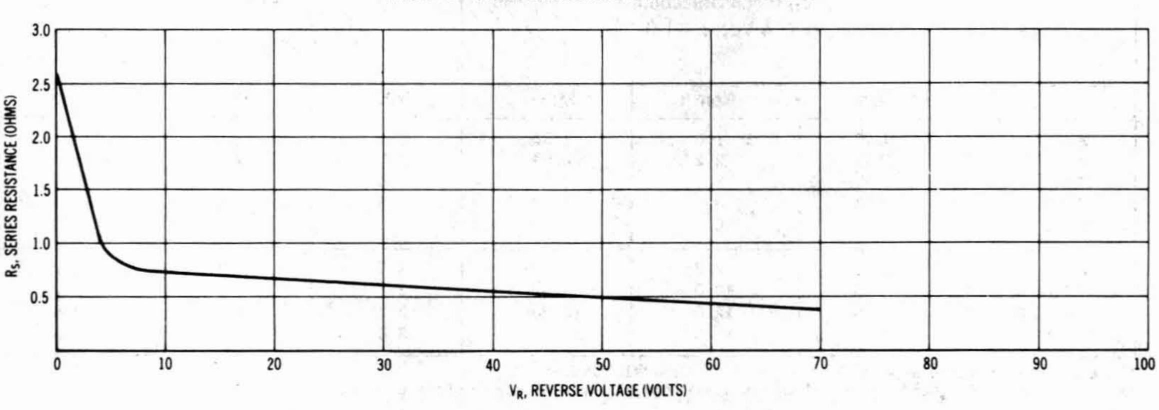


FIGURE 4 — SERIES RESISTANCE versus REVERSE VOLTAGE



MV1858D (SILICON)
thru
MV1870D

Silicon Epicap diodes designed for electronic tuning and control applications in the UHF and lower microwave frequency ranges, where extremely high Q and broad tuning ratio are required.

CASE 45

CASE 46
MV1858B
thru
MV1870B

CASE 48
MV1858A
thru
MV1870A

AVAILABLE ON SPECIAL REQUEST

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	60	Vdc
Forward Current	I_F	250	mAdc
Device Dissipation @T_C = 25°C Derate above 25°C	P_D	5.0 28.6	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic (all types)	Test Conditions	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage	I_R = 10 μAdc	B_{VR}	60	-	-	Vdc
Reverse Voltage Leakage Current	V_R = 55 Vdc V_R = 55 Vdc, T_A = 150°C	I_R	- -	- -	0.02 20	μAdc
Series Inductance	f = self-resonant frequency	L_S	-	0.8	-	nH
Case Capacitance	f = 1 MHz	C_C	-	0.15*	-	pF

Device	C_T, Diode Capacitance † V_R = 4 Vdc, f = 1.0 MHz pF			TR, Tuning Ratio C_4/C_{60} f = 1 MHz		R_S, Series Resistance V_R = 4 Vdc, OHMS
	Min	Nom	Max	Min	Max	Max
MV1858D	0.70	1.0	1.30	2.1	2.7	4.5
MV1860D	1.76	2.2	2.64	2.5	3.1	2.1
MV1862D	2.97	3.3	3.63	2.6	3.3	1.6
MV1863D	4.23	4.7	5.17	2.6	3.3	1.1
MV1864D	6.10	6.8	7.50	2.7	3.4	0.8
MV1865D	7.38	8.2	9.02	2.7	3.4	0.8
MV1866D	9.00	10.0	11.00	2.8	3.5	0.7
MV1868D	10.80	12.0	13.20	2.8	3.5	0.6
MV1870D	13.50	15.0	16.50	2.8	3.5	0.5

*Case Capacitance = 0.26 pF typical for types MV1858A thru MV1870A (case 48).
†All C_T values 0.11 pF higher for types MV1858A thru MV1870A (case 48). TR is reduced proportionately.

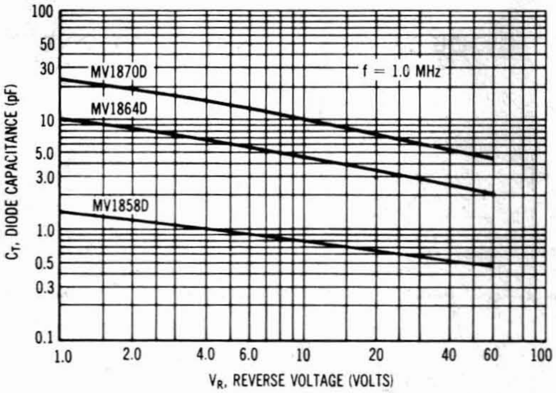


FIGURE 1 — DIODE CAPACITANCE versus REVERSE VOLTAGE

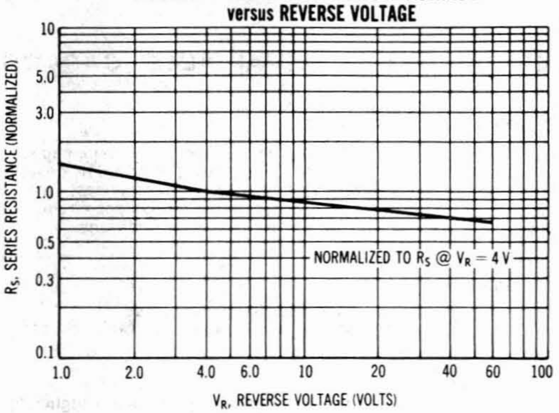


FIGURE 2 — NORMALIZED SERIES RESISTANCE versus REVERSE VOLTAGE

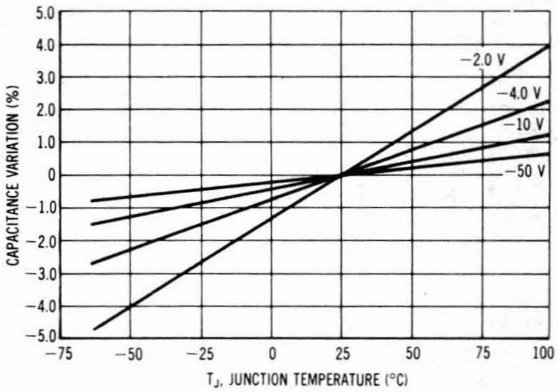


FIGURE 3 — CAPACITANCE VARIATION versus TEMPERATURE

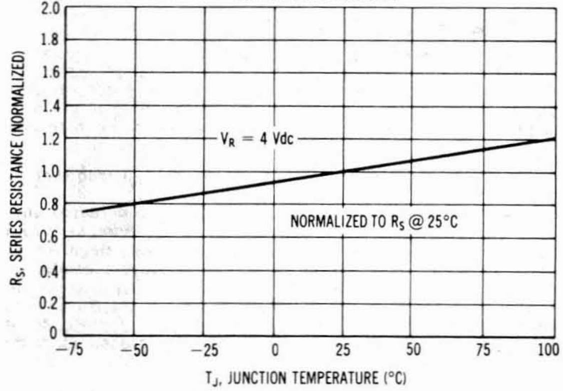


FIGURE 4 — NORMALIZED SERIES RESISTANCE versus TEMPERATURE

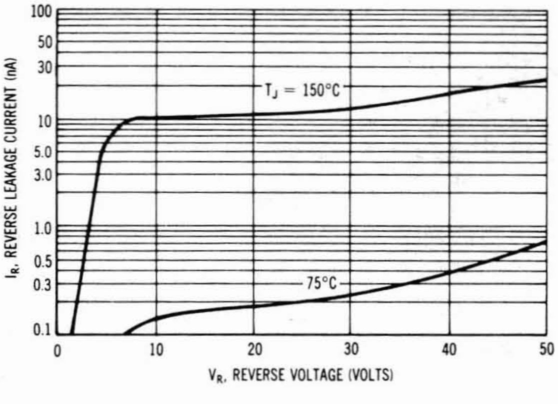


FIGURE 5 — REVERSE LEAKAGE CURRENT versus REVERSE VOLTAGE

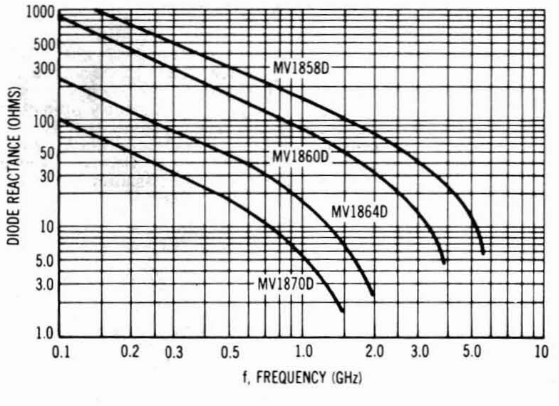


FIGURE 6 — DIODE REACTANCE versus FREQUENCY

EPICAP VOLTAGE-VARIABLE CAPACITANCE DIODE DEVICE CONSIDERATIONS

A. EPICAP NETWORK PRESENTATION

The equivalent circuit in Figure 7 shows the voltage capacitance and parasitic elements of an EPICAP diode. For design purposes at all but very high and very low frequencies, L_S, R_J, and C_C can be neglected. The simplified equivalent circuit of Figure 8 represents the diode under these conditions.

Definitions:

C_J — Voltage-Variable Junction Capacitance
R_S — Series Resistance (semiconductor bulk, contact, and lead resistance)
C_C — Case Capacitance
L_S — Series Inductance
R_J — Voltage-Variable Junction Resistance (negligible above 100 kHz)

FIGURE 7

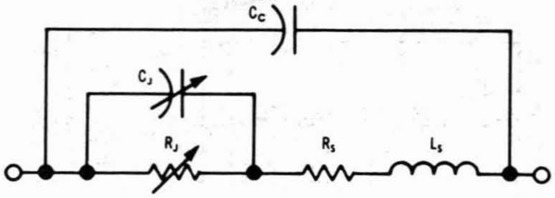
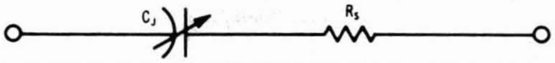


FIGURE 8



B. EPICAP CAPACITANCE vs REVERSE BIAS VOLTAGE

The most important design characteristic of an EPICAP diode is the C_T versus V_R variation as shown in equations 1 and 2. Since the designer is primarily interested in the slope of C_T versus V_R, the C_C, C_O, ϕ, and γ characteristics have been encompassed by the simplified equation 3. Min/max limits on α can be guaranteed over a specified V_R range.

$$C_T = C_C + C_J \tag{1}$$

$$C_T = C_C + \frac{C_o}{\left(1 + \frac{V_R}{\phi}\right)^{\gamma}} \tag{2}$$

$C_o = C_J$ at $V_R = 0$

$\phi =$ Contact Potential, $\phi \approx 0.6$ Volt

$V_R =$ Reverse Bias

$\gamma = C_J$ slope, $\gamma \approx 0.5$

$$C_T = \frac{K}{V_R{}^{\alpha}} \tag{3}$$

C. EPICAP CAPACITANCE vs FREQUENCY

Variations in EPICAP effective capacitance, as a function of operating frequency, can be derived from a simplified equivalent circuit similar to that of Figure 7, but neglecting R_S and R_J. The admittance expression for such a circuit is given in equation 4. Examination of equation 4 yields the following information:

At low frequencies, $C_{eq} \approx C_J$; at very high frequencies ($f \approx \infty$) $C_{eq} \approx C_C$.

As frequency is increased from 1 MHz, C_{eq} increases until it is maximum at $\omega^2 = 1/L_SC_J$; and as ω^2 is increased from $1/L_SC_J$ toward infinity, C_{eq} increases from a very negative capacitance (inductance) toward $C_{eq} = C_C$, a positive capacitance.

Very simple calculations for C_{eq} at higher frequencies indicate the problems encountered when capacity measurements are made above 1 MHz. As ω approaches $\omega_o = 1/\sqrt{L_SC_J}$, small variations in L_S cause extreme variations in measured diode capacitance.

$$Y = j\omega C_{eq} = j\omega C_c + \frac{j\omega C_J}{1 - \omega^2 L_S C_J} \tag{4}$$

D. EPICAP FIGURE OF MERIT (Q) AND CUTOFF FREQUENCY (f_{co})

The efficiency of EPICAP response to an input frequency is related to the Figure of Merit of the device as defined in equation 5. For very low frequencies, equation 6 applies whereas at high frequencies, where R_J can be neglected, equation 5 may be rewritten into the familiar form of equation 7.

Another useful parameter for EPICAP devices is the cutoff frequency (f_{co}), and is the frequency point where Q is equal to 1. Equation 8 gives this relationship.

$$Q = \frac{X_{Seq}}{R_{Seq}} \tag{5}$$

$$Q_{lf} = \frac{\omega C_J R_J{}^2}{R_J + R_S(1 + \omega^2 C_J{}^2 R_J{}^2)} \tag{6}$$

$$Q_{hf} = \frac{1}{\omega R_S C_{eq}} \tag{7}$$

$$f_{co} = Qf_{max} \approx \frac{1}{2\pi R_S C_{BVR}} \tag{8}$$

E. HARMONIC GENERATION USING EPICAPS

Efficient harmonic generation is possible with EPICAPS because of their high cutoff frequency and breakdown voltage. Since EPICAP junction capacitance varies inversely with the square root of the breakdown voltage, harmonic generator performance can be accurately predicted from various idealized models. Equation 9 gives the level of maximum input power for the EPICAP and equation 10 gives the relationships governing EPICAP circuit efficiency. In these equations, adequate heat sinking has been assumed.

$$P_{in(max)} = \frac{M(BV_R + \phi)^2}{R_S} \, \frac{f_{in}}{f_{co}} \tag{9}$$

$M(x2) = 0.0285; M(x3) = 0.0241; M(x4) = 0.196$

$$\text{Eff} = 1 - N\,\frac{f_{out}}{f_{co}} \tag{10}$$

$N(x2) = 20.8; N(x3) = 34.8; N(x4) = 62.5$

M and N are Constants

MV2101 thru MV2115

VVC

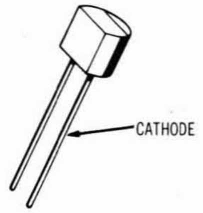
SILICON EPICAP DIODES

. . . designed in the popular PLASTIC PACKAGE for high volume requirements of FM Radio and TV tuning and AFC, general frequency control and tuning applications; providing solid-state reliability in replacement of mechanical tuning methods.

- High Q with Guaranteed Minimum Values
- Controlled and Uniform Tuning Ratio
- Standard Capacitance Tolerance – 10%
- Complete Typical Design Curves
- Case TO-92 with Two Leads

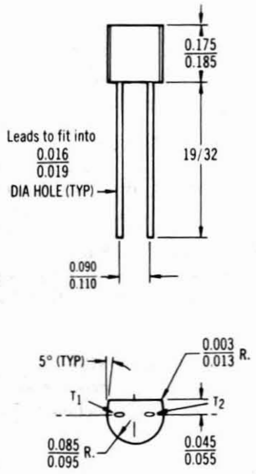
VOLTAGE-VARIABLE CAPACITANCE DIODES

6.8–100 pF
30 VOLTS



MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	30	Volts
Forward Current	I_F	200	mA
Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	280 2.8	mW mW/°C
Junction Temperature	T_J	+125	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C


0.175
0.185
Leads to fit into
0.016
0.019
DIA HOLE (TYP)
19/32
0.090
0.110
5° (TYP)
0.003
0.013 R.
T1
T2
0.085
0.095 R.
0.045
0.055

CASE 182

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic—All Types	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage (I_R = 10 μAdc)	BV_R	30	–	–	Vdc
Reverse Voltage Leakage Current (V_R = 25 Vdc, T_A = 25°C)	I_R	–	–	0.10	μAdc
Series Inductance (f = 250 MHz, Lead Length ≈ 1/16")	L_S	–	6.0	–	nH
Case Capacitance (f = 1.0 MHz, Lead Length ≈ 1/16")	C_C	–	0.18	–	pF
Diode Capacitance Temperature Coefficient (V_R = 4.0 Vdc, f = 1.0 MHz)	TC_C	–	280	400	ppm/°C

	C_T, Diode Capacitance V_R = 4.0 Vdc, f = 1.0 MHz pF			Q, Figure of Merit V_R = 4.0 Vdc, f = 50 MHz	TR, Tuning Ratio C_2/C_{30} f = 1.0 MHz		
Device	Min	Nom	Max	Min	Min	Typ	Max
MV2101	6.1	6.8	7.5	450	2.5	2.7	3.2
MV2102	7.4	8.2	9.0	450	2.5	2.8	3.2
MV2103	9.0	10.0	11.0	400	2.5	2.9	3.2
MV2104	10.8	12.0	13.2	400	2.5	2.9	3.2
MV2105	13.5	15.0	16.5	400	2.5	2.9	3.2
MV2106	16.2	18.0	19.8	350	2.5	2.9	3.2
MV2107	19.8	22.0	24.2	350	2.5	2.9	3.2
MV2108	24.3	27.0	29.7	300	2.5	3.0	3.2
MV2109	29.7	33.0	36.3	200	2.5	3.0	3.2
MV2110	35.1	39.0	42.9	150	2.5	3.0	3.2
MV2111	42.3	47.0	51.7	150	2.5	3.0	3.2
MV2112	50.4	56.0	61.6	150	2.6	3.0	3.3
MV2113	61.2	68.0	74.8	150	2.6	3.0	3.3
MV2114	73.8	82.0	90.2	100	2.6	3.0	3.3
MV2115	90.0	100.0	110.0	100	2.6	3.0	3.3

PARAMETER TEST METHODS

1. L_S, SERIES INDUCTANCE

L_S is measured on a shorted package at 250 MHz using an impedance bridge (Boonton Radio Model 250A RX Meter).

2. C_C, CASE CAPACITANCE

C_C is measured on an open package at 1.0 MHz using a capacitance bridge (Boonton Electronics Model 75A or equivalent).

3. C_T, DIODE CAPACITANCE

($C_T = C_C + C_J$). C_T is measured at 1.0 MHz using a capacitance bridge (Boonton Electronics Model 75A or equivalent).

4. TR, TUNING RATIO

TR is the ratio of C_T measured at 2.0 Vdc divided by C_T measured at 30 Vdc.

5. Q, FIGURE OF MERIT

Q is calculated by taking the G and C readings of an admittance bridge at the specified frequency and substituting in the following equations:

$$Q = \frac{2\pi fC}{G}$$

(Boonton Electronics Model 33AS8). Use Lead Length ≈1/16".

6. TC_C, DIODE CAPACITANCE TEMPERATURE COEFFICIENT

TC_C is guaranteed by comparing C_T at V_R = 4.0 Vdc, f = 1.0 MHz, T_A = -65°C with C_T at V_R = 4.0 Vdc, f = 1.0 MHz, T_A = +85°C in the following equation which defines TC_C:

$$TC_C = \frac{C_T(+85^\circ C) - C_T(-65^\circ C)}{85 + 65} \cdot \frac{10^6}{C_R(25^\circ C)}$$

Accuracy limited by measurement of C_T to ± 0.1 pF.

TYPICAL DEVICE PERFORMANCE

FIGURE 1 – DIODE CAPACITANCE versus REVERSE VOLTAGE

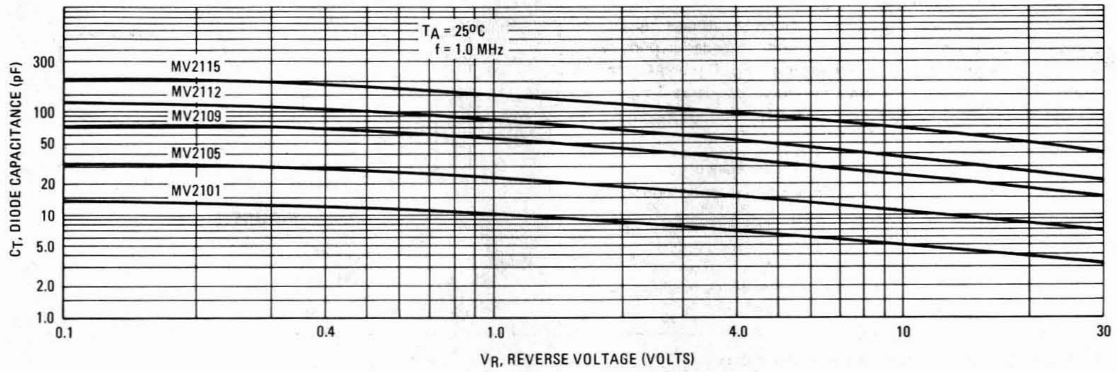


FIGURE 2 – NORMALIZED DIODE CAPACITANCE versus JUNCTION TEMPERATURE

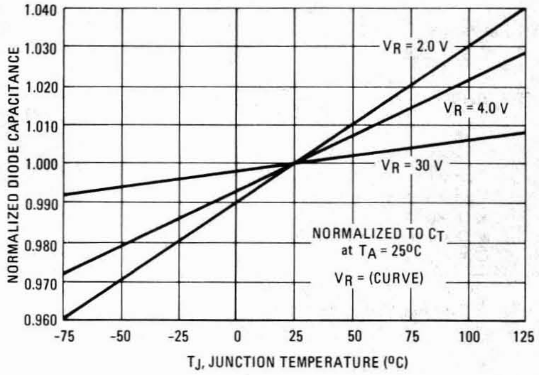


FIGURE 3 – REVERSE CURRENT versus REVERSE BIAS VOLTAGE

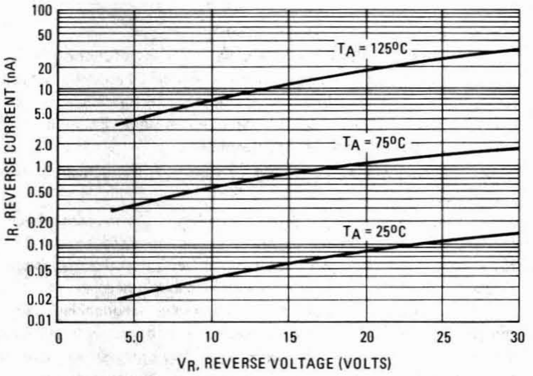


FIGURE 4 – FIGURE OF MERIT versus REVERSE VOLTAGE

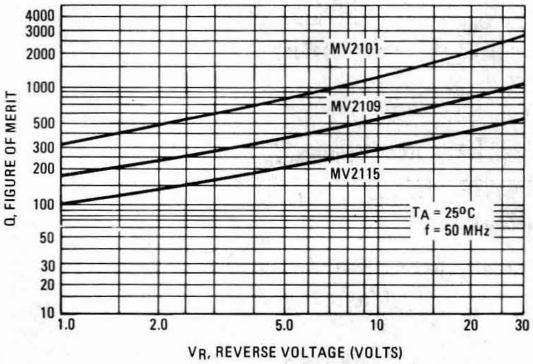
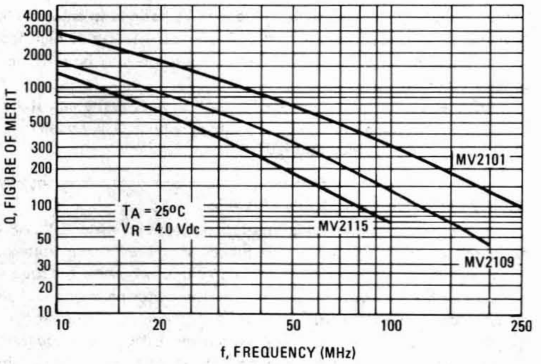


FIGURE 5 – FIGURE OF MERIT versus FREQUENCY



EPICAP VOLTAGE-VARIABLE CAPACITANCE DIODE DEVICE CONSIDERATIONS

A. Epicap Network Presentation

The equivalent circuit in Figure 6 shows the voltage capacitance and parasitic elements of an EPICAP diode. For design purposes at all but very high and very low frequencies, L_S, R_J, and C_C can be neglected. The simplified equivalent circuit of Figure 7 represents the diode under these conditions.

Definitions:

C_J – Voltage-Variable Junction Capacitance

R_S – Series Resistance (semiconductor bulk, contact, and lead resistance)

C_C – Case Capacitance

L_S – Series Inductance

R_J – Voltage-Variable Junction Resistance (negligible above 100 kHz)

FIGURE 6

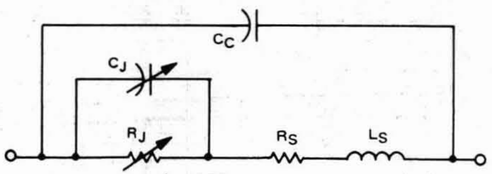
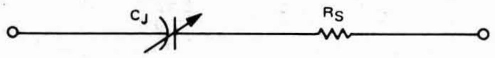


FIGURE 7



B. Epicap Capacitance versus Reverse Bias Voltage

The most important design characteristic of an EPICAP diode is the C_T versus V_R variation as shown in equations 1 and 2. Tuning Ratio, TR, between any two voltage points on curve of equation (2) is determined from equations (3) and (4).

$$C_T = C_C + C_J \qquad (1)$$

$$C_T = C_C + \frac{C_o}{\left(1 + \frac{V_R}{\phi}\right)^{\gamma}} \qquad (2)$$

$$\text{TR Junction} = \frac{C_{J1}}{C_{J2}} = \left(\frac{V_{R2} + \phi}{V_{R1} + \phi}\right)^{\gamma} \qquad (3)$$

$$\text{TR Diode} = \frac{C_{T1}}{C_{T2}} = \frac{C_{J1} + C_C}{C_{J2} + C_C} \qquad (4)$$

Conditions:

$C_o = C_J$ at $V_R = 0$

V_R = Reverse Bias (Volts)

γ, Diode Power Law, ≈ 0.44

ϕ, Contact Potential, ≈ 0.6 Volt

$C_c \approx 0.18$ pF

C. Epicap Capacitance versus Frequency

Variations in EPICAP effective capacitance, as a function of operating frequency, can be derived from a simplified equivalent circuit similar to that of Figure 6, but neglecting R_S and R_J. The admittance expression for such a circuit is given in equation 5. Examination of equation 5 yields the following information:

At low frequencies, $C_{eq} \approx C_J$; at very high frequencies ($f \approx \infty$) $C_{eq} \approx C_C$.

As frequency is increased from 1.0 MHz, C_{eq} increases until it is maximum at $\omega^2 = 1/L_SC_J$; and as ω^2 is increased from $1/L_SC_J$ toward infinity, C_{eq} increases from a very negative capacitance (inductance) toward $C_{eq} = C_C$, a positive capacitance.

Very simple calculations for C_{eq} at higher frequencies indicate the problems encountered when capacity measurements are made above 1.0 MHz. As ω approaches $\omega_o = 1/\sqrt{L_SC_J}$, small variations in L_S cause extreme variations in measured diode capacitance.

$$Y = j\omega C_{eq} = j\omega C_C + \frac{j\omega C_J}{1 - \omega^2 L_S C_J} \qquad (5)$$

D. EPICAP Figure of Merit (Q) and Cutoff Frequency (f_{co})

The efficiency of EPICAP response to an input frequency is related to the Figure of Merit of the device as defined in equation 6. For very low frequencies, equation 7 applies whereas at high frequencies, where R_J can be neglected, equation 6 may be rewritten into the familiar form of equation 8.

Another useful parameter for EPICAP devices is the cutoff frequency (f_{co}), and is the frequency point where Q is equal to 1. Equation 9 gives this relationship.

$$Q = \frac{X_{Seq}}{R_{Seq}} \qquad (6)$$

$$Q_{Lf} = \frac{\omega C_J R_J{}^2}{R_J + R_S(1 + \omega^2 C_J{}^2 R_J{}^2} \qquad (7)$$

$$Q_{hf} = \frac{1}{\omega R_S C_{eq}} \qquad (8)$$

$$f_{co} = Qf_{meas} \approx \frac{1}{2\pi R_S C_{BVR}} \qquad (9)$$

E. Harmonic Generation Using EPICAPS

Efficient harmonic generation is possible with EPICAPS because of their high cutoff frequency and breakdown voltage. Since EPICAP junction capacitance varies inversely with the square root of the breakdown voltage, harmonic generator performance can be accurately predicted from various idealized models. Equation 10 gives the level of maximum input power for the EPICAP and equation 11 gives the relationships governing EPICAP circuit efficiency. In these equations, adequate heat sinking has been assumed.

$$P_{in(max)} = \frac{M(BV_R + \phi)^2}{R_S} \; \frac{f_{in}}{f_{co}} \qquad (10)$$

$M(x2) = 0.0285; M(x3) = 0.0241; M(x4) = 0.196$

$$\text{Eff} = 1 - N\frac{f_{out}}{f_{co}} \qquad (11)$$

$N(x2) = 20.8; N(x3) = 34.8; N(x4) = 62.5$

M and N are Constants

MZ500-1 thru MZ500-40 (SILICON)

400 mW
2.4-100 V

CASE 51
(DO-7)

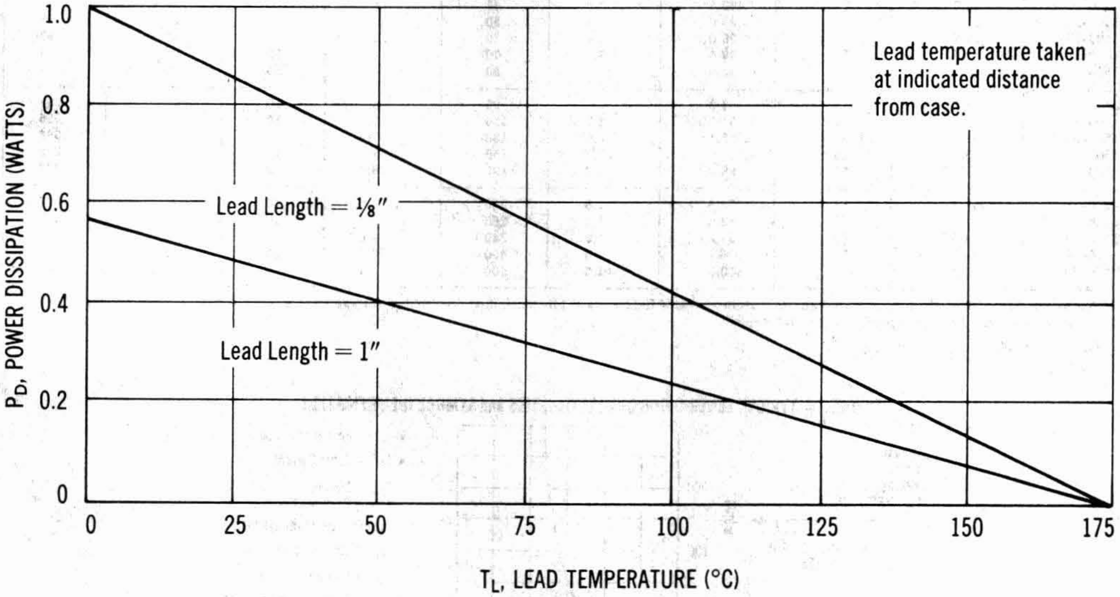
Miniature plastic encapsulated zener diodes for regulated power supply circuits, surge protection, arc suppression and other functions in television, automotive and other consumer product applications.

MAXIMUM RATINGS

Rating	Value	Unit
DC Power Dissipation @ T_L = 50°C	400	mW
Derate above 50°C	3.2	mW/°C
Junction Temperature*	-65 to +175	°C

*Maximum lead temperature for 10 seconds at 1/16" from case = 230°C

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



MECHANICAL CHARACTERISTICS

CASE: Void free, transfer molded.

FINISH: All external surfaces are corrosion resistant. Leads are readily solderable.

POLARITY: Cathode indicated by color band. When operated in zener mode, cathode will be positive with respect to anode.

MOUNTING POSITION: Any.

WEIGHT: 0.42 gram (approximately).

MZ500-1 thru MZ500-40 (continued)

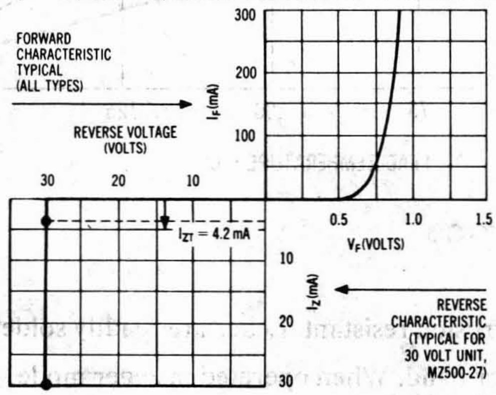
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted) V_F = 1.5 V max @ 200 mA on all types

Type No.	Zener Voltage V_Z @ I_{ZT} Volts* Min	Nom	Max	Test Current I_{ZT} mA	Typical Z_{ZT} @ I_{ZT} Ohms	Max DC Zener Current I_{ZM} mA	Maximum Reverse Leakage Current I_R μA Max	@ V_R Volts	Typical Temperature Coefficient %/°C
MZ500-1	2.16	2.4	2.64	20	35	150	—	—	-.085
MZ500-2	2.43	2.7	2.94	20	30	135	—	—	-.080
MZ500-3	2.7	3.0	3.3	20	30	120	—	—	-.075
MZ500-4	2.97	3.3	3.63	20	30	110	20	1	-.070
MZ500-5	3.24	3.6	3.96	20	25	100	20	1	-.065
MZ500-6	3.51	3.9	4.29	20	25	95	20	1	-.060
MZ500-7	3.87	4.3	4.73	20	25	85	5	1	-.050
MZ500-8	4.23	4.7	5.17	20	20	80	5	1	-.043
MZ500-9	4.59	5.1	5.61	20	20	70	5	1	±.030
MZ500-10	5.04	5.6	6.16	20	15	65	5	1	±.028
MZ500-11	5.58	6.2	6.82	20	10	60	5	1	+.045
MZ500-12	6.12	6.8	7.48	20	5	55	5	1	.050
MZ500-13	6.75	7.5	8.25	20	10	50	5	1	.058
MZ500-14	7.38	8.2	9.02	20	10	45	5	1	.062
MZ500-15	8.19	9.1	10.02	20	10	40	5	1	.068
MZ500-16	9.0	10	11.0	20	20	36	5	1	.075
MZ500-17	9.9	11	12.1	20	20	35	5	1	.076
MZ500-18	10.8	12	13.2	20	30	32	5	1	.077
MZ500-19	11.7	13	14.3	9.5	15	30	10	9.4	.079
MZ500-20	13.5	15	16.5	8.5	20	26	10	10.8	.082
MZ500-21	14.4	16	17.6	7.8	20	25	10	11.5	.083
MZ500-22	16.2	18	19.8	7.0	25	21	10	13.0	.085
MZ500-23	18.0	20	22.0	6.2	30	19	10	14.4	.086
MZ500-24	19.8	22	24.2	5.6	30	17	10	15.8	.087
MZ500-25	21.6	24	26.4	5.2	35	16	10	17.3	.088
MZ500-26	24.3	27	29.7	4.6	45	14	10	19.4	.090
MZ500-27	27.0	30	33.0	4.2	50	13	10	21.6	.091
MZ500-28	29.7	33	36.3	3.8	60	12	10	23.8	.092
MZ500-29	32.4	36	39.6	3.4	70	11	10	25.9	.093
MZ500-30	35.1	39	42.9	3.2	80	9.1	10	28.1	.094
MZ500-31	38.7	43	47.3	3.0	95	8.8	10	31.0	.095
MZ500-32	42.3	47	51.7	2.7	110	7.9	10	33.8	.095
MZ500-33	45.9	51	56.1	2.5	130	7.4	10	36.7	.096
MZ500-34	50.4	56	61.6	2.2	150	6.9	10	40.3	.096
MZ500-35	55.8	62	68.2	2.0	190	6.0	10	44.6	.097
MZ500-36	61.2	68	74.8	1.8	240	5.5	10	49.0	.097
MZ500-37	67.5	75	82.5	1.7	280	5.1	10	54.0	.098
MZ500-38	73.8	82	90.2	1.5	340	4.6	10	59.0	.098
MZ500-39	81.9	91	100.1	1.4	400	4.2	10	65.5	.099
MZ500-40	90.0	100	110.0	1.3	500	3.7	10	72.0	.100

*1. Nominal voltages other than those stated above, matched sets of tight voltage tolerance devices, tighter voltage tolerances and double anode clippers, are available from the .4M3.3ZS5 series on special request.

2. Voltages to 200 volts are available.

FIGURE 2 — TYPICAL ZENER DIODE CHARACTERISTICS and SYMBOL IDENTIFICATION



- I_F — Forward Current
- I_Z — Zener Current
- I_{ZM} — Maximum DC Zener Current (Limited by Power Dissipation)
- I_{ZT} — Zener Test Current
- V_F — Forward Voltage
- V_Z — Nominal Zener Voltage
- Z_Z — Zener Impedance
- Z_{ZT} — Zener Impedance at Test Current (I_{ZT})

MZ600 SERIES (SILICON)

6.2 Volts

MZ800 SERIES

8.4 Volts

PRECISION REFERENCE DIODES

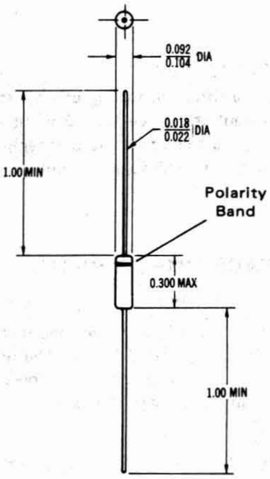
. . . designed, manufactured and tested for applications requiring a precision voltage reference with ultra-high stability of voltage with time and temperature change.

Special test laboratory uses precision measurement equipment, four-terminal (separate contacts for current and voltage) measurement techniques and voltage standards to provide calibration directly traceable to the National Bureau of Standards.

PRECISION REFERENCE DIODES

with
CERTIFIED
ZENER VOLTAGE-TIME
STABILITY

CASE 51
(DO-7)



DO-7 GLASS PACKAGE

MECHANICAL CHARACTERISTICS:
Case:
Glass, Hermetically Sealed
Leads: Dumet
Lead Finish:
Nickel 50-100 μin. then gold plated 50-200 μin.
Weight:
0.2 grams (approx)

Certified TEST DATA

Every Precision Reference Diode is individually serialized and its test data recorded on a Certificate of Precision that accompanies the device when shipped. This data shows:

- Device voltages at each test temperature (+25, +75 and +100°C)
- Voltage stability within the measuring temperature range
- Actual device voltage at 168 hour intervals during verification test
- Voltage stability throughout the entire 1000 hour test period
- Certification of Precision
- All diodes are marked with the device type number and polarity band

OPERATING TEMPERATURE RANGE:* 25 to 100°C.

MZ600 SERIES (Voltage 6.2V ± 5%, I_{ZT} = 7.5 mAdc †, ΔV_Z = 2.5 mVdc)**

Type No.	Voltage-Time Stability (μV/1000 Hours)	Parts Per Million Change (ppm/1000 Hours)
MZ605	30 Maximum	< 5
MZ610	60 Maximum	<10
MZ620	120 Maximum	<20
MZ640	240 Maximum	<40

DYNAMIC IMPEDANCE: 10 ohms at I_{ZT} = 7.5 mAdc, I_{ac} = 0.75 mA.

MZ800 SERIES (Voltage 8.4V ± 5%, I_{ZT} = 10 mAdc†, ΔV_Z = 3.5 mVdc)**

Type No.	Voltage-Time Stability (μV/1000 Hours)	Parts Per Million Change (ppm/1000 Hours)
MZ805	45 Maximum	< 5
MZ810	90 Maximum	<10
MZ820	180 Maximum	<20
MZ840	360 Maximum	<40

DYNAMIC IMPEDANCE: 15 ohms at I_{ZT} = 10 mAdc, I_{ac} = 1.0 mA.

NOTES

†TEST CURRENT

For certification testing of time stability, Motorola maintains I_{ZT} constant and repeatable to ±0.05 μA tolerance. For voltage tolerance, impedance and voltage temperature stability I_{ZT} needs to be held to 0.01 mA tolerance only.

*Maximum limits for use as a precision reference device. Limits are well below the maximum thermal limits.

**VOLTAGE-TEMPERATURE STABILITY: Maximum allowable voltage change between voltages recorded at 25, 75 and 100° C ambient.

VOLTAGE-TIME STABILITY
(ΔV_Z/1000 Hours).

The device voltage is read and recorded initially and at 168 hour intervals through 1000 hours. The maximum change of voltage between readings, taken at any of the seven points, must be less than the maximum voltage change per 1000 hours specified as Voltage-Time Stability.

TURN-ON CHARACTERISTICS

Precision Reference Diodes have been tested to determine the behavior of the device under interrupted power operation.

To insure specified performance, adequate time must be allowed for the device and its environment to reach thermal equilibrium. "Warm-up" time may range from 10 to 30 minutes. Thermal equilibrium is reached when the chamber is cycling at the required temperature with the device energized.

After this "warm-up" period, the device voltage will be between the minimum and the maximum voltage of those recorded at the seven points of the Voltage-Time Stability certification.

MOUNTING

Excellent results have been obtained by using a mechanical mounting. If necessary, the device may be soldered into a circuit using a heat sink between the heat source and the body of the diode. A low thermal EMF solder is recommended.

SPECIAL NOTE

Voltage tolerance less than 5.0% is available upon special request.

Precision Reference Diodes capable of meeting special requirements for standard voltages regardless of required test current, temperature range, or test temperatures are available. Custom requirements of particular devices for specific applications are also available.

VOLTAGE-CURRENT STABILITY CHARACTERISTICS

For verification of time stability, and for repeatable operation, I_{ZT} should be maintained with a tolerance of ±0.1 μA. Figure 1 will assist in design where the supply current stability cannot be maintained to better than 0.2 μA deviation.

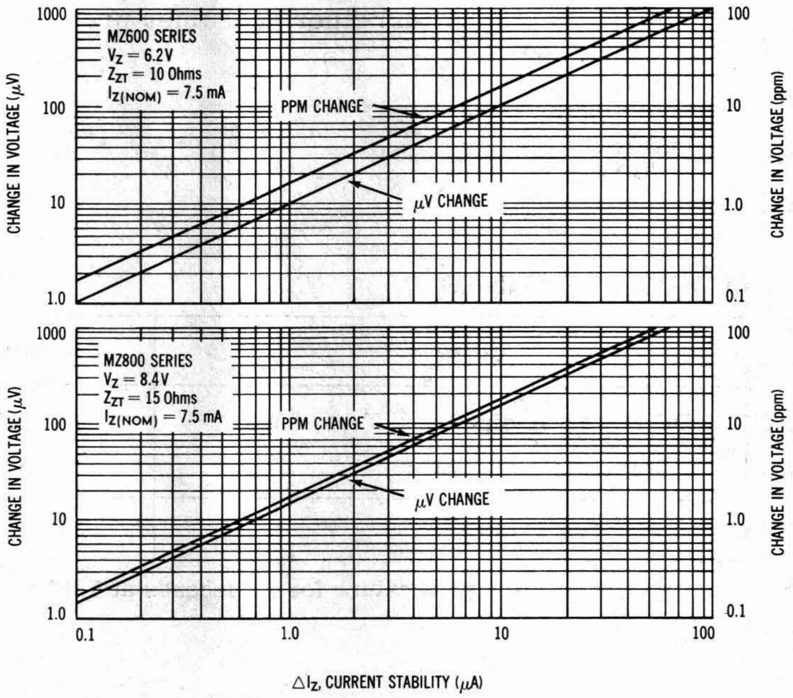


FIGURE 1 – MAXIMUM VOLTAGE CHANGE, IN μV AND PPM, DUE TO CURRENT SUPPLY STABILITY

VOLTAGE-TEMPERATURE CHARACTERISTICS

CHOICE OF OPERATING TEMPERATURE

The stability certification is performed at 65°C ± 0.02°C. The operating temperature can be selected within the operating temperature range. If the desired temperature is not 65°C, the precise voltage of the device will be different but the certified stability will still be observed.

VOLTAGE TEMPERATURE STABILITY

For verification of time stability and/or repeatable operation, the ambient temperature should be controlled to ±0.1°C.

Figure 2 will assist in designs where ambient temperature cannot be controlled to better than 0.2°C deviation.

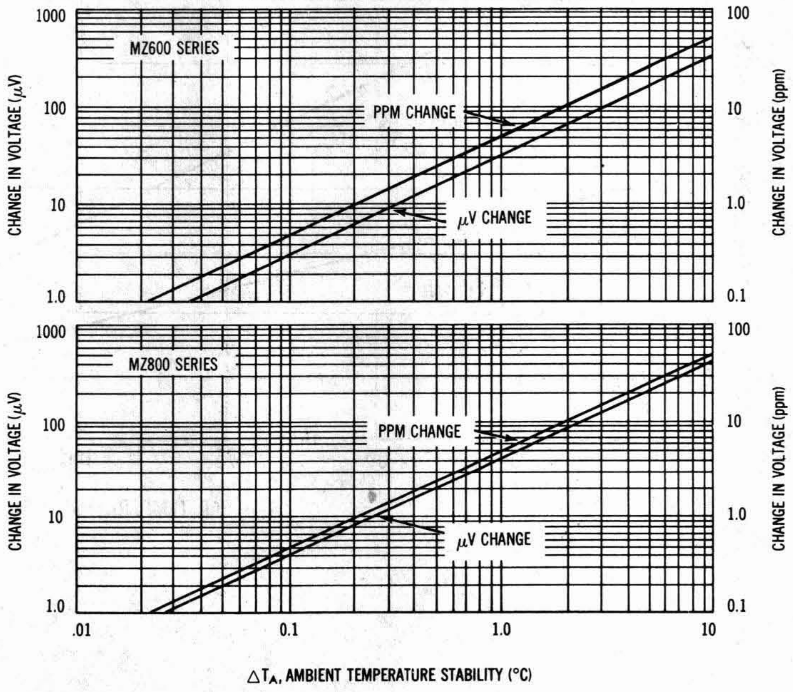
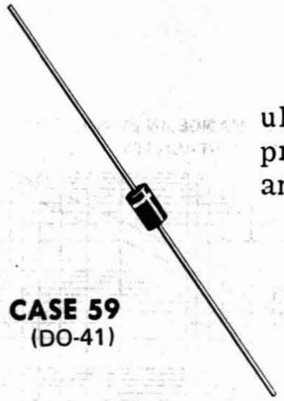


FIGURE 2 – TYPICAL VOLTAGE CHANGE, IN μV AND PPM, DUE TO AMBIENT TEMPERATURE STABILITY

MZ1000-1 thru MZ1000-37 (SILICON)

1 W
3.3-100 V



CASE 59
(DO-41)

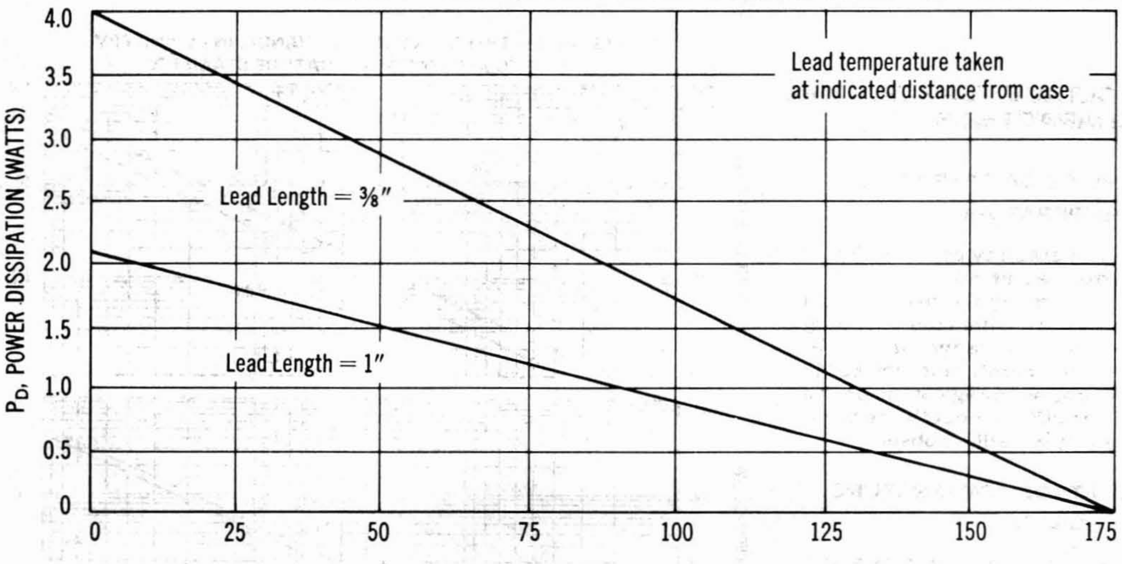
Miniature plastic encapsulated zener diodes for regulated power supply circuits, surge protection, arc suppression and other functions in television, automotive and other consumer product applications.

MAXIMUM RATINGS

Rating	Value	Unit
DC Power Dissipation @ T_L = 50°C Derate above 50°C	1.5 8.33	Watt mW/°C
Lead Temperature*	-65 to +175	°C

*Maximum lead temperature for 10 seconds at 1/16" from case = 230°C

FIGURE 1 — POWER-TEMPERATURE DERATING CURVE



MZ1000-1 thru MZ1000-37 (continued)

MECHANICAL CHARACTERISTICS

CASE: Void free, transfer molded.

FINISH: All external surfaces are corrosion resistant. Leads are readily solderable.

POLARITY: Cathode indicated by color band. When operated in zener mode, cathode will be positive with respect to anode.

MOUNTING POSITION: Any.

WEIGHT: 0.42 gram (approximately).

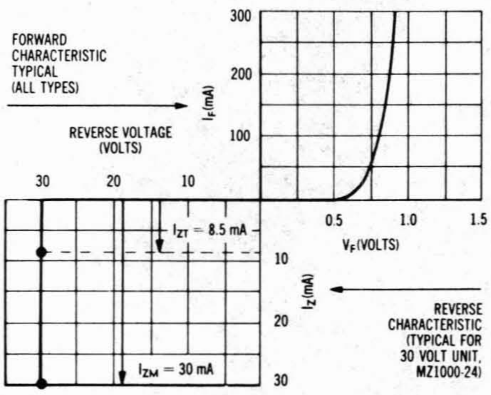
ELECTRICAL CHARACTERISTICS (T_C = 25°C unless otherwise noted) V_F = 1.5 V max @ 200 mA on all types

Type No.	Zener Voltage V_Z @ I_{ZT} Volts*			Test Current I_{ZT} mA	Typical Z_{ZT} @ I_{ZT} Ohms	Max DC Zener Current I_{ZM} mA	Maximum Reverse Leakage Current		Temperature Coefficient %/°C
	Min	Nom	Max				I_R @ µA Max	V_R Volts	
MZ1000-1	2.97	3.3	3.63	76	15	276	150	1	-.070
MZ1000-2	3.24	3.6	3.96	69	15	252	150	1	-.065
MZ1000-3	3.51	3.9	4.29	64	13.5	234	75	1	-.060
MZ1000-4	3.87	4.3	4.73	58	13.5	217	20	1	-.050
MZ1000-5	4.23	4.7	5.17	53	12	193	20	1	-.043
MZ1000-6	4.59	5.1	5.61	49	10.5	178	20	1	±.030
MZ1000-7	5.04	5.6	6.16	45	7.5	162	20	2	±.028
MZ1000-8	5.58	6.2	6.82	41	3	146	20	3	+.045
MZ1000-9	6.12	6.8	7.48	37	5.25	133	20	4	.050
MZ1000-10	6.75	7.5	8.25	34	6	121	20	5	.058
MZ1000-11	7.38	8.2	9.02	31	6.75	110	20	5.9	.062
MZ1000-12	8.19	9.1	10.01	28	7.5	100	20	6.6	.068
MZ1000-13	9	10	11	25	10.5	91	20	7.2	.075
MZ1000-14	9.9	11	12.1	23	12	83	10	8.0	.076
MZ1000-15	10.8	12	13.2	21	13.5	76	10	8.6	.077
MZ1000-16	11.7	13	14.3	19	15	69	10	9.4	.079
MZ1000-17	13.5	15	16.5	17	21	61	10	10.8	.082
MZ1000-18	14.4	16	17.6	15.5	24	57	10	11.5	.083
MZ1000-19	16.2	18	19.8	14	30	50	10	13.0	.085
MZ1000-20	18	20	22	12.5	33	45	10	14.4	.086
MZ1000-21	19.8	22	24.2	11.5	34.5	41	10	15.8	.087
MZ1000-22	21.6	24	26.4	10.5	37.5	38	10	17.3	.088
MZ1000-23	24.3	27	29.7	9.5	52.5	34	10	19.4	.090
MZ1000-24	27	30	33	8.5	60	30	10	21.6	.091
MZ1000-25	29.7	33	36.3	7.5	67.5	27	10	23.8	.092
MZ1000-26	32.4	36	39.6	7	75	25	10	25.9	.093
MZ1000-27	35.1	39	42.9	6.5	90	23	10	28.1	.094
MZ1000-28	38.7	43	47.3	6	105	22	10	31.0	.095
MZ1000-29	42.3	47	51.7	5.5	120	19	10	33.8	.095
MZ1000-30	45.9	51	56.1	5	142.5	18	10	36.7	.096
MZ1000-31	50.4	56	61.6	4.5	165	16	10	40.3	.096
MZ1000-32	55.8	62	68.2	4	177.5	14	10	44.6	.097
MZ1000-33	61.2	68	74.8	3.7	225	13	10	49.0	.097
MZ1000-34	67.5	75	82.5	3.3	262.5	12	10	54.0	.098
MZ1000-35	73.8	82	90.2	3	300	11	10	59.0	.098
MZ1000-36	81.9	91	100.1	2.8	375	10	10	65.5	.099
MZ1000-37	90	100	110	2.5	525	9	10	72.0	.100

*1. Nominal voltages other than those stated above, matched sets, and tighter voltage tolerances are available, 1N4728 thru 1N4764 series (1M3.3ZS10 thru 1M100ZS10).

2. Voltages to 200 volts are available in other package configurations on request.

FIGURE 2 — TYPICAL ZENER DIODE CHARACTERISTICS and SYMBOL IDENTIFICATION



- I_F – Forward Current
- I_Z – Zener Current
- I_{ZM} – Maximum DC Zener Current (Limited by Power Dissipation)
- I_{ZT} – Zener Test Current
- V_F – Forward Voltage
- V_Z – Nominal Zener Voltage
- Z_Z – Zener Impedance
- Z_{ZT} – Zener Impedance at Test Current (I_{ZT})

MZ4614 thru MZ4627

For Specifications, See 1N4099 Data.

M4L3052 thru M4L3056

For Specifications, See 1N5158 Data.

HARDWARE

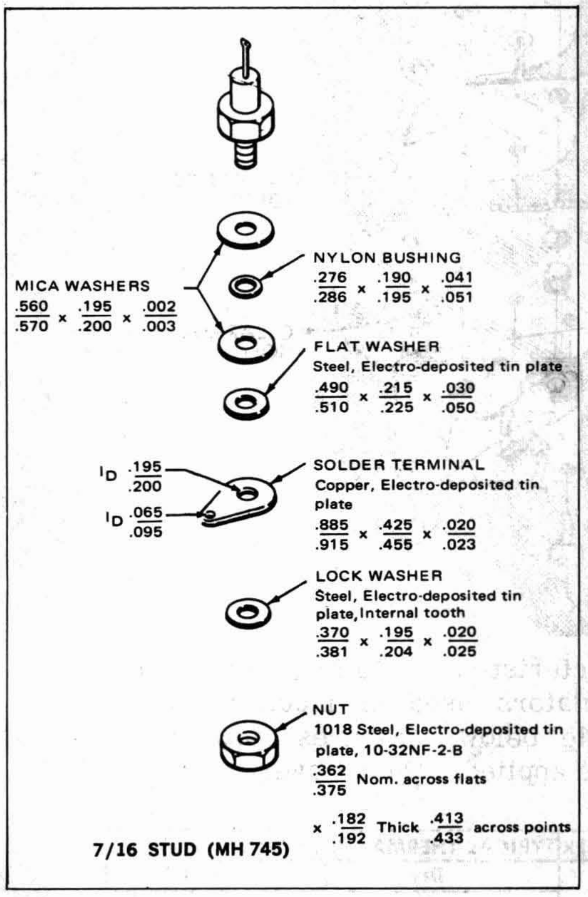
THE FOLLOWING SEMICONDUCTOR HARDWARE IS INCLUDED IN THIS SECTION.

MH745	Rectifier - zener diode mounting hardware
MH746	
MK10	Power transistor mounting hardware
MK15	
MK20	
MK25	
MK30	
MK35	
MS10	Power transistor heat-sinks
MS15	
XC63	Integrated circuit interconnecting patchboards
XC72	
XC73	

MH745
MH746

MOUNTING HARDWARE for STUD PACKAGES

7/16" RECTIFIER and 10 WATT ZENER DIODE
11/16" RECTIFIER and 50 WATT ZENER DIODE



MICA WASHERS
$\frac{.560}{.570} \times \frac{.195}{.200} \times \frac{.002}{.003}$

NYLON BUSHING
$\frac{.276}{.286} \times \frac{.190}{.195} \times \frac{.041}{.051}$

FLAT WASHER
Steel, Electro-deposited tin plate
$\frac{.490}{.510} \times \frac{.215}{.225} \times \frac{.030}{.050}$

ID $\frac{.195}{.200}$

ID $\frac{.065}{.095}$

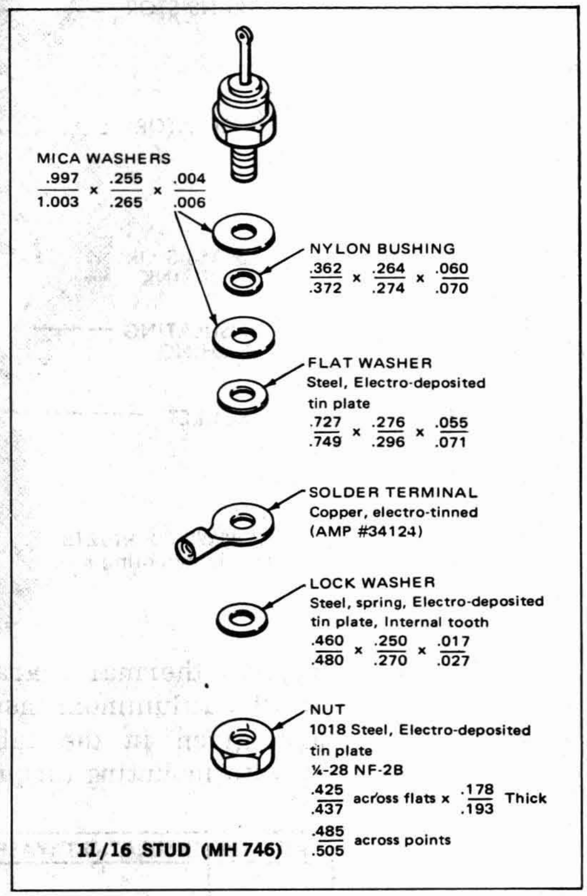
SOLDER TERMINAL
Copper, Electro-deposited tin plate
$\frac{.885}{.915} \times \frac{.425}{.455} \times \frac{.020}{.023}$

LOCK WASHER
Steel, Electro-deposited tin plate, Internal tooth
$\frac{.370}{.381} \times \frac{.195}{.204} \times \frac{.020}{.025}$

NUT
1018 Steel, Electro-deposited tin plate, 10-32NF-2-B
$\frac{.362}{.375}$ Nom. across flats

$\times \frac{.182}{.192}$ Thick $\frac{.413}{.433}$ across points

7/16 STUD (MH 745)



MICA WASHERS
$\frac{.997}{1.003} \times \frac{.255}{.265} \times \frac{.004}{.006}$

NYLON BUSHING
$\frac{.362}{.372} \times \frac{.264}{.274} \times \frac{.060}{.070}$

FLAT WASHER
Steel, Electro-deposited tin plate
$\frac{.727}{.749} \times \frac{.276}{.296} \times \frac{.055}{.071}$

SOLDER TERMINAL
Copper, electro-tinned
(AMP #34124)

LOCK WASHER
Steel, spring, Electro-deposited tin plate, Internal tooth
$\frac{.460}{.480} \times \frac{.250}{.270} \times \frac{.017}{.027}$

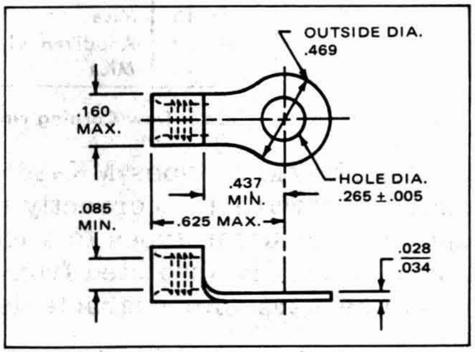
NUT
1018 Steel, Electro-deposited tin plate
¼-28 NF-2B
$\frac{.425}{.437}$ across flats x $\frac{.178}{.193}$ Thick
$\frac{.485}{.505}$ across points

11/16 STUD (MH 746)

Mounting hardware is supplied with the units. For additional hardware, order by kit number:

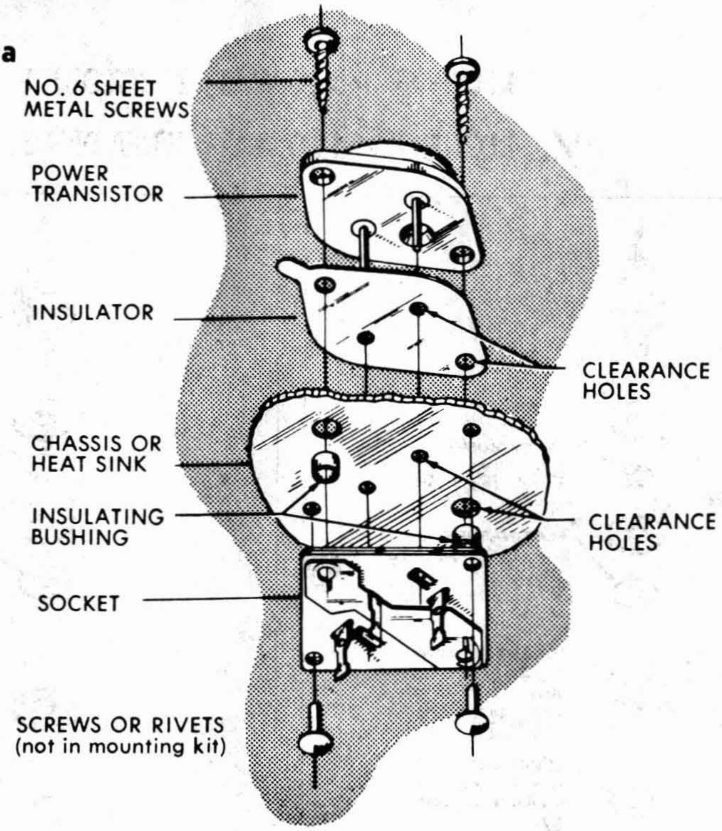
MH745 — 7/16" STUD MOUNTING HARDWARE

MH746 — 11/16" STUD MOUNTING HARDWARE



POWER TRANSISTOR MOUNTING KITS

MK-10 – teflon
MK-15 – mica
MK-20 – anodized aluminum
MK-25 – mica


NO. 6 SHEET METAL SCREWS
POWER TRANSISTOR
INSULATOR
CLEARANCE HOLES
CHASSIS OR HEAT SINK
INSULATING BUSHING
CLEARANCE HOLES
SOCKET
SCREWS OR RIVETS (not in mounting kit)

Typical thermal characteristics for teflon, mica, and anodized aluminum insulators used in mounting kits are given in the table below. (Figures may vary with mounting torque applied. Do not over stress.)

KIT TYPE	INSULATING WASHER	TYPICAL THERMAL RESISTANCE (°C/Watt)	
		Dry	With DC4*
–	No Insulator	.20	.10
MK-10	Teflon	1.45	.80
MK-15	Mica	.80	.40
MK-20	Anodized Aluminum	.40	.35
MK-25	Mica	.80	.40

*DC4 is Dow Corning No. 4 Silicone Lubricant.

Mounting kits, types MK-10, MK-15, MK-20, and MK-25 provide the necessary hardware for correctly mounting all TO-3 and TO-66 industry standard power transistor types to a chassis. With these kits, power transistors can be electrically insulated from the heat sink chassis, while maintaining complete heat transfer characteristics.

Included in these highly useful kits are a transistor mounting socket, front and back mounting templates for hole drilling guides, two #6 mounting screws, two insulating bushings, an insulating washer and complete mounting instructions.

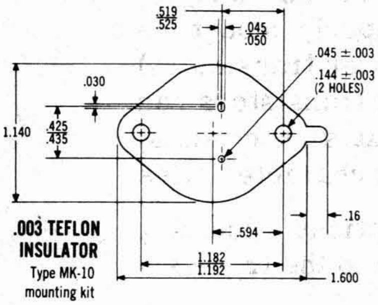
MK-10, MK-15, MK-20, MK-25 (continued)

The teflon-coated glass cloth insulating washer, included in kit MK-10, will find use in installations requiring an insulator of excellent durability. The mica insulator, in kit MK-15 and MK-25, is characterized by very high thermal conductivity. In applications where both good thermal conduction and durability are necessary, the anodized aluminum insulator supplied in kit MK-20, is recommended.

The transistor socket included in all mounting kits, is made of rugged laminated phenolic, with contacts of phosphor bronze.

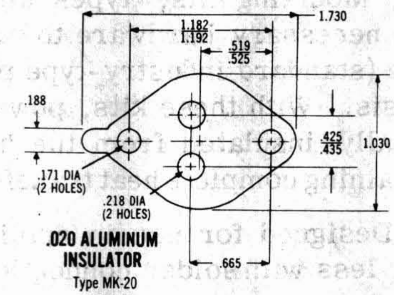
Three cadmium plated solder lugs, having a 15-amp maximum current capacity, are provided for base, emitter and collector connections.

TO-3



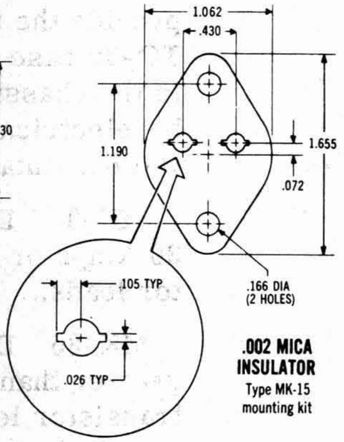
.519
.525
.045
.050
.045 ±.003 DIA
.144 ±.003 DIA
(2 HOLES)
.030
1.140
.425
.435
.16
.594
1.182
1.192
1.600

.003 TEFLON INSULATOR
Type MK-10
mounting kit



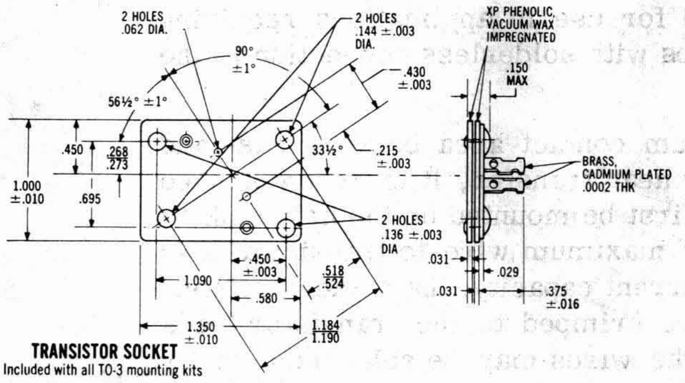
1.730
1.182
1.192
.519
.525
.188
.425
.435
1.030
.171 DIA
(2 HOLES)
.218 DIA
(2 HOLES)
.665

.020 ALUMINUM INSULATOR
Type MK-20
mounting kit



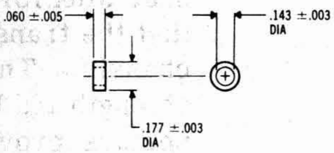
1.062
.430
1.190
1.655
.072
.105 TYP
.026 TYP
.166 DIA
(2 HOLES)

.002 MICA INSULATOR
Type MK-15
mounting kit



2 HOLES
.062 DIA.
2 HOLES
.144 ±.003
DIA.
90°
±1°
.430
±.003
56½° ±1°
.450
.268
.273
33½°
.215
±.003
1.000
±.010
.695
2 HOLES
.136 ±.003
DIA
.450
±.003
1.090
.580
.518
.524
1.350
±.010
1.184
1.190
XP PHENOLIC,
VACUUM WAX
IMPREGNATED
.150
MAX
BRASS,
CADMIUM PLATED
.0002 THK
.031
.029
.031
.375
±.016

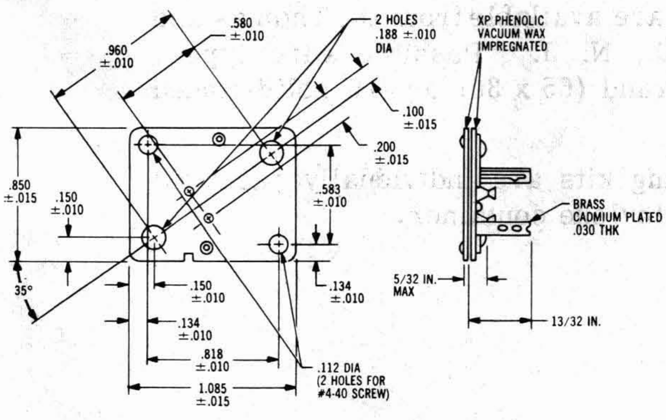
TRANSISTOR SOCKET
Included with all TO-3 mounting kits



.060 ±.005
.143 ±.003
DIA
.177 ±.003
DIA

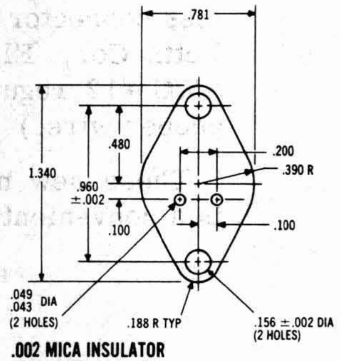
TEFLON INSULATING BUSHING
Included with all mounting kits

TO-66



.580
±.010
.960
±.010
2 HOLES
.188 ±.010
DIA
XP PHENOLIC
VACUUM WAX
IMPREGNATED
.100
±.015
.200
±.015
.850
±.015
.150
±.010
.583
±.010
BRASS
CADMIUM PLATED
.030 THK
35°
.150
±.010
.134
±.010
.134
±.010
5/32 IN.
MAX
13/32 IN.
.818
±.010
.112 DIA
(2 HOLES FOR
#4-40 SCREW)
1.085
±.015

TRANSISTOR SOCKET
Included with all TO-66 mounting kits



.781
.480
.200
.390 R
1.340
.960
±.002
.100
.100
.049
.043 DIA
(2 HOLES)
.188 R TYP
.156 ±.002 DIA
(2 HOLES)

.002 MICA INSULATOR
Type MK-25 mounting kit

TEFLON INSULATING BUSHING
Included with all mounting kits
(Same as for TO-3)

POWER TRANSISTOR MOUNTING KITS

Mounting kits, types MK-30 and MK-35, provide the necessary hardware to properly mount the TO-36 case (standard industry-type power transistors) to the chassis. With these kits, power transistors can be electrically insulated from the heat sink chassis, while maintaining complete heat transfer characteristics

MK-30 Designed for use in applications requiring 30 Amps or less with solder connection to the transistor leads.

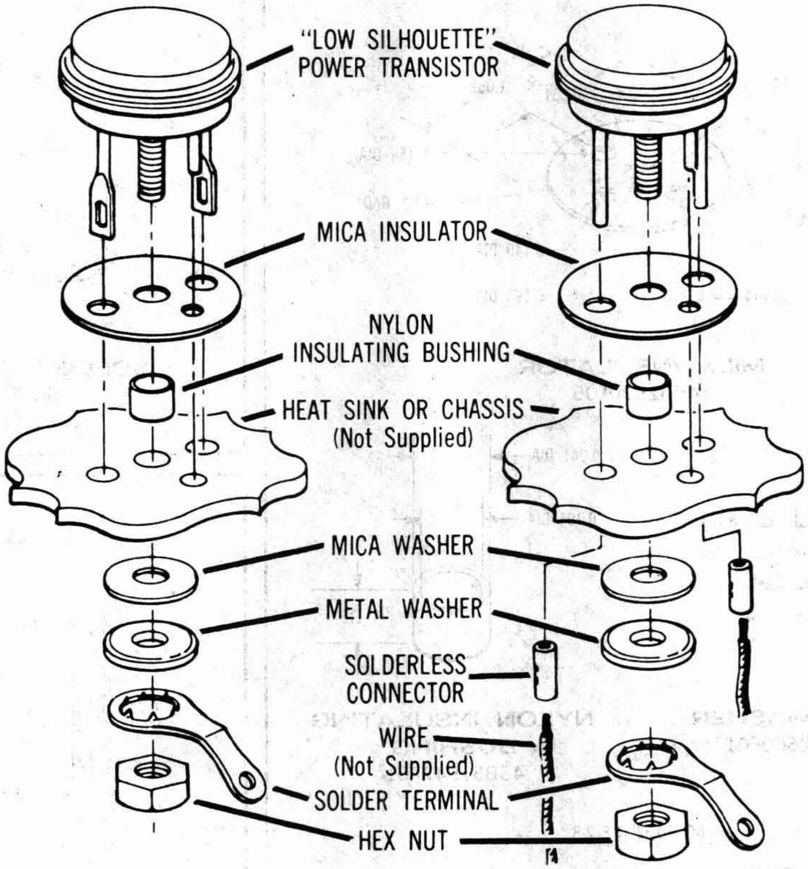
MK-35 Designed for use in applications requiring greater than 30 Amps with solderless connection to the transistor leads.

To obtain maximum contact area between case and heat sink for better heat transfer, it is recommended that the transistor first be mounted on the heat sink or chassis. Then, for maximum wire-to transistor lead strength and high-current capacity, the solderless connectors provided are crimped to the transistor leads and heavy wire. The wires may be soldered directly to the leads if strength and high currents (approximately 50 Amps) are not the primary considerations. (Solderless connector tools are available from the Thomas and Betts Co., Elizabeth, N. J. Possible wire types: AWG #12 regular strand (65 x 30) or #10 solid-tinned copper wire.)

These new mounting kits are individually packaged in a convenient polyethylene container.

MK-30
15 AND 30
AMP UNITS

MK-35
60 AMP UNITS


"LOW SILHOUETTE" POWER TRANSISTOR
MICA INSULATOR
NYLON INSULATING BUSHING
HEAT SINK OR CHASSIS (Not Supplied)
MICA WASHER
METAL WASHER
SOLDERLESS CONNECTOR
WIRE (Not Supplied)
SOLDER TERMINAL
HEX NUT

NOTE: The surface to which the transistor is mounted must be smooth, flat and free of burrs or irregularities which may damage insulation or prevent intimate contact with the transistor mounting base.

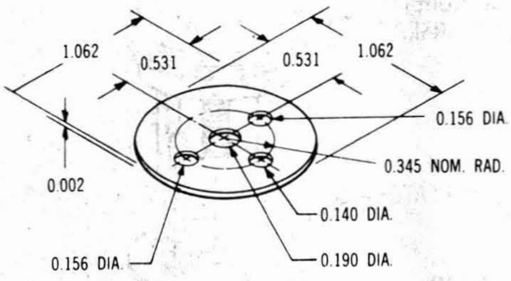
Typical thermal characteristics for mica insulators are given in the table below. (Figures may vary with mounting torque applied. Do not over stress.)

KIT TYPE	INSULATING WASHER	MAXIMUM THERMAL RESISTANCE (°C/Watt)	
		Dry	With DC4*
—	No Insulator	.20	.10
MK-30	Mica	.80	.40
MK-35	Mica	.80	.40

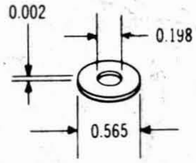
*DC4 is Dow Corning No. 4 Silicone Lubricant.

OUTLINE DIMENSIONS

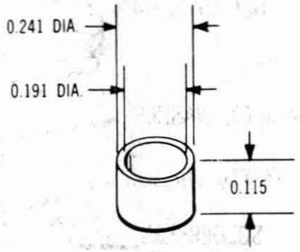
MK-30 / MK-35


1.062
0.531
0.531
1.062
0.156 DIA.
0.345 NOM. RAD.
0.002
0.140 DIA.
0.156 DIA.
0.190 DIA.

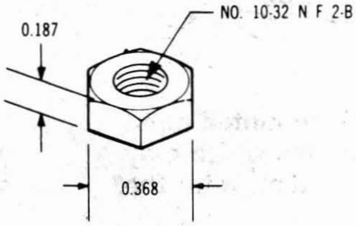
MICA INSULATOR
14B52600F06


0.002
0.198
0.565

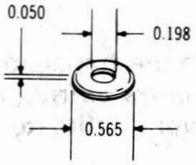
MICA WASHER
14B52600F01


0.241 DIA.
0.191 DIA.
0.115

NYLON INSULATING BUSHING
43B51547F01


NO. 10-32 N F 2-B
0.187
0.368

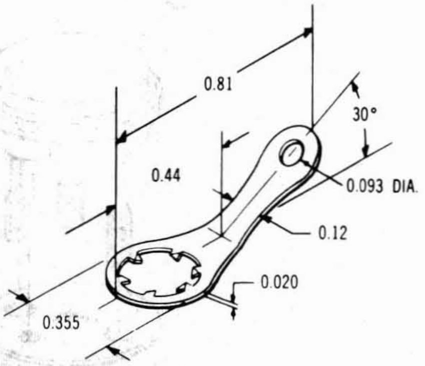
HEX NUT
(Cadmium Plated)
02B51568F13


0.050
0.198
0.565

METAL WASHER
(Cadmium Plated)
04B51567F17

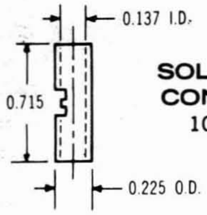
NOTE: All Dimensions Nominal

MK-30 ONLY

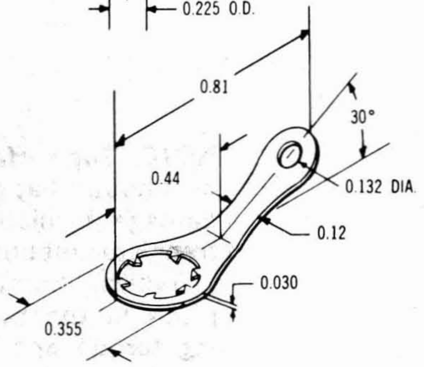

0.81
30°
0.44
0.093 DIA.
0.12
0.020
0.355

SOLDER TERMINAL
(Tin Dipped)
29B52595F13

MK-35 ONLY


0.137 I.D.
0.715
0.225 O.D.

SOLDERLESS CONNECTOR
10M52014A


0.81
30°
0.44
0.132 DIA.
0.12
0.030
0.355

SOLDER TERMINAL
(Cadmium Plated)
29B52595F09

MS-10 POWER TRANSISTOR HEAT SINK

Designed specifically for use with the industry standard type TO-3 (diamond) power transistor, this heat sink will reduce transistor junction temperatures and permit safe operation at higher power levels or under high ambient temperatures.

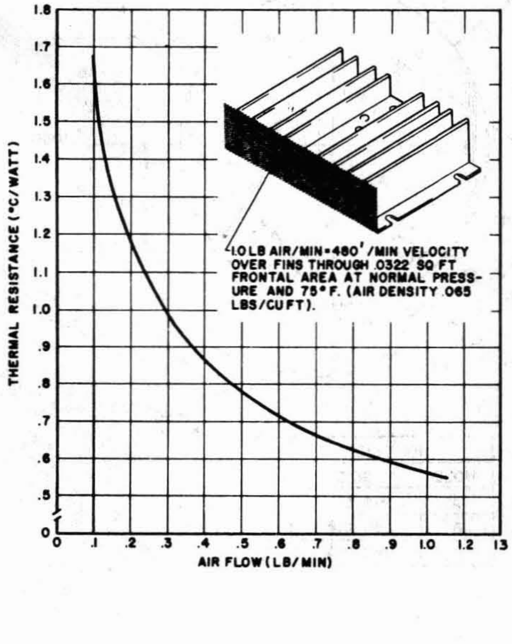
Cooling is accomplished with the MS-10 by conduction, convection and radiation. Although measuring only 4-1/2" by 3-1/16", the MS-10 makes possible thermal dissipation effectively equal to that of a flat sheet of aluminum 10" by 8" by 1/8". This greatly reduces the chassis area necessary for heat dissipation at higher power levels.

The transistor with use of silicon grease should be mounted directly to the MS-10 heat sink with the insulating washers placed at each of the (4) mounting points located on the heat sink flange. This is accomplished by placing (1) shoulder washer on the bottom and (1) flat washer on top of each mounting point of the heat sink. A mica washer is supplied to isolate the transistor from the heat sink if desired.

The MS-10 has a hole pattern arrangement which will accommodate the mounting of one TO-3 power transistor and/or two 10/32" stud mounting diodes. Provided with each MS-10 package is an MK-15 power transistor mounting kit which contains a power transistor socket, mounting screws, complete mounting instructions and a mica insulating washer for use in mounting transistors to the heat sink.

This heat sink is easy to install and does not interfere with the operation of the transistor. For optimum efficiency, the MS-10 should be mounted with the fins vertical.

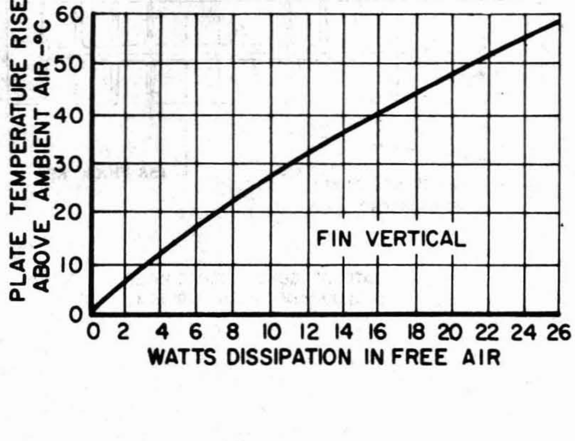
PERFORMANCE UNDER FORCED AIR FLOW OF MS-10 NATURAL CONVECTION TRANSISTOR HEAT SINK

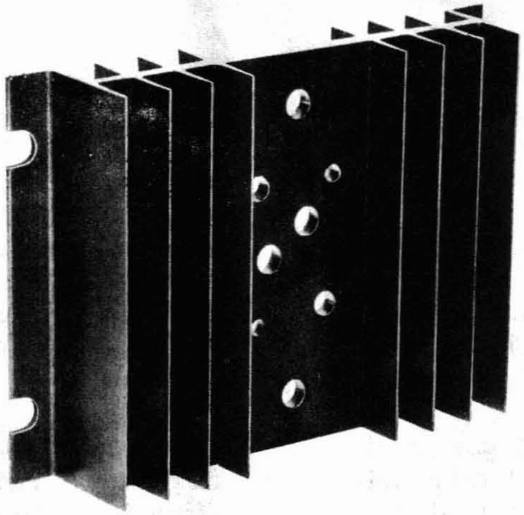


SPECIFICATIONS

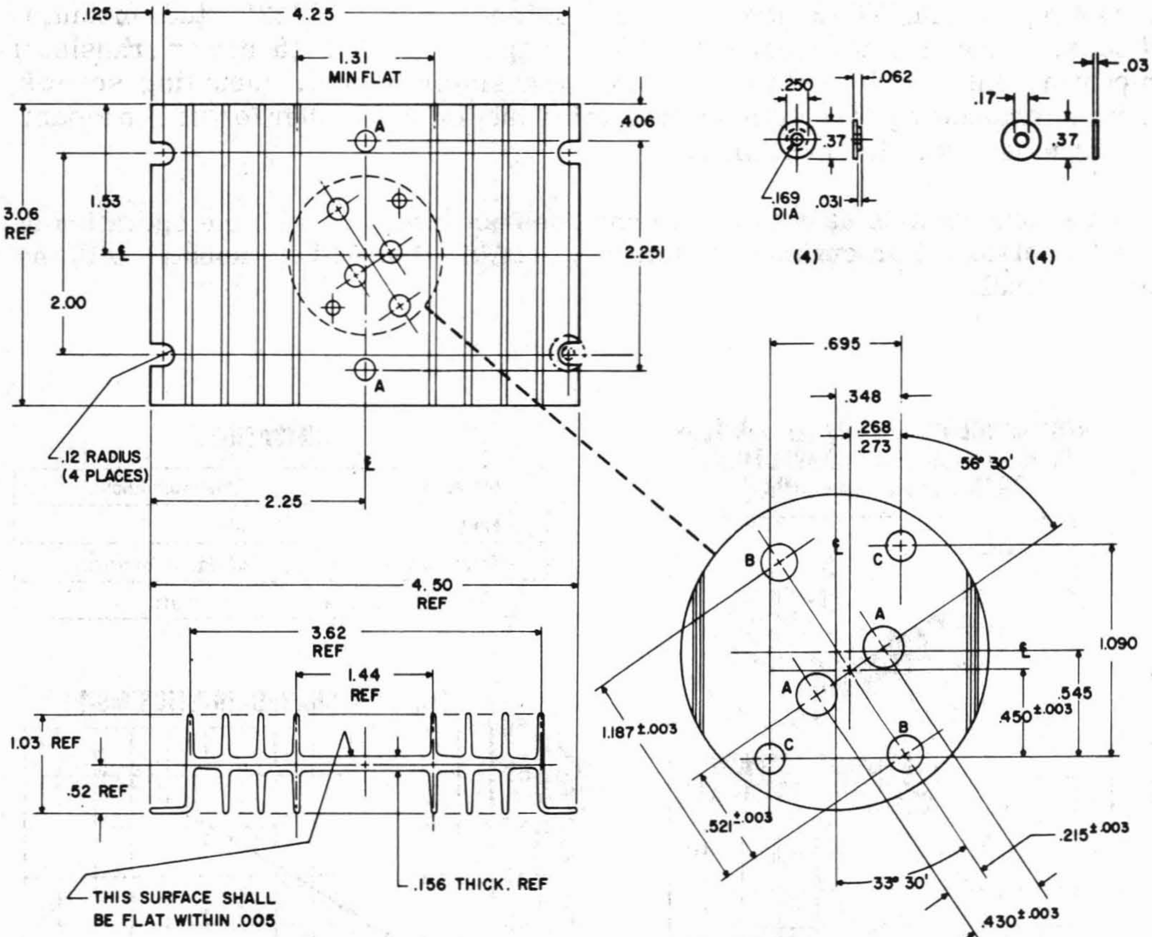
Material	Aluminum Alloy
Finish	Black
Total Surface Area	65 Sq. In. (approx.)
Thermal Resistance	3°C/watt

THERMAL CHARACTERISTICS MS-10





Providing cooling by conduction, convection and radiation, the MS-10 Heat Sink, measuring only 4-1/2" by 3-1/16", has thermal dissipation equal to that of a flat sheet of aluminum 10" x 8" x 1/8".


.125
4.25
1.31
MIN FLAT
A
.406
3.06
REF
1.53
2.00
℄
2.251
A
.12 RADIUS
(4 PLACES)
℄
2.25
4.50
REF
3.62
REF
1.44
REF
1.03 REF
.52 REF
THIS SURFACE SHALL
BE FLAT WITHIN .005
.156 THICK. REF
.250
.062
.37
.169
DIA
.031
(4)
.03
.17
.37
(4)
.695
.348
.268
.273
56° 30'
B
℄
C
A
℄
1.090
A
.545
.450±.003
B
1.187±.003
C
.521±.003
.215±.003
33° 30'
.430±.003

HOLE LIST	
HOLE	SIZE
A	.218 DIA
B	.188 DIA
C	.140 DIA

NATURAL CONVECTION COOLER IS ALUMINUM. FINISH IS BLACK.

MS-15 POWER TRANSISTOR HEAT SINK

Designed specifically for use with the industry standard type TO-36 ("doorknob") power transistor, this heat sink will reduce transistor junction temperatures and permit safe operation at higher power levels or under high ambient temperatures.

Cooling is accomplished with the MS-15 by conduction, convection and radiation. Although measuring only 4-1/2" by 3-1/16", the MS-15 makes possible thermal dissipation effectively equal to that of a flat sheet of aluminum 10" by 8" by 1/8". This greatly reduces the chassis area necessary for heat dissipation at higher power levels.

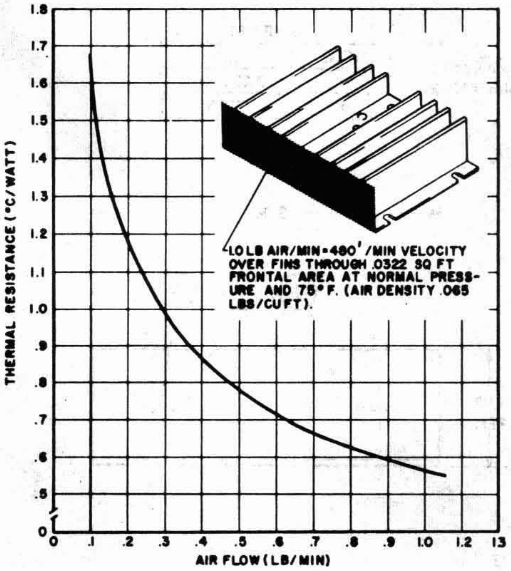
The MS-15 has a hole pattern arrangement which will accommodate the mounting of one TO-36 power transistor. Provided with each MS-15 package is assorted mounting hardware such as: insulating bushing, mica washer, nut, flat washer, solder terminal and insulating washers used in mounting the heat sink to the chassis.

The transistor with use of silicon grease should be mounted directly to the MS-15 heat sink with the insulating washers placed at each of the (4) mounting points located on the heat sink flange. This is accomplished by placing (1) shoulder washer on the bottom and (1) flat washer on top of each mounting point of the heat sink. A mica washer is supplied to isolate the transistor from the heat sink if desired.

> NOTE: When mounting the transistor to the heat sink a torque of 20 in. lbs. max should be applied to the stud.

This heat sink is easy to install and does not interfere with the operation of the transistor. For optimum efficiency, the MS-15 should be mounted with the fins vertical.

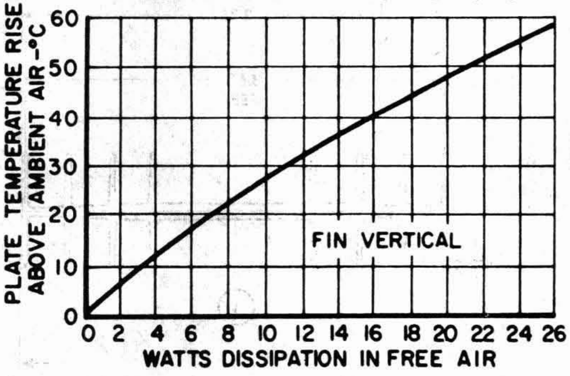
PERFORMANCE UNDER FORCED AIR FLOW OF MS-15 NATURAL CONVECTION TRANSISTOR HEAT SINK

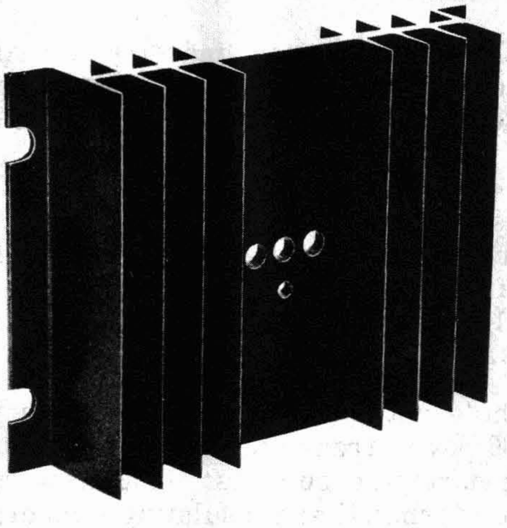


SPECIFICATIONS

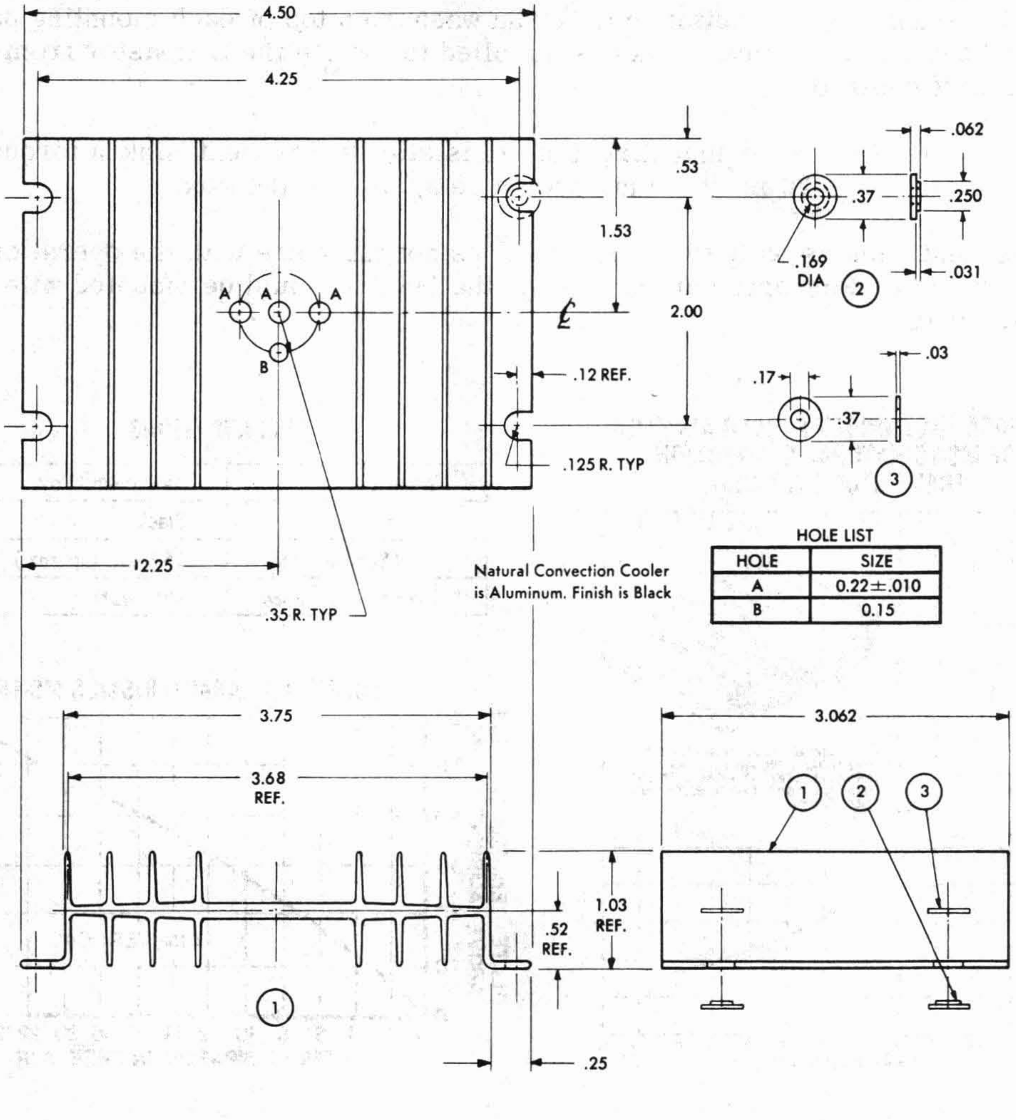
Material	**Aluminum Alloy**
Finish	**Black**
Total Surface Area	**65 Sq. In. (approx.)**
Thermal Resistance	**3°C/watt**

THERMAL CHARACTERISTICS MS-15





Providing cooling by conduction, convection and radiation, the MS-15 Heat Sink, measuring only 4-1/2" by 3-1/16", has thermal dissipation equal to that of a flat sheet of aluminum 10" x 8" x 1/8".


4.50
4.25
.53
1.53
2.00
℄
A
A
A
B
.12 REF.
.125 R. TYP
2.25
.35 R. TYP
.062
.37
.250
.169
DIA
②
.031
.03
.17
.37
③
3.75
3.68
REF.
1.03
REF.
.52
REF.
①
.25
3.062
①
②
③

Natural Convection Cooler is Aluminum. Finish is Black

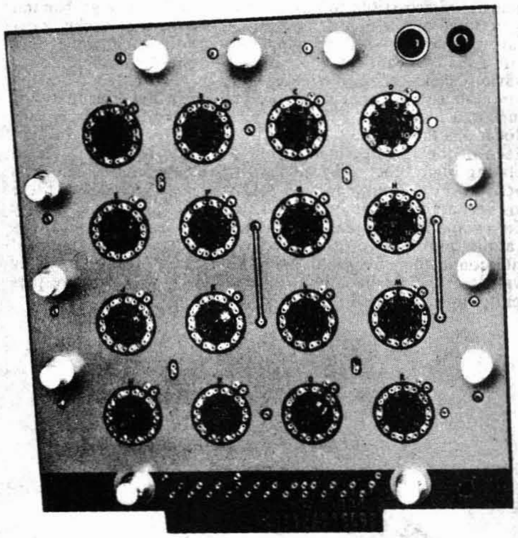
HOLE LIST

HOLE	SIZE
A	0.22±.010
B	0.15

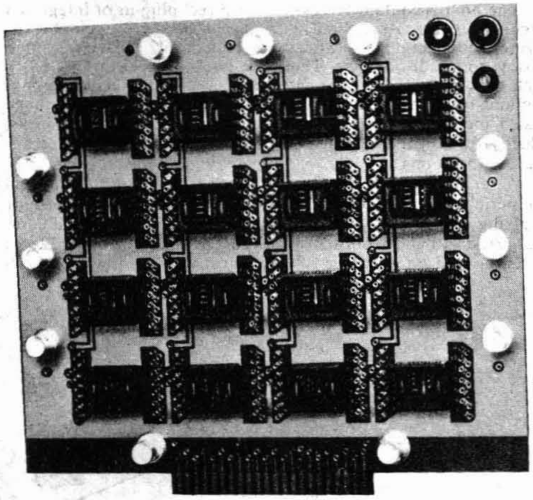
xc63
xc72
xc73

INTEGRATED CIRCUIT INTERCONNECTION BREADBOARDS

Integrated Circuit Interconnection Breadboards, designed to allow rapid interconnection and evaluation of individual integrated circuits or complete logic designs. Little or no soldering is required as a result of the extensive use of sockets and connectors.



XC63



XC72

BREADBOARD SPECIFICATIONS

Specification	XC63	XC72, XC73
Number of Sockets	16	16
Type of Socket	10-pin	14-pin
Number of Pin Jacks per Socket Pin	2	2
Input/Output	22-pin PC edge connector or 11 BNC coaxial connectors	22-pin PC edge connector or 11 BNC coaxial connectors
Power Connection	banana plugs or edge connector pins	banana plugs or edge connector pins
Power Distribution	3 voltage distribution points next to each socket	3 voltage distribution points next to each socket
Temperature Range	-65°C to $+150^{o}$C	-65°C to $+150^{o}$C
Printed Circuit	1/16" glass epoxy with 2 oz gold plated runs	1/16" glass epoxy with 2 oz gold plated runs
Frequency Range	DC to 50 MHz	DC to 50 MHz
Edge Connector*	22 pins	22 pins

*Fits into Amphenol 143-022-01 connector, which is not included with breadboard

HOW TO USE INTERCONNECTION PATCHBOARDS

The Integrated Circuit Interconnection Patchboards are, in effect, "universal chassis" designed to simplify testing of individual devices and breadboarding of complete integrated circuit subsystems. Patchboard XC63 is designed for TO-5 integrated circuit packages with up to 10 leads, and Patchboard XC72 is designed for flat packs with up to 14 leads.

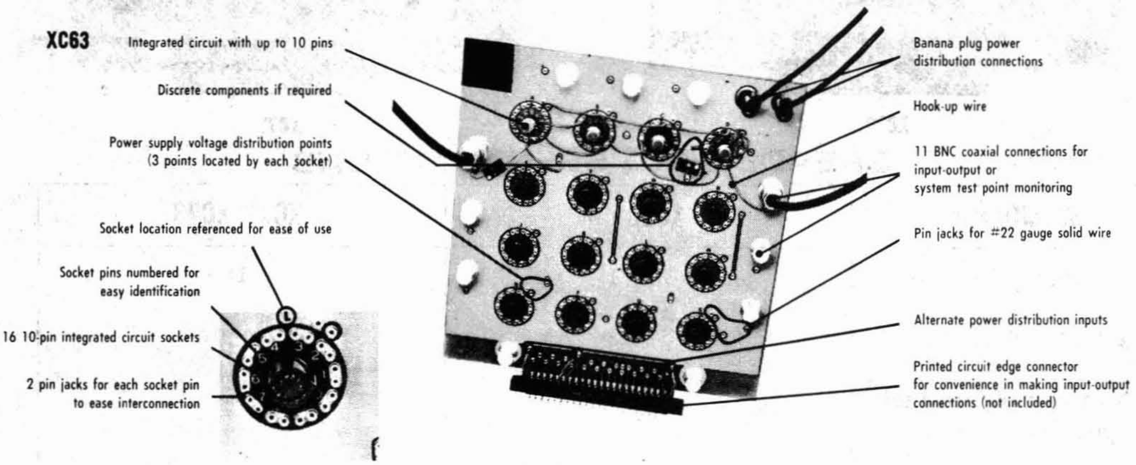
The boards contain 16 sockets for direct plug-in of integrated circuit packages. Associated with each socket are a number of spring-loaded pin jacks which are connected, through printed wiring, to the device pins. There are two pin jacks connected to each socket pin for greater interconnection flexibility. Interconnections between circuits are made simply by inserting 22 gauge (0.025 inch) solid hook-up wire into the appropriate pin jacks, which are designed for high retention capability even after numerous insertions.

A series of eleven BNC coaxial connectors, located around the periphery of the board provide convenient access points for applying input signals and sampling the outputs. Additional communication to and from the board can be made through 22 pin jacks, located on one edge of the board, which are wired to accommodate an edge-mounted, printed circuit strip connector (not supplied).

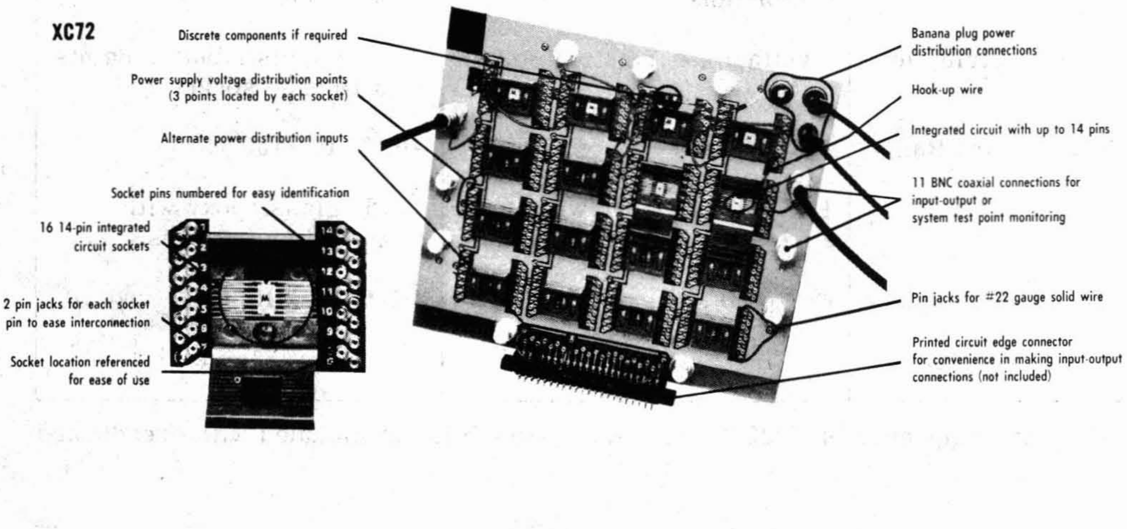
Three voltage-distribution planes are provided on each board. Two of these, in the form of a copper lamination on each side of the board, are accessible to power supply inputs through banana jacks mounted on the board. Two pin jacks near each socket location are in contact with the copper (one with each plane) and provide a ready means for applying the power supply voltages to the various jacks. A third voltage may be distributed from the edge-mounted strip connector pin jacks which have printed wiring runs to a number of additional pin jacks mounted at convenient locations throughout the board.

Each of the 16 integrated circuit sockets is lettered to aid in correlating logic block diagrams with the patchboard. The pins of each socket are numbered as a further aid. The use of these boards permits the same integrated circuits to be used repeatedly for the evaluation of many commonly used logic configurations with a minimum of effort. More complex designs may be studied by interconnecting several breadboards. Thus, all designs may be evaluated and finalized before the integrated circuits are permanently interconnected in the system.

XC63


Integrated circuit with up to 10 pins
Discrete components if required
Power supply voltage distribution points (3 points located by each socket)
Socket location referenced for ease of use
Socket pins numbered for easy identification
16 10-pin integrated circuit sockets
2 pin jacks for each socket pin to ease interconnection
Banana plug power distribution connections
Hook-up wire
11 BNC coaxial connections for input-output or system test point monitoring
Pin jacks for #22 gauge solid wire
Alternate power distribution inputs
Printed circuit edge connector for convenience in making input-output connections (not included)

XC72


Discrete components if required
Power supply voltage distribution points (3 points located by each socket)
Alternate power distribution inputs
Socket pins numbered for easy identification
16 14-pin integrated circuit sockets
2 pin jacks for each socket pin to ease interconnection
Socket location referenced for ease of use
Banana plug power distribution connections
Hook-up wire
Integrated circuit with up to 14 pins
11 BNC coaxial connections for input-output or system test point monitoring
Pin jacks for #22 gauge solid wire
Printed circuit edge connector for convenience in making input-output connections (not included)

INTEGRATED CIRCUITS

CONTENTS

Page No.

INDEX IC-2

DIGITAL

Selector Guide IC-6
MECL MC300/350 Series IC-9
MECL II MC1000/1200 Series IC-13
MECL III MC1600 Series IC-20
MHTL MC660 Series IC-23
MTTL MC5400/7400 Series IC-27
MTTL I MC400/500 Series IC-31
MTTL II MC2000/2100 Series IC-37
MTTL III MC3000 Series IC-40
MTTL MC4000 Series Complex Functions IC-45
MDTL MC830/930 Series IC-49
DTL MC200/250 Series IC-56
MRTL MC700/800/900 Series IC-59
mW MRTL MC708/808/908 Series IC-65
MOS MC1120 Series IC-69
Special Logic Products for Custom Applications IC-73

LINEAR

Selector Guide IC-77
Operational Amplifiers IC-79
High-Frequency Amplifiers IC-87
Power Amplifiers IC-92
Differential Amplifiers IC-94
Sense Amplifiers IC-96
Stereo Preamplifiers IC-101
Chroma Demodulators IC-102
Voltage Regulators IC-103

INTEGRATED CIRCUITS INDEX

DEVICE TYPE	FAMILY
MC201F,G thru MC210F,G	DTL
MC212F,G	DTL
MC213F,G	DTL
MC215F,G	DTL
MC217F,G	DTL
MC251F,G thru MC260F,G	DTL
MC262F,G	DTL
MC263F,G	DTL
MC265F,G	DTL
MC267F,G	DTL
MC301F,G thru MC312F,G	MECL
MC312AF,G	MECL
MC313F	MECL
MC314F,G thru MC318F,G	MECL
MC351F,G	MECL
MC352F,G	MECL
MC352AF,G	MECL
MC353F,G thru MC357F,G	MECL
MC358AF,G	MECL
MC359F,G thru MC363F,G	MECL
MC362AF,G	MECL
MC363F	MECL
MC364F,G thru MC369F,G	MECL
MC400F,L thru MC418F,L	MTTL I
MC420F,L	MTTL I
MC421F,L	MTTL I
MC425F,L	MTTL I
MC450F,L thru MC468F,L	MTTL I
MC470F,L	MTTL I
MC471F,L	MTTL I
MC475F,L	MTTL I
MC500F,L thru MC518F,L	MTTL I
MC520F,L	MTTL I
MC521F,L	MTTL I
MC525F,L	MTTL I

DEVICE TYPE	FAMILY
MC550F,L thru MC568F,L	MTTL I
MC570F,L	MTTL I
MC571F,L	MTTL I
MC575F,L	MTTL I
MC660L,P thru MC674L,P	MHTL
MC700F,G	MRTL
MC701G	MRTL
MC702G	MRTL
MC703F,G thru MC707F,G	MRTL
MC708F,G thru MC713F,G	mW MRTL
MC714F,G	MRTL
MC715F,G,P	MRTL
MC717F,P	mW MRTL
MC718F,G,P	mW MRTL
MC719F,P	mW MRTL
MC720F,G	mW MRTL
MC721F,G	mW MRTL
MC722F,G,P	mW MRTL
MC723F,G,P	MRTL
MC724F,P	MRTL
MC725F,P	MRTL
MC726F,G,P	MRTL
MC727F,G	MRTL
MC728F,G	mW MRTL
MC729F,G	MRTL
MC771F,P	MRTL
MC774G	MRTL
MC775F,P	MRTL
MC776F,P	mW MRTL
MC778F,P	mW MRTL
MC779P	MRTL
MC781G	mW MRTL
MC782G	mW MRTL
MC783F,P thru MC786F,P	MRTL
MC787P	MRTL
MC788F,P thru MC792F,P	MRTL
MC793F,P	mW MRTL
MC796F,P	MRTL
MC797F,P	MRTL
MC798F,P	mW MRTL
MC799F,G,P	MRTL
MC800F,G	MRTL
MC801G	MRTL
MC802G	MRTL
MC803F,G thru MC807F,G	MRTL

INTEGRATED CIRCUITS INDEX (continued)

DEVICE TYPE	FAMILY
MC808F,G thru MC813F,G	mW MRTL
MC814F,G	MRTL
MC815F,G,P	MRTL
MC816F,G,P	MRTL
MC817F,P	mW MRTL
MC818F,G,P	mW MRTL
MC819F,P	mW MRTL
MC820F,G	mW MRTL
MC821F,G	mW MRTL
MC822F,G,P	mW MRTL
MC824F,P	MRTL
MC825F,P	MRTL
MC826F,G,P	MRTL
MC827F,G	MRTL
MC828F,G	mW MRTL
MC829F,G	MRTL
MC830F,G,P thru MC833F,G,P	MDTL
MC834F,P thru MC842F,P	MDTL
MC843G	MDTL
MC844F,G,P thru MC846F,G,P	MDTL
MC847F,P	MDTL
MC848F,G,P thru MC851F,G,P	MDTL
MC852F,P	MDTL
MC853F,P	MDTL
MC855F,P thru MC858F,P	MDTL
MC861F,G,P thru MC863F,G,P	MDTL
MC871F,P	MRTL
MC874G	MRTL
MC875F,P	MRTL
MC876F,P	mW MRTL
MC878F,P	mW MRTL
MC879P	MRTL
MC881G	mW MRTL
MC882G	mW MRTL
MC883F,P thru MC886F,P	MRTL
MC887P	MRTL
MC888F,P thru MC892F,P	MRTL
MC893F,P	mW MRTL
MC896F,P	MRTL
MC897F,P	MRTL

DEVICE TYPE	FAMILY
MC898F,P	mW MRTL
MC899F,G,P	MRTL
MC900F,G	MRTL
MC901G	MRTL
MC902G	MRTL
MC903F,G thru MC907F,G	MRTL
MC908F,G thru MC913F,G	mW MRTL
MC914F,G	MRTL
MC915F,G	MRTL
MC916F,G	MRTL
MC917F	mW MRTL
MC918F,G	mW MRTL
MC919F	mW MRTL
MC920F,G	mW MRTL
MC921F,G	mW MRTL
MC922F,G	mW MRTL
MC924F	MRTL
MC925F	MRTL
MC926F,G	MRTL
MC927F,G	MRTL
MC928F,G	mW MRTL
MC929F,G	MRTL
MC930F,G thru MC933F,G	MDTL
MC934F thru MC942F	MDTL
MC943G	MDTL
MC944F,G thru MC946F,G	MDTL
MC947F	MDTL
MC948F,G thru MC951F,G	MDTL
MC952F	MDTL
MC953F	MDTL
MC955F thru MC958F	MDTL
MC961F,G thru MC963F,G	MDTL
MC971F	MRTL
MC974G	MRTL
MC975F	MRTL
MC976F	mW MRTL
MC978F	mW MRTL
MC981G	mW MRTL
MC982G	mW MRTL
MC983F thru MC986F	MRTL

INTEGRATED CIRCUITS INDEX (continued)

DEVICE TYPE	FAMILY
MC988F thru MC992F	MRTL
MC993F	mW MRTL
MC996F	MRTL
MC997F	MRTL
MC998F	mW MRTL
MC999F,G	MRTL
MC1001L thru MC1027L	MECL II
MC1029L thru MC1031L	MECL II
MC1033L thru MC1039L	MECL II
MC1110G	High-Frequency Amplifier
MC1124L	MOS
MC1150L	MOS
MC1151L	MOS
MC1170L	MOS
MC1201F thru MC1222F	MECL II
MC1224F thru MC1226F	MECL II
MC1229F thru MC1231F	MECL II
MC1233F	MECL II
MC1235F	MECL II
MC1238F	MECL II
MC1303L,P	Stereo Preamplifier
MC1325L,P	Dual Chroma Demodulator
MC1414L,P	Sense Amplifier
MC1429G	Differential Amplifier
MC1430F,G,L,P	Operational Amplifier
MC1431F,G,L,P	Operational Amplifier
MC1433F,G,L,P	Operational Amplifier
MC1435F,G,L,P	Operational Amplifier
MC1437L,P	Operational Amplifier
MC1439G	Operational Amplifier
MC1440F,G,L,P	Sense Amplifier
MC1441F,L,P	Sense Amplifier
MC1460G,R	Voltage Regulator
MC1461G,R	Voltage Regulator
MC1509F	High-Frequency Amplifier
MC1510F,G	High-Frequency Amplifier
MC1514L	Sense Amplifier
MC1519G	Differential Amplifier
MC1520F,G	Operational Amplifier
MC1524G	Power Amplifier
MC1525G	Differential Amplifier
MC1526G	Differential Amplifier
MC1529G	Differential Amplifier
MC1530F,G	Operational Amplifier
MC1531F,G	Operational Amplifier
MC1533F,G,L	Operational Amplifier
MC1535F,G	Operational Amplifier
MC1537L	Operational Amplifier
MC1539G	Operational Amplifier

DEVICE TYPE	FAMILY
MC1540F,G,L	Sense Amplifier
MC1541F,L	Sense Amplifier
MC1545F,G,L	High-Frequency Amplifier
MC1550F,G	High-Frequency Amplifier
MC1552G	High-Frequency Amplifier
MC1553G	High-Frequency Amplifier
MC1554G	Power Amplifier
MC1560G,R	Voltage Regulator
MC1561G,R	Voltage Regulator
MC1660S	MECL III
MC1662S	MECL III
MC1670S	MECL III
MC1709F,G,L	Operational Amplifier
MC1709CF,G,L,P	Operational Amplifier
MC1710F,G,L	Sense Amplifier
MC1710CF,G,L,P	Sense Amplifier
MC1711F,G,L	Sense Amplifier
MC1711CF,G,L,P	Sense Amplifier
MC1712F,G,L	Operational Amplifier
MC1712CF,G,L,P	Operational Amplifier
MC1800F,P thru MC1812F,P	MDTL
MC1813P	MDTL
MC1814F,P	MDTL
MC1900F thru MC1912F	MDTL
MC1914F	MDTL
MC2000F,L thru MC2007F,L	MTTL II
MC2009F,L	MTTL II
MC2010F,L	MTTL II
MC2013F,L	MTTL II
MC2025F,L	MTTL II
MC2026F,L	MTTL II
MC2028F,L	MTTL II
MC2050F,L thru MC2057F,L	MTTL II
MC2059F,L	MTTL II
MC2060F,L	MTTL II
MC2063F,L	MTTL II
MC2075F,L	MTTL II
MC2076F,L	MTTL II
MC2078F,L	MTTL II
MC2100F,L thru MC2107F,L	MTTL II
MC2109F,L	MTTL II
MC2110F,L	MTTL II
MC2113F,L	MTTL II
MC2125F,L	MTTL II
MC2126F,L	MTTL II
MC2128F,L	MTTL II
MC2150F,L thru MC2157F,L	MTTL II
MC2159F,L	MTTL II
MC2160F,L	MTTL II

INTEGRATED CIRCUITS INDEX (continued)

DEVICE TYPE	FAMILY
MC2163F,L	MTTL II
MC2175F,L	MTTL II
MC2176F,L	MTTL II
MC2178F,L	MTTL II
MC3000F,L thru MC3003F,L	MTTL III
MC3005F,L	MTTL III
MC3006F,L	MTTL III
MC3010F,L	MTTL III
MC3015F,L	MTTL III
MC3020F,L	MTTL III
MC3025F,L	MTTL III
MC3026F,L	MTTL III
MC3028F,L	MTTL III
MC3029F,L	MTTL III
MC3030F,L	MTTL III
MC3050F,L	MTTL III
MC3052F,L	MTTL III
MC3060F,L	MTTL III
MC3061F,L	MTTL III
MC3062F,L	MTTL III
MC4000L	MTTL Complex
MC4002L	MTTL Complex
MC4004L	MTTL Complex
MC4005L	MTTL Complex
MC4006L	MTTL Complex
MC4007L	MTTL Complex
MC4008L	MTTL Complex
MC4010L	MTTL Complex
MC4038P	MTTL Complex
MC4039P	MTTL Complex
MC4040P	MTTL Complex
MC4041P	MTTL Complex
MC5400F,L	MTTL
MC5401F,L	MTTL
MC5402F,L	MTTL
MC5410F,L	MTTL
MC5420F,L	MTTL
MC5430F,L	MTTL
MC5440F,L	MTTL
MC5450F,L	MTTL
MC5451F,L	MTTL
MC5453F,L	MTTL
MC5454F,L	MTTL
MC5460F,L	MTTL
MC5472F,L	MTTL
MC5473F,L	MTTL
MC5479F,L	MTTL
MC7400F,L,P	MTTL
MC7401F,L,P	MTTL
MC7402F,L,P	MTTL
MC7410F,L,P	MTTL
MC7420F,L,P	MTTL
MC7430F,L,P	MTTL
MC7440F,L,P	MTTL
MC7450F,L,P	MTTL
MC7451F,L,P	MTTL
MC7435F,L,P	MTTL
MC7454F,L,P	MTTL
MC7460F,L,P	MTTL
MC7472F,L,P	MTTL
MC7473F,L,P	MTTL
MC7479F,L,P	MTTL
MC9718F,P	mW MRTL
MC9719F,P	MRTL

DEVICE TYPE	FAMILY
MC9720F.P	mW MRTL
MC9721F,P	mW MRTL
MC9818F,P	mW MRTL
MC9819F,P	MRTL
MC9820F,P	mW MRTL
MC9821F,P	mW MRTL
MC9918F	mW MRTL
MC9919F	MRTL
MC9920F	mW MRTL
MC9921F	mW MRTL
MCH1439G	Operational Amplifier
MCH1539G	Operational Amplifier
XC157	Special Logic
XC170	Special Logic
XC177	Special Logic

DIGITAL APPLICATION SELECTOR GUIDE

This table shows the various circuit functions available in each integrated circuit logic family. "F" indicates the device is available in ceramic flat package, "G" indicates metal can, "P" indicates dual in-line plastic package, "L" indicates dual in-line ceramic package, and "S" suffix denotes stud-mounted ceramic flat package.

Many of these devices have provision for expanding input capability. See individual family specifications for detail.

FUNCTION (Positive Logic)	MECL	MECL II	MECL III	MHTL	MTTL MC5400/7400	MTTL I MC500/400	MTTL II	MTTL III	MTTL MC4000	MDTL	DTL	MRTL	mW MRTL
GATES													
Quad Inverter										G		F,G	
Hex Inverter					F,L	F,L				F,P		F,P	P
3-Input OR/NOR Gate	F,G												
4-Input OR/NOR Gate													F,G
5-Input OR/NOR Gate	F,G												
6-Input OR/NOR Gate		F,L											
Dual 2-Input OR/NOR Gate	G	F,L											
Dual 4-Input OR/NOR Gate	F	F,L	S										
3-Input NOR Gate												F,G	
4-Input NOR Gate												F,G	
5-Input NOR Gate												F,G	F,G
Dual 2-Input NOR Gate	F,G											F,G	F,G
Dual 3-Input NOR Gate	F,G											F,G,P	F,G,P
Dual 4-Input NOR Gate												F,G,P	F,P
Triple 3-Input NOR Gate		F,L										F,P	F,P
Quad 2-Input NOR Gate	F	F,L	S		F,L			F,L		F,P		F,P	F,P
3-Input NAND Gate											F,G		
4-Input NAND Gate											F,G		
8-Input NAND Gate					F,L	F,L	F,L	F,L		F,P			
10-Input NAND Gate										F,P			
Dual 2-Input NAND Gate											F,G		
Dual 3-2 Input NAND Gate										G	F,G		
Dual 3-Input NAND Gate											F,G		
Dual 4-Input NAND Gate				L	F,L	F,L	F,L			F,P			
Dual 5-Input NAND Gate										F,P			
Dual 2-Input NAND Gate plus Inverter										G			
Triple 3-Input NAND Gate				L	F,L	F,L	F,L	F,L		F,P			
Quad 2-Input NAND Gate				L	F,L	F,L	F,L	F,L					
Quad 2-Input OR Gate								F,L		F,P			
6-Input AND Gate											F,G		
Dual 3-Input AND Gate											F,G		
Triple 3-Input AND Gate								F,L					
Quad 2-Input AND Gate								F,L		F,P			
Quad Exclusive NOR Gate		F,L											
Quad Exclusive OR Gate		F,L								F,P		F,P	
2-Wide 3-Input AND-OR-INVERT Gate with Gated Complement						F,L							
2-Wide 4-Input AND-OR-INVERT Gate						F,L	F,L						
3-Wide 3-Input AND-OR-INVERT Gate						F,L							
4-Wide 2-Input AND-OR-INVERT Gate					F,L								
4-Wide 2-2-2-3 Input AND-OR-INVERT Gate						F,L	F,L						
Dual 2-Wide 2-Input AND-OR-INVERT Gate					F,L	F,L	F,L	F,L					
GATE EXPANDERS													
5-Input Gate Expander	F,G												
6-Input Gate Expander											F,G		
Dual 2-Input Gate Expander													F,G
Dual 3-Input Gate Expander											F,G		
Dual 3-4 Input Gate Expander										G			
Dual 4-Input Expander for NAND Gates						F,L				F,P			
Dual 4-Input Expander for AND-OR-INVERT Gates					F,L	F,L	F,L	F,L					
Dual 4-Input Gate Expander				L								F,P	
Dual 4-5 Input Gate Expander		F,L											
4-Wide 3-2-2-3 Input Expander for AND-OR-INVERT Gates						F,L	F,L						
Quad 2-Input Gate Expander										F,P		F,P	F,P
Hex Expander												F,P	P
FLIP FLOPS													
J-K Flip-Flop	F,G	F,L			F,L	F,L	F,L	F,L		F,G,P		F,G,P	F,G,P
R-S Flip-Flop	F,G			L		F,L						G	
Clocked R-S Flip-Flop										F,G,P	F,G		
Type D Flip-Flop		F,L	S			F,L							F,G
Dual J-K Flip-Flop				L	F,L			F,L		F,P		F,P	F,P
Dual Clocked R-S Flip-Flop		F,L											
Dual Type D Flip-Flop					F,L	F,L		F,L					F,P
Quad Latch					L					F,P			

APPLICATION SELECTOR GUIDE (continued)

FUNCTION (Positive Logic)	MECL	MECL II	MECL III	MHTL	MTTL MC5400/7400	MTTL I MC500/400	MTTL II	MTTL III	MTTL MC4000	MDTL	DTL	MRTL	mW MRTL
DRIVERS & BUFFERS													
3-Input NAND Power Gate											F,G		
Dual 3-2 Input NAND Power Gate										G			
Dual 4-Input NAND Power Gate								F,L		F,P			
Dual 4-Input AND Power Gate								F,L					
Quad 2-Input NAND Power Gate										F,P			
Bias Driver	F,G												
Line Driver	F,G			L		F,L		F,L		F,G,P	F,G		
Lamp Driver	F,G									G			
Dual 2-Input Clock Driver	G												
Dual 3-4 Input Transmission Line and Clock Driver		F,L											
Dual 4-Input OR/NOR Clock Driver	F	L											
Buffer Inverter												F,G	
2-Input Buffer													F,G
Dual Buffer Inverter												F,G,P	
Dual 2-Input Buffer													F,G,P
Dual 3-2 Input Buffer										G			
Dual 3-Input Buffer												F,P	
Dual 4-Input Buffer					F,L					F,P			
Quad 2-Input Buffer										F,P			
ADDERS & SUBTRACTORS													
Half Adder	F,G											F,G	F,G
Dual Half Adder												F,P	
Full Adder		F,L										F,G	F,G
Dual Full Adder												F,P	
Full Subtractor		F,L											
Dual Full Subtractor												F,P	
REGISTERS													
Half-Shift Register												F,G	
Half-Shift Register (without inverter)												F,G	
Dual Half-Shift Register												F,P	
Dual Half-Shift Register (without inverter)												F,P	
MEMORIES (Also see "Special Logic Products")													
16-Bit Random Access (16 one-bit words)		L							F,L				
MISCELLANEOUS													
Monostable Multivibrator				L						F,G,P			
Level Translator	F,G	F,L											
Quad Line Receiver		F,L											
1 J-K FF, 1 Expander, 2 Buffers												P	
1 J-K FF, 1 Inverter, 2 Buffers												P	
Type D FF plus 2-Wide 2-Input AND-OR-INVERT Gate										F,P			
Dual 3-Input Diode Array											F,G		
Counter Adapter												G	
Decade Counter										F,P			
Binary Up Counter (Divide by 16)										F,P			
Data Distributor		F,L											
8-Channel Data Selector		F,L											
Dual Schmitt Trigger/Triple Differential Amplifier		F,L											
Binary to 1-of-8 Line Decoder									F,L				

SPECIAL LOGIC PRODUCTS FOR CUSTOM APPLICATIONS

12-Gate Array	XC157	Twelve gates with custom second layer of metalization completing the circuit to obtain desired function. Compatible with MDTL and all MTTL lines.
25-Gate Array	XC177	Twenty-five gates with two custom layers of metalization required to complete the circuit and obtain the desired function. Compatible with MDTL and all MTTL lines.
128-Bit Read Only Memory	XC170	Bipolar read only memory organized as 16 eight-bit words. Compatible with MDTL and all MTTL lines.

MECL

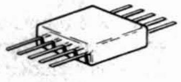
INTEGRATED CIRCUITS

MECL

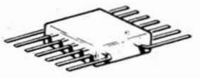
MC300 Series (−55° to +125°C)
MC350 Series (0° to +75°C)

G SUFFIX
CASE 602B
(Formerly Case 71)

G SUFFIX
CASE 604
(Formerly Case 98)



F SUFFIX
CASE 606
(Formerly Case 72)
TO-91



F SUFFIX
CASE 607
(Formerly Case 83)
TO-86

FEATURES

- Propagation delay typically 8 ns per logic decision
- Virtually constant noise immunity with ±20% power supply variation and over corresponding temperature range
- Simultaneous OR/NOR or AND/NAND outputs
- High fan-in and fan-out capabilities

The MECL series of integrated logic circuits forms a versatile set of monolithic digital building blocks representing all the necessary circuitry for the arithmetic portion of a computer. MECL circuits combine high speed with a systems-oriented design approach that permits implementation with the fewest possible number of individual devices. This represents both a cost saving and a potential increase in system reliability. The MECL circuits in this series are compatible with higher speed MECL lines, such as MECL II.

FUNCTIONS AND CHARACTERISTICS ($V_{CC} = 0$, $V_{EE} = -5.2$ V, $T_A = 25°C$)

FUNCTION	Type ① −55 to +125°C	Type ① 0 to +75°C	DC Output Loading Factor Each Output	Propagation Delay t_{pd} ns typ	Total Power Dissipation mW typ	Case
5-Input OR/NOR Gate	MC301	MC351	25	7.5	37	602B, 606
R-S Flip-Flop	MC302	MC352A	↓	11	42	↓
R-S Flip-Flop w/o Buffered Outputs	—	MC352	↓	11	40	↓
Half-Adder	MC303	MC353	↓	7.5	63	↓
Bias Driver	MC304	MC354	↓	—	18	↓
5-Input Gate Expander	MC305	MC355	—	4.5	—	↓
3-Input OR/NOR Gate	MC306	MC356	25	7.5	37	↓
3-Input OR/NOR Gate	MC307	MC357	↓	7.5	15	↓
AC-Coupled J-K Flip-Flop	MC308	MC358A	↓	8.5	87	↓
Dual 2-Input NOR Gate	MC309	MC359	↓	7.0	54	↓
Dual 2-Input NOR Gate	MC310	MC360	↓	7.0	54	↓
Dual 2-Input NOR Gate	MC311	MC361	↓	7.0	41	↓
Dual 3-Input NOR Gate (With Internal Bias)	MC312A	MC362A	↓	7.5	70	↓
Dual 3-Input NOR Gate	MC312	MC362	↓	7.5	54	604, 607
Quad 2-Input NOR Gate	MC313F	MC363F	↓	7.0	125	607
AC-Coupled J-K Flip-Flop	MC314	MC364	↓	12	118	602B, 606
Line Driver	MC315	MC365	—	14	180② — 270③	↓
Lamp Driver	MC316	MC366	—	—	135	↓
Level Translator — MECL to Saturated Logic	MC317	MC367	7 (DTL)	27.5	63	↓
Level Translator — Saturated Logic to MECL	MC318	MC368	25 (MECL)	17	105	602B, 606
Dual 4-Input Clock Driver/High-Speed Gate	—	MC369F	100	3.0	250	607
Dual 2-Input Clock Driver/High-Speed Gate	—	MC369G	100	3.0	250	602B

① G suffix denotes Metal Can. F suffix denotes Flat Package. (i.e., MC301G = Metal Can, MC301F = Flat Package.)
② With 93-ohm load for MC315 (each side)
③ With 50-ohm load for MC365 (each side)

MECL LOGIC DIAGRAMS

MECL — LOGIC DESCRIPTION

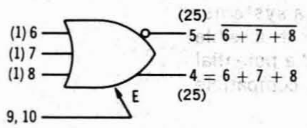
The logic diagrams shown describe the circuits of the MECL line and permit quick selection of circuits required to implement a particular logic system. Pertinent information, such as logic equations and truth tables, is provided to show line compatibility. Package pin numbers and loading factors for each device are specified on each logic diagram. The numbers at the ends of the terminals are package pin numbers. The numbers in parentheses indicate loading factors at each terminal.

MECL circuits require a bias voltage that, for best results, should be obtained from a regulated, temperature-compensated, bias supply. A bias driver, type MC304 or MC354, is included in the MECL line to provide this function when the bias driver is not self-contained in a logic element.

(For supply voltage pin connections, see data sheets)

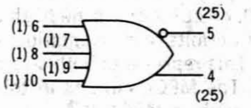
GATES

MC306, MC307*, MC356, MC357* 3-INPUT GATE


(1) 6
(1) 7
(1) 8
(25)
5 = $\overline{6+7+8}$
4 = 6 + 7 + 8
(25)
E
9, 10

*No pull-down resistors

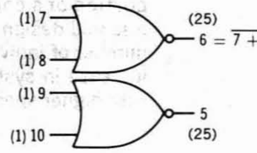
MC301, MC351 — 5-INPUT GATE


(1) 6
(1) 7
(1) 8
(1) 9
(1) 10
(25)
5
4
(25)

$5 = \overline{6+7+8+9+10}$

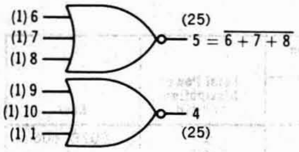
$4 = 6+7+8+9+10$

MC309, MC310*, MC311*, MC359, MC360*, MC361* — DUAL 2-INPUT GATE

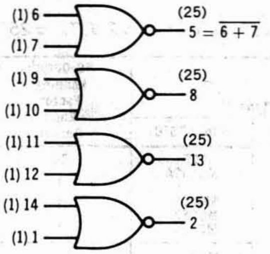

(1) 7
(1) 8
(25)
6 = $\overline{7+8}$
(1) 9
(1) 10
5
(25)

*Optional pull-down resistors

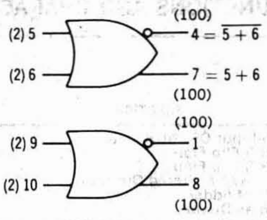
MC312A, MC362, MC362A DUAL 3-INPUT GATE


(1) 6
(1) 7
(1) 8
(25)
5 = $\overline{6+7+8}$
(1) 9
(1) 10
(1) 1
4
(25)

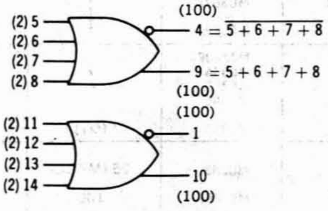
MC313F, MC363F — QUAD 2-INPUT GATE


(1) 6
(1) 7
(25)
5 = $\overline{6+7}$
(1) 9
(1) 10
(25)
8
(1) 11
(1) 12
(25)
13
(1) 14
(1) 1
(25)
2

MC369G — HIGH-SPEED CLOCK DRIVER OR DUAL 2-INPUT GATE

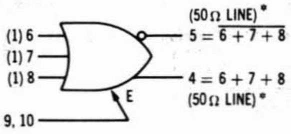

(2) 5
(2) 6
(100)
4 = $\overline{5+6}$
7 = 5 + 6
(100)
(2) 9
(2) 10
(100)
1
8
(100)

MC369F — HIGH-SPEED CLOCK DRIVER OR DUAL 4-INPUT GATE


(2) 5
(2) 6
(2) 7
(2) 8
(100)
4 = $\overline{5+6+7+8}$
9 = 5 + 6 + 7 + 8
(100)
(2) 11
(2) 12
(2) 13
(2) 14
(100)
1
10
(100)

DRIVERS

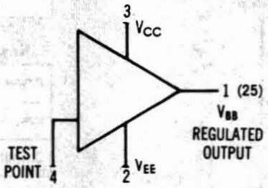
MC315, MC365 – LINE DRIVER



(50 Ω LINE)*
5 = $\overline{6+7+8}$
(1) 6
(1) 7
(1) 8
4 = 6 + 7 + 8
(50 Ω LINE)*
E
9, 10

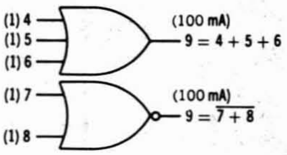
*93Ω line recommended for −55 to +125°C operation

MC304, MC354 – BIAS DRIVER



3
V_{CC}
1 (25)
V_{BB}
REGULATED OUTPUT
TEST POINT 4
2
V_{EE}

MC316, MC366 – LAMP DRIVER



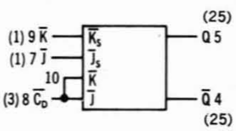
(1) 4
(1) 5
(1) 6
(100 mA)
9 = 4 + 5 + 6
(1) 7
(1) 8
(100 mA)
9 = $\overline{7+8}$

FLIP-FLOPS

MC308, MC314, MC358A, MC364 – AC-COUPLED J-K FLIP-FLOP

CLOCKED J-K OPERATION

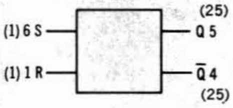
$\overline{J}_S$	$\overline{K}_S$	$\overline{C}_D$	Q^{n+1}
φ	φ	0	Q^n
0	0	1	$\overline{Q^n}$
0	1	1	1
1	0	1	0
1	1	1	Q^n



(1) 9 $\overline{K}$
(1) 7 $\overline{J}$
10
(3) 8 $\overline{C}_D$
$\overline{K}_S$
$\overline{J}_S$
$\overline{K}$
$\overline{J}$
(25)
Q 5
$\overline{Q}$ 4
(25)

R-S OPERATION

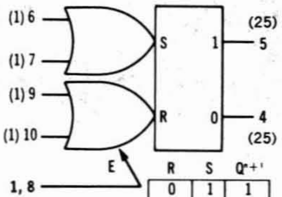
R	S	Q^{n+1}
0	1	1
1	0	0
0	0	Q^n
1	1	N.D.



(1) 6 S
(1) 1 R
(25)
Q 5
$\overline{Q}$ 4
(25)

The $\overline{J}_S$ and $\overline{K}_S$ inputs refer to logic levels while the $\overline{C}_D$ input refers to dynamic logic swings. The $\overline{J}_S$ and $\overline{K}_S$ inputs would be changed to a logical "1" only while the $\overline{C}_D$ input is in a logic "1" state. ($\overline{C}_D$ maximum "1" level = V_{CC} − 0.6 volts)

MC302, MC352, MC352A
R-S FLIP-FLOP

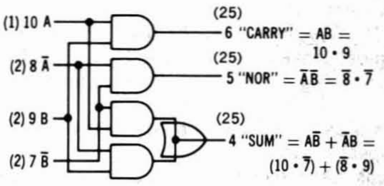


(1) 6
(1) 7
(1) 9
(1) 10
S
R
1
0
(25)
5
4
(25)
E
1, 8

R	S	Q^{n+1}
0	1	1
1	0	0
0	0	Q^n
1	1	N.D.

HALF ADDER

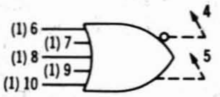
MC303, MC353 – HALF-ADDER



(1) 10 A
(2) 8 $\overline{A}$
(2) 9 B
(2) 7 $\overline{B}$
(25)
6 "CARRY" = AB = 10 • 9
(25)
5 "NOR" = $\overline{A}\,\overline{B}$ = $\overline{8}$ • $\overline{7}$
(25)
4 "SUM" = A$\overline{B}$ + $\overline{A}$B = (10 • $\overline{7}$) + ($\overline{8}$ • 9)

EXPANDER

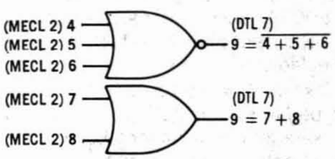
MC305, MC355 – 5-INPUT EXPANDER



(1) 6
(1) 7
(1) 8
(1) 9
(1) 10
4
5

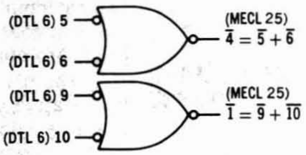
LEVEL TRANSLATORS

MC317, MC367 – LEVEL TRANSLATOR



(MECL 2) 4
(MECL 2) 5
(MECL 2) 6
(DTL 7)
9 = $\overline{4+5+6}$
(MECL 2) 7
(MECL 2) 8
(DTL 7)
9 = 7 + 8

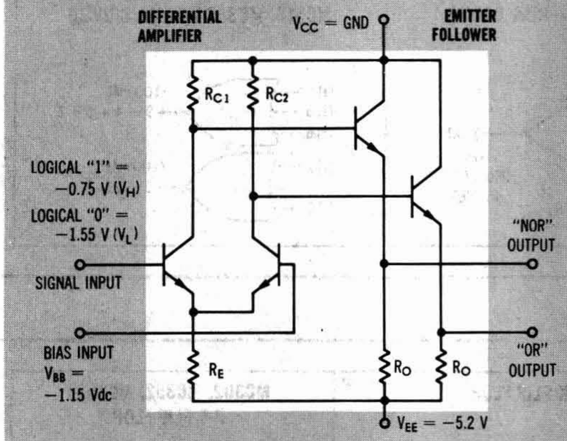
MC318, MC368 – LEVEL TRANSLATOR



(DTL 6) 5
(DTL 6) 6
(MECL 25)
$\overline{4}$ = $\overline{5}$ + $\overline{6}$
(DTL 6) 9
(DTL 6) 10
(MECL 25)
$\overline{1}$ = $\overline{9}$ + $\overline{10}$

MECL INTEGRATED CIRCUITS

BASIC MECL GATE CIRCUIT



FOR LOGICAL "1" INPUT, "NOR" OUTPUT = −1.55 V
"OR" OUTPUT = −0.75 V

FOR LOGICAL "0" INPUT, "NOR" OUTPUT = −0.75 V
"OR" OUTPUT = −1.55 V

MAXIMUM RATINGS

Characteristic	Symbol	Rating	Unit

Ratings above which device life may be impaired:

Characteristic	Symbol	Rating	Unit
Power Supply Voltage (V_{CC} = 0 Vdc)	V_{EE}	−10	Vdc
Base Input Voltage (V_{CC} = 0 Vdc)	V_{in}	0 to V_{EE}	Vdc
Output Source Current	I_O	20	mAdc
Storage Temperature Range	T_{stg}	−65 to +150	°C

Rcommended maximum ratings above which performance may be degraded:

Characteristic	Symbol	Rating	Unit
Operating Temperature Range MC300 Series MC350 Series	T_A	−55 to +125 0 to +75	°C
AC Fan-In (Expandable Gates)	m	18	—
AC Fan-Out* (Gates and FlipFlops)	n	15	—

*Although a minimum dc fan-out of 25 is guaranteed in each electrical specification, it is recommended that the maximum ac fan-out of 15 be used for high-speed operation.

CIRCUIT DESCRIPTION

The MECL line of monolithic integrated logic circuits designed as a non-saturating form of logic eliminates transistor storage time as a speed limiting characteristic, and permits extremely high-speed operation.

The typical MECL circuit consists of a differential-amplifier input, with emitter-follower output to restore dc levels. High fan-out operation is possible because of the high input impedance of the differential amplifier and the low output impedance of the emitter followers. Power-supply noise is virtually eliminated by the nearly constant current drain of the differential amplifier, even during the transition period. Basic gate design provides for simultaneous output of both the function and its complement.

POWER-SUPPLY CONNECTIONS

Any one of the power supply nodes, V_{BB}, V_{CC}, or V_{EE} may be used as ground; however, the manufacturer has found it most convenient to ground the V_{CC} node. In such a case: $V_{CC} = 0$, $V_{BB} = -1.15$ V, $V_{EE} = -5.2$ V, as shown in the schematic diagram above.

SYSTEM LOGIC SPECIFICATIONS

The output logic swing of 0.8 V then varies from a low state of $V_L = -1.55$ V to a high state of $V_H = -0.75$ V with respect to ground.

Positive logic is used when reference is made to logical "0's" or "1's". Then

$$\left.\begin{aligned}\text{"0"} &= -1.55\text{ V}\\ \text{"1"} &= -0.75\text{ V}\end{aligned}\right\}\text{ typical}$$

Dynamic logic refers to a change of logic states. Dynamic "0" is a negative going voltage excursion and a dynamic "1" is a positive going voltage excursion.

CIRCUIT OPERATION

A fixed bias of −1.15 volts is applied to the "bias input" of the differential amplifier and the logic signals are applied to the "signal input". If a logical "0" is applied, the current through R_E is supplied by the fixed-biased transistor. A drop of 800 mV occurs across R_{C2}. The OR output then is −1.55 V, or one V_{BE}-drop below 800 mV. Since no current flows in the "signal input" transistor, the NOR output is a V_{BE}-drop below ground, or −0.75 volts. When a logical "1" level is applied to the "signal input", the current through R_{C2} is switched to the "signal input" transistor and a drop of 800 mV occurs across R_{C1}. The OR output then goes to −0.75 volts and the NOR output goes to −1.55 volts.

Note: Any unused input should be connected to V_{EE}.

BIAS VOLTAGE SOURCE

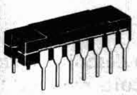
The bias voltage applied to the bias input is obtained from a regulated, temperature-compensated bias driver, type MC304 or MC354. The temperature characteristics of the bias driver compensate for any variations in circuit operating point over the temperature range or supply voltage changes, to insure that the threshold point is always in the center of the transfer characteristic curves. The bias driver can be used to drive up to 25 logic elements and should be employed for all elements except those with built-in bias networks.

MECL II INTEGRATED CIRCUITS MECL II

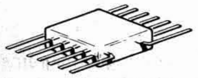
MC1000 Series (0 to +75°C)
MC1200 Series (−55 to +125°C)

FEATURES

- Propagation typically 4 ns per logic decision
- Excellent noise immunity characteristics
- Simultaneous OR/NOR or AND/NAND outputs
- High fan-in and fan-out capabilities



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



F SUFFIX
CASE 607
(Formerly Case 83)
TO-86

L SUFFIX
CERAMIC PACKAGE
CASE 620

The MECL II series of monolithic integrated logic circuits presents the system design engineer with an integrated circuit family designed to permit system implementation with the fewest possible number of individual units. This approach offers cost savings, reduced power supply requirements, smaller physical size and high reliability.

MECL II circuits feature the fastest propagation delay times with commensurate rise and fall times of any family of integrated circuits. This feature plus the constant current feature of MECL imposes fewer restrictions on design, layout and system fabrication than any other high-speed family.

FUNCTIONS AND CHARACTERISTICS (V_{CC} = 0, V_{EE} = −5.2 V, T_A = 25°C)

Function	Type		DC Output Loading Factor Each Output	Propagation Delay t_{pd} ns typ	Total Power Dissipation mW typ	Case ①
	−55 to +125°C	0 to +75°C				
Single 6 Input Gate, 3 OR Outputs w Pulldowns 3 NOR Outputs w Pulldowns	MC1201F	MC1001L	25	4.0	115	605C, 607
Single 6 Input Gate, 3 OR Outputs w Pulldowns 3 NOR Outputs w/o Pulldowns	MC1202F	MC1002L			80	
Single 6 Input Gate, 3 OR Outputs w/o Pulldowns 3 NOR Outputs w/o Pulldowns	MC1203F	MC1003L			40	
Dual 4 Input Gate, 2 OR Outputs w Pulldowns 2 NOR Outputs w Pulldowns	MC1204F	MC1004L			95	
Dual 4 Input Gate, 2 OR Outputs w Pulldowns 2 NOR Outputs w/o Pulldowns	MC1205F	MC1005L			65	
Dual 4 Input Gate, 2 OR Outputs w/o Pulldowns 2 NOR Outputs w/o Pulldowns	MC1206F	MC1006L			45	
Triple 3 Input Gate, 3 NOR Outputs w Pulldowns	MC1207F	MC1007L			110	
Triple 3 Input Gate, 1 NOR Outputs w Pulldown 2 NOR Outputs w/o Pulldowns	MC1208F	MC1008L			75	
Triple 3 Input Gate, 3 NOR Outputs w/o Pulldowns	MC1209F	MC1009L			60	
Quad 2 Input Gate, 4 NOR Outputs w Pulldowns	MC1210F	MC1010L		5.0	115	
Quad 2 Input Gate, 2 NOR Outputs w Pulldowns 2 NOR Outputs w/o Pulldowns	MC1211F	MC1011L			95	
Quad 2 Input Gate, 4 NOR Outputs w/o Pulldowns	MC1212F	MC1012L			65	
85 MHz AC Coupled J-K Flip-Flop	MC1213F	MC1013L		6.0	125	
Dual R-S Flip-Flop (Positive Clock)	MC1214F	MC1014L			140	
Dual R-S Flip-Flop (Negative Clock)	MC1215F	MC1015L			140	
Dual R-S Flip-Flop (Single Rail)	MC1216F	MC1016L			140	
Level Translator (Saturated Logic to MECL)	MC1217F	MC1017L	25 (MECL)	15	105	
Level Translator (MECL to Saturated Logic)	MC1218F	MC1018L	7 (DTL)	20	70	
Full Adder	MC1219F	MC1019L	25	4.0	110	
Quad Line Receiver	MC1220F	MC1020L			115	
Full Subtractor	MC1221F	MC1021L			110	
Type "D" Flip-Flops	MC1222F	MC1022L		8.0	110	
Dual 4-Input OR/NOR Clock Driver	—	MC1023L		2.0	250	605C
Dual 2-Input Expandable Gate	MC1224F	MC1024L		4.0	95	605C, 607
Dual 4 and 5 Input Expander	MC1225F	MC1025L	—	—	—	
Dual 3-4-Input Transmission Line and Clock Driver	MC1226F	MC1026L	25	2.0	140	
120 MHz AC Coupled J-K Flip-Flop	—	MC1027L	25	4.0	250	605C
Data Distributor	MC1229F	MC1029L		4.0	160	605C, 607
Quad Exclusive OR Gate	MC1230F	MC1030L		5.0	130	
Quad Exclusive NOR Gate	MC1231F	MC1031L		5.0	130	
Dual R-S Flip-Flop (Single Rail, Negative Clock)	MC1233F	MC1033L		6.0	140	
Type "D" Flip-Flop	—	MC1034L		4.0	185	605C
Dual Schmitt Trigger Triple Differential Amplifier	MC1235F	MC1035L		5.0	140	605C, 607
16-Bit Coincident Memory	—	MC1036L	5.0	17	250	605C
16-Bit Coincident Memory w/o Pulldowns	—	MC1037L	5.0	17	250	605C
8-Channel Data Selector	MC1238F	MC1038L	25	7.0	150	605C, 607
Quad Level Translator (MECL to Saturated Logic)	—	MC1039L	7 (DTL)	10	200	620

① Type numbers with F suffix use Case 607, Type numbers with L suffix use Case 605C or 620 as indicated.

MECL II LOGIC DIAGRAMS

The logic diagrams shown describe the circuits of the MECL II line and permit quick selection of those circuits required to implement a particular logic system. Pertinent information, such as logic equations, truth tables, typical propagation delay time (t_{pd}), and typical power dissipation per package (P_D) is provided to show line compatibility. Package pin numbers and dc loading factors for each device are specified on each logic diagram. The numbers at the ends of the terminals are package pin numbers. The numbers in parentheses indicate dc loading factors at each terminal.

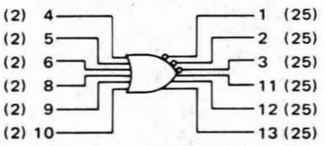
MECL II circuits contain internal bias networks, insuring that the transistion point is always in the center of the transfer characteristic curves over the temerature range.

GATES

(V_{CC} = pin 14, V_{EE} = pin 7 for Case 83 and Case 605C) (V_{CC} = pin 16, V_{EE} = pin 8 for Case 620)

MC1001, MC1002, MC1003 MC1201, MC1202, MC1203

6-Input Gate



(2) 4
(2) 5
(2) 6
(2) 8
(2) 9
(2) 10
1 (25)
2 (25)
3 (25)
11 (25)
12 (25)
13 (25)

$1 = \overline{4+5+6+8+9+10}$

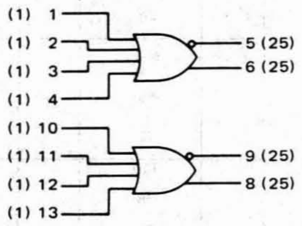
$11 = 4+5+6+8+9+10$

t_{pd} = 4.0 ns

P_D = MC1001/MC1201 – 115 mW
MC1002/MC1202 – 80 mW
MC1003/MC1203 – 40 mW

MC1004, MC1005, MC1006 MC1204, MC1205, MC1206

Dual 4-Input Gate



(1) 1
(1) 2
(1) 3
(1) 4
5 (25)
6 (25)
(1) 10
(1) 11
(1) 12
(1) 13
9 (25)
8 (25)

$5 = \overline{1+2+3+4}$

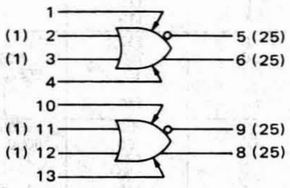
$6 = 1+2+3+4$

t_{pd} = 4.0 ns

P_D = MC1004/MC1204 – 95 mW
MC1005/MC1205 – 65 mW
MC1006/MC1206 – 45 mW

MC1024, MC1224

Dual 2-Input Expandable Gate



1
(1) 2
(1) 3
4
5 (25)
6 (25)
10
(1) 11
(1) 12
13
9 (25)
8 (25)

$5 = \overline{2+3}$

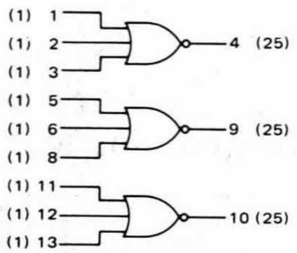
$6 = 2+3$

t_{pd} = 4.0 ns

P_D = 95 mW

MC1007, MC1008, MC1009 MC1207, MC1208, MC1209

Triple 3-Input Gate



(1) 1
(1) 2
(1) 3
4 (25)
(1) 5
(1) 6
(1) 8
9 (25)
(1) 11
(1) 12
(1) 13
10 (25)

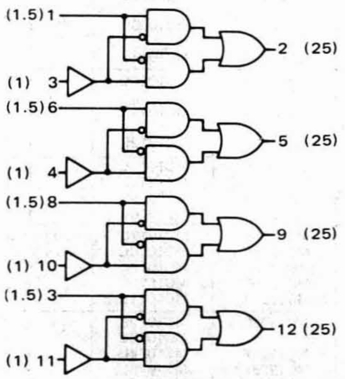
$4 = \overline{1+2+3}$

t_{pd} = 4.0 ns

P_D = MC1007/MC1207 – 110 mW
MC1008/MC1208 – 75 mW
MC1009/MC1209 – 60 mW

MC1030, MC1230

Quad Exclusive OR Gate



(1.5) 1
(1) 3
2 (25)
(1.5) 6
(1) 4
5 (25)
(1.5) 8
(1) 10
9 (25)
(1.5) 3
(1) 11
12 (25)

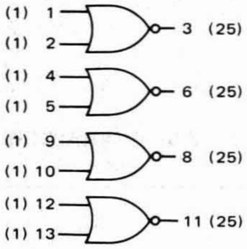
$2 = 1 \cdot \overline{3} + \overline{1} \cdot 3$

t_{pd} = 5.0 ns

P_D = 130 mW

MC1010, MC1011, MC1012 MC1210, MC1211, MC1212

Quad 2-Input Gate



(1) 1
(1) 2
3 (25)
(1) 4
(1) 5
6 (25)
(1) 9
(1) 10
8 (25)
(1) 12
(1) 13
11 (25)

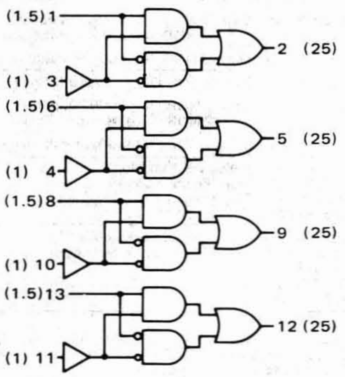
$3 = \overline{1+2}$

t_{pd} = 4.0 ns

P_D = MC1010/MC1210 – 115 mW
MC1011/MC1211 – 95 mW
MC1012/MC1212 – 65 mW

MC1031, MC1231

Quad Exclusive NOR Gate



(1.5) 1
(1) 3
2 (25)
(1.5) 6
(1) 4
5 (25)
(1.5) 8
(1) 10
9 (25)
(1.5) 13
(1) 11
12 (25)

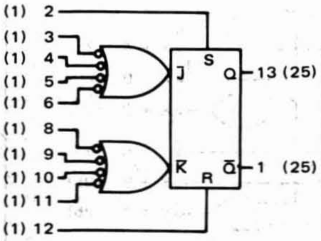
$2 = 1 \cdot 3 + \overline{1} \cdot \overline{3}$

t_{pd} = 5.0 ns

P_D = 130 mW

FLIP-FLOPS

MC1013, MC1213
85 MHz AC-Coupled J-K Flip Flop


(1) 2
(1) 3
(1) 4
(1) 5
(1) 6
(1) 8
(1) 9
(1) 10
(1) 11
(1) 12
J
S
Q
13 (25)
K̄
R
Q̄
1 (25)

t_{pd} = 6.0 ns
P_D = 125 mW

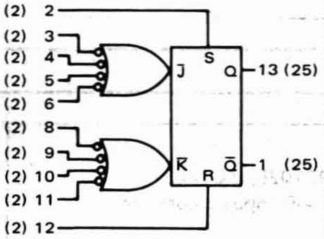
CLOCKED J-K OPERATION

$\bar{J}$	$\bar{K}$	$\bar{C}_D$	Q^n
φ	φ	0	Q^n
0	0	1	$\bar{Q}^n$
0	1	1	1
1	0	1	0
1	1	1	Q^n

The $\bar{J}$ and $\bar{K}$ inputs refer to logic levels while the $\bar{C}_D$ input refers to dynamic logic swings. The $\bar{J}$ and $\bar{K}$ inputs should be changed to a logical "1" only while the $\bar{C}_D$ input is in a logic "1" state. ($\bar{C}_D$ maximum "1" level = V_{CC} − 0.6 V.) Clock $\bar{C}_D$ is obtained by tying one $\bar{J}$ and one $\bar{K}$ input together.

R-S OPERATION

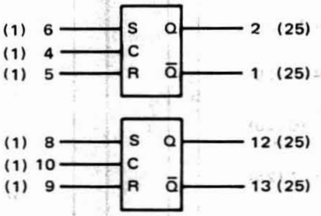
R	S	Q^{n+1}
0	1	1
1	0	0
0	0	Q^n
1	1	N.D.


(2) 2
(2) 3
(2) 4
(2) 5
(2) 6
(2) 8
(2) 9
(2) 10
(2) 11
(2) 12
J
S
Q
13 (25)
K̄
R
Q̄
1 (25)

t_{pd} = 4.0 ns
P_D = 250 mW

MC1027
120 MHz AC-Coupled J-K Flip-Flop

MC1014, MC1214
MC1015, MC1215
Dual Clocked R-S Flip-Flop


(1) 6
(1) 4
(1) 5
S
C
R
Q
Q̄
2 (25)
1 (25)
(1) 8
(1) 10
(1) 9
S
C
R
Q
Q̄
12 (25)
13 (25)

MC1014/1214

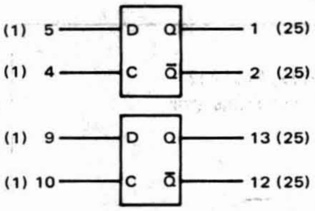
C	R	S	Q^{n+1}
1	0	0	Q^n
1	0	1	1
1	1	0	0
1	1	1	ND
0	φ	φ	Q^n

MC1015/1215

C	R	S	Q^{n+1}
0	0	0	Q^n
0	0	1	1
0	1	0	0
0	1	1	ND
1	φ	φ	Q^n

t_{pd} = 6.0 ns
P_D = 140 mW

MC1016, MC1216
MC1033, MC1233
Dual Clocked Single Rail R-S Flip-Flop


(1) 5
(1) 4
D
C
Q
Q̄
1 (25)
2 (25)
(1) 9
(1) 10
D
C
Q
Q̄
13 (25)
12 (25)

MC1016/1216

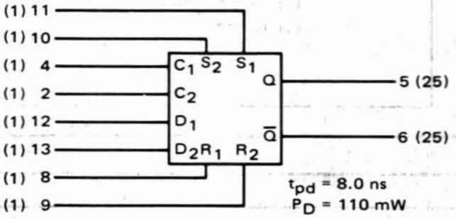
C	D	Q^{n+1}
0	0	Q^n
0	1	Q^n
1	0	0
1	1	1

MC1033/1233

C	D	Q^{n+1}
1	0	Q^n
1	1	Q^n
0	0	0
0	1	1

t_{pd} = 6.0 ns
P_D = 140 mW

MC1022, MC1222
Type "D" Flip-Flop


(1) 11
(1) 10
(1) 4
(1) 2
(1) 12
(1) 13
(1) 8
(1) 9
C1 S2 S1
C2
D1
D2 R1 R2
Q
Q̄
5 (25)
6 (25)

t_{pd} = 8.0 ns
P_D = 110 mW

R-S TRUTH TABLE

	R	S	Q^{n+1}	$\bar{Q}^{n+1}$
Pin No.	8 or 9	10 or 11	5	6
	0	0	Q^n	$\bar{Q}^n$
	0	1	1	0
	1	0	0	1
	1	1	N.D.	N.D.

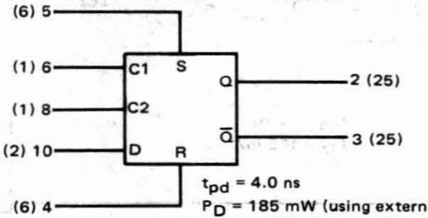
N.D. = Not Defined

CLOCKED TRUTH TABLE

	D	C	Q^{n+1}	$\bar{Q}^{n+1}$
Pin No.	12 or 13	2 or 4	5	6
	0	0	Q^n	$\bar{Q}^n$
	1	0	Q^n	$\bar{Q}^n$
	0	1*	0	1
	1	1*	1	0

*A "1" or Clock input is defined for this flip-flop as a change in level from a low input to a high input.

MC1034
Type "D" Flip-Flop


(6) 5
(1) 6
(1) 8
(2) 10
(6) 4
C1
S
C2
D
R
Q
Q̄
2 (25)
3 (25)

t_{pd} = 4.0 ns
P_D = 185 mW (using external 600-ohm pull-down resistors)
240 mW (using internal pull-down resistors)

R-S TRUTH TABLE

	R	S	Q^{n+1}	Q^{n+1}
Pin No.	4	5	2	3
	0	0	Q^n	$\bar{Q}^n$
	0	1	1	0
	1	0	0	1
	1	1	N.D.	N.D.

N.D. = Not Defined

CLOCKED TRUTH TABLE

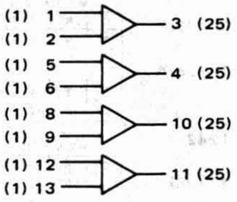
	D	C	Q^{n+1}	Q^{n+1}
Pin No.	10	6 or 8	2	3
	0	0	Q^n	$\bar{Q}^n$
	1	0	Q^n	$\bar{Q}^n$
	0	1*	0	1
	1	1*	1	0

*A "1" or Clock input is defined for this flip-flop as a change in level from a low input to a high input.

MECL II LOGIC DIAGRAMS

RECEIVER

MC1020, MC1220
Quad Line Receiver

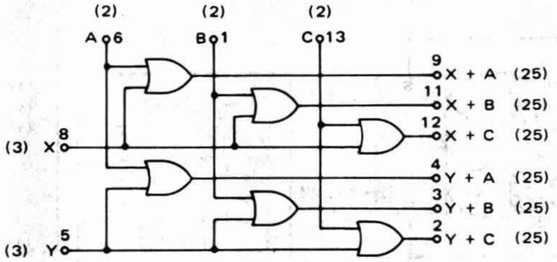


(1) 1
(1) 2
3 (25)
(1) 5
(1) 6
4 (25)
(1) 8
(1) 9
10 (25)
(1) 12
(1) 13
11 (25)

t_{pd} = 4.0 ns
P_D = 115 mW

DATA DISTRIBUTOR

MC1029, MC1229
2 X 3 Data Distributor

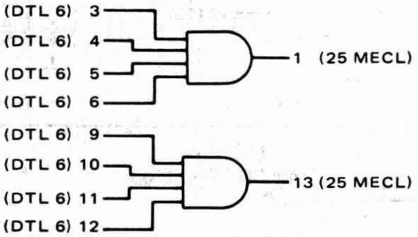


(2)
A 6
(2)
B 1
(2)
C 13
(3) X 8
(3) Y 5
9 X + A (25)
11 X + B (25)
12 X + C (25)
4 Y + A (25)
3 Y + B (25)
2 Y + C (25)

t_{pd} = 4.0 ns
P_D = 160 mW

TRANSLATORS

MC1017, MC1217
Dual Level Translator

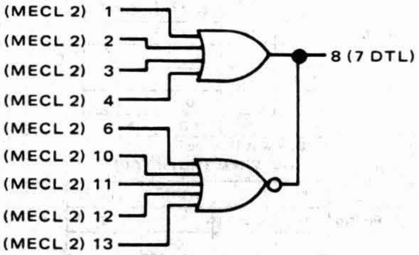


(DTL 6) 3
(DTL 6) 4
(DTL 6) 5
(DTL 6) 6
1 (25 MECL)
(DTL 6) 9
(DTL 6) 10
(DTL 6) 11
(DTL 6) 12
13 (25 MECL)

1 = 3•4•5•6

t_{pd} = 15 ns
P_D = 105 mW

MC1018, MC1218
Level Translator



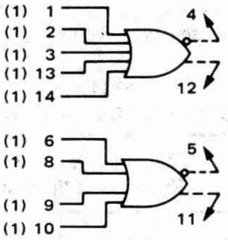
(MECL 2) 1
(MECL 2) 2
(MECL 2) 3
(MECL 2) 4
8 (7 DTL)
(MECL 2) 6
(MECL 2) 10
(MECL 2) 11
(MECL 2) 12
(MECL 2) 13

8 = 1+2+3+4
or
$8 = \overline{6+10+11+12+13}$

t_{pd} = 20 ns P_D = 70 mW

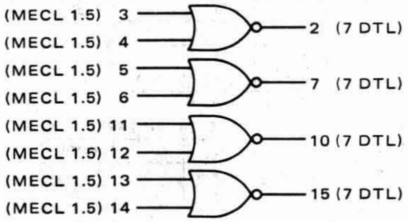
EXPANDER

MC1025, MC1225
Dual 4-5 Input Expander



(1) 1
(1) 2
(1) 3
(1) 13
(1) 14
4
12
(1) 6
(1) 8
(1) 9
(1) 10
5
11

MC1039
Quad Level Translator



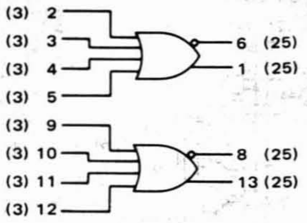
(MECL 1.5) 3
(MECL 1.5) 4
2 (7 DTL)
(MECL 1.5) 5
(MECL 1.5) 6
7 (7 DTL)
(MECL 1.5) 11
(MECL 1.5) 12
10 (7 DTL)
(MECL 1.5) 13
(MECL 1.5) 14
15 (7 DTL)

2 = 3 + 4
or $2 = \overline{3 + 4}$

t_{pd} = 10 ns
P_D = 200 mW

DRIVERS

MC1023
Dual 4-Input Clock Driver



(3) 2
(3) 3
(3) 4
(3) 5
(3) 9
(3) 10
(3) 11
(3) 12
6 (25)
1 (25)
8 (25)
13 (25)

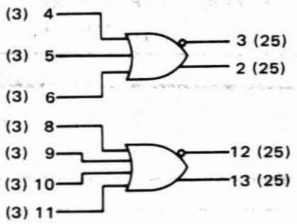
$6 = \overline{2 + 2 + 4 + 5}$

$1 = 2 + 3 + 4 + 5$

$t_{pd} = 2.0$ ns

$P_D = 250$ mW

MC1026, MC1226
Dual 3-4 Input Transmission Line and Clock Driver



(3) 4
(3) 5
(3) 6
(3) 8
(3) 9
(3) 10
(3) 11
3 (25)
2 (25)
12 (25)
13 (25)

$3 = \overline{4 + 5 + 6}$

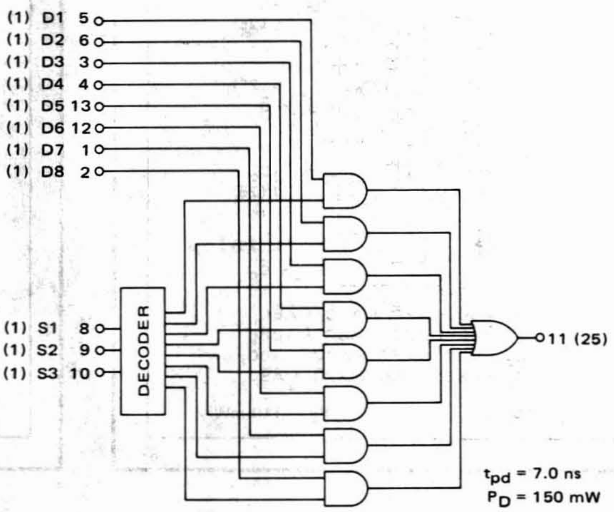
$2 = 4 + 5 + 6$

$t_{pd} = 2.0$ ns

$P_D = 140$ mW

DATA SELECTOR

MC1038, MC1238
8-Channel Data Selector



(1) D1 5
(1) D2 6
(1) D3 3
(1) D4 4
(1) D5 13
(1) D6 12
(1) D7 1
(1) D8 2
(1) S1 8
(1) S2 9
(1) S3 10
DECODER
11 (25)

$t_{pd} = 7.0$ ns

$P_D = 150$ mW

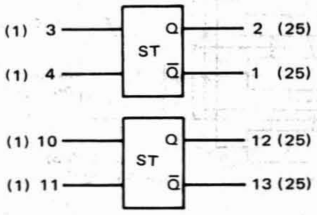
OUTPUT FUNCTION:

$\overline{S1}\,\overline{S2}\,\overline{S3}\,D1 + \overline{S1}\,\overline{S2}\,S3\,D2 + \overline{S1}\,S2\,\overline{S3}\,D3 + \overline{S1}\,S2\,S3\,D4 + S1\,\overline{S2}\,\overline{S3}\,D5 + S1\,\overline{S2}\,S3\,D6 + S1\,S2\,\overline{S3}\,D7 + S1\,S2\,S3\,D8$

TRIGGER AND AMPLIFIER

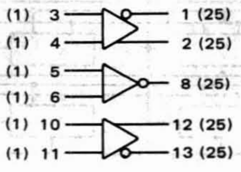
MC1035, MC1235

Dual Schmitt Trigger



(1) 3
(1) 4
(1) 10
(1) 11
ST
ST
Q
Q̄
Q
Q̄
2 (25)
1 (25)
12 (25)
13 (25)

Triple Differential Amplifier



(1) 3
(1) 4
(1) 5
(1) 6
(1) 10
(1) 11
1 (25)
2 (25)
8 (25)
12 (25)
13 (25)

$t_{pd} = 5.0$ ns

$P_D = 140$ mW

TRUTH TABLE

Inputs		Outputs	
3	4	1	2
5	6	8	–
10	11	13	12
H	V_{BB}	▨ L	H
L	V_{BB}	▨ H	L
V_{BB}	H	H	▨ L
V_{BB}	L	L	▨ H

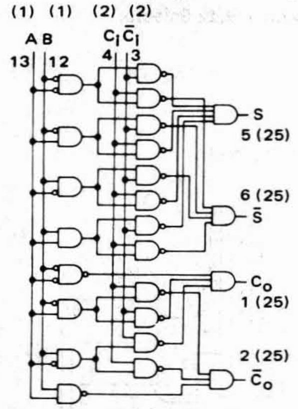
OR ☐ NOR ▨

The output polarities shown in the logic diagrams above are true only when V_{BB} is applied on Pins 4, 6 and 11.

MECL II LOGIC DIAGRAMS

FULL ADDER

MC1019, MC1219
Full Adder

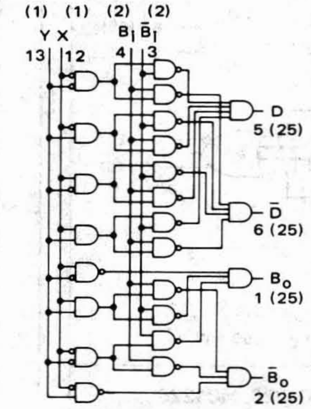

(1) (1) (2) (2)
A B
C_i $\bar{C}_i$
13 12
4 3
S
5 (25)
6 (25)
$\bar{S}$
C_o
1 (25)
2 (25)
$\bar{C}_o$

$S = ABC_i + A\bar{B}\bar{C}_i + \bar{A}B\bar{C}_i + \bar{A}\bar{B}C_i$
$\bar{S} = \bar{A}\bar{B}\bar{C}_i + AB\bar{C}_i + A\bar{B}C_i + \bar{A}BC_i$
$C_o = ABC_i + AB\bar{C}_i + A\bar{B}C_i + \bar{A}BC_i$
$\bar{C}_o = \bar{A}\bar{B}\bar{C}_i + A\bar{B}\bar{C}_i + \bar{A}B\bar{C}_i + \bar{A}\bar{B}C_i$

t_{pd} = 8.0 ns P_D = 110 mW

SUBTRACTOR

MC1021, MC1221
Full Subtractor

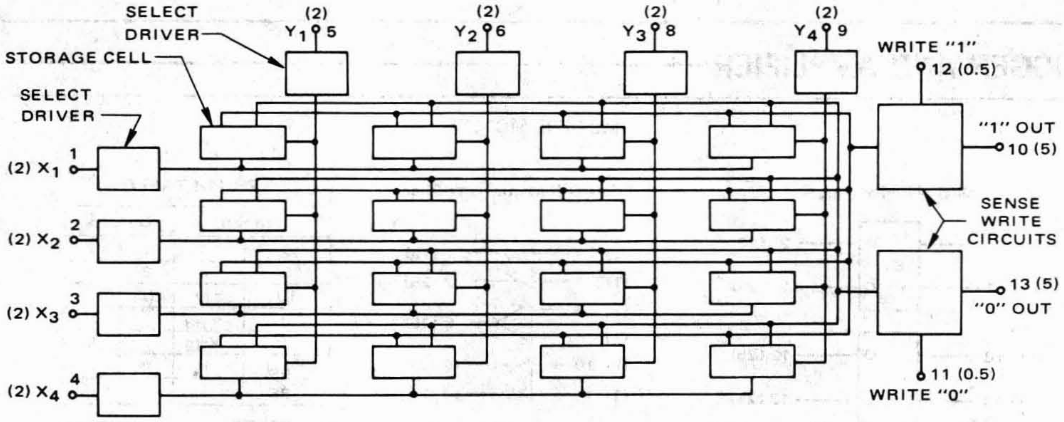

(1) (1) (2) (2)
Y X
B_i $\bar{B}_i$
13 12
4 3
D
5 (25)
$\bar{D}$
6 (25)
B_o
1 (25)
$\bar{B}_o$
2 (25)

$D = YXB_i + Y\bar{X}\bar{B}_i + \bar{Y}X\bar{B}_i + \bar{Y}\bar{X}B_i$
$\bar{D} = \bar{Y}\bar{X}\bar{B}_i + YX\bar{B}_i + Y\bar{X}B_i + \bar{Y}XB_i$
$B_o = \bar{Y}\bar{X}B_i + Y\bar{X}\bar{B}_i + Y\bar{X}B_i + YXB_i$
$\bar{B}_o = \bar{Y}\bar{X}\bar{B}_i + \bar{Y}X\bar{B}_i + \bar{Y}XB_i + YX\bar{B}_i$

t_{pd} = 8.0 ns P_D = 110 mW

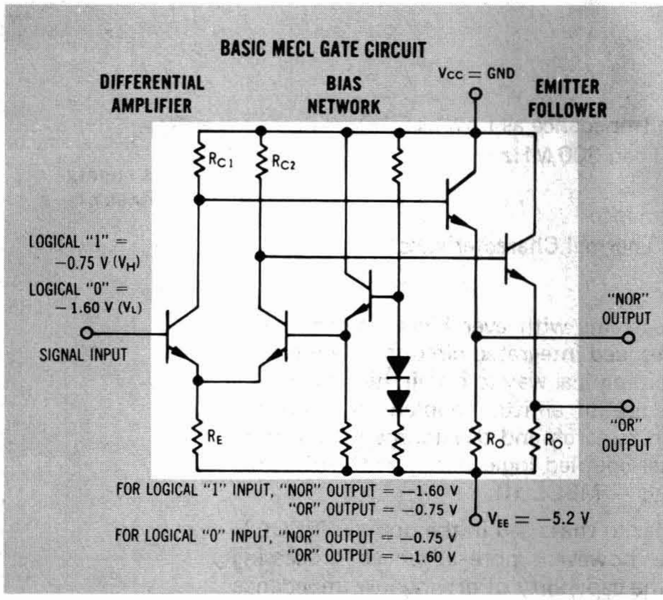
MEMORY

MC1036, MC1037
16-Bit Coincident Memory


SELECT DRIVER
STORAGE CELL
SELECT DRIVER
(2) Y_1 5
(2) Y_2 6
(2) Y_3 8
(2) Y_4 9
WRITE "1"
12 (0.5)
"1" OUT
10 (5)
SENSE WRITE CIRCUITS
13 (5)
"0" OUT
11 (0.5)
WRITE "0"
(2) X_1 1
(2) X_2 2
(2) X_3 3
(2) X_4 4

Cycle Time = 50 ns P_D = 250 mW

MECL II INTEGRATED CIRCUITS


BASIC MECL GATE CIRCUIT

FOR LOGICAL "1" INPUT, "NOR" OUTPUT = −1.60 V
"OR" OUTPUT = −0.75 V
FOR LOGICAL "0" INPUT, "NOR" OUTPUT = −0.75 V
"OR" OUTPUT = −1.60 V

MAXIMUM RATINGS

Characteristic	Symbol	Rating	Unit
Ratings above which device life may be impaired:			
Power Supply Voltage ($V_{CC} = 0$)	V_{EE}	−10	Vdc
Input Voltage ($V_{CC} = 0$)	V_{in}	0 to V_{EE}	Vdc
Output Source Current	I_O	20	mAdc
Storage Temperature Range MC1000L MC1200F	T_{stg}	−55 to +125 −65 to +175	°C
Recommended maximum ratings above which performance may be degraded:			
Operating Temperature Range MC1000L MC1200F	T_A	0 to +75 −55 to +125	°C
AC Fan-In (Expandable Gates)	m	20	—
AC Fan-Out* (Gates and Flip-Flops)	n	15	—

*Although a minimum dc fan-out of 25 is guaranteed in each electrical specification, it is recommended that the maximum ac fan-out of 15 be used for high-speed operation.

CIRCUIT DESCRIPTION

The MECL II line of monolithic integrated logic circuits was designed as a non-saturating form of logic which eliminates transistor storage time as a speed limiting characteristic, and permits extremely high-speed operation.

The typical MECL II circuit comprises a differential-amplifier input with internal bias reference and with emitter-follower output to restore dc levels. High fan-out operation is possible because of the high input impedance of the differential amplifier and the low output impedance of the emitter followers. Power-supply noise is virtually eliminated by the nearly constant current drain of the differential amplifier, even during the transition period. Basic gate design provides for simultaneous output of both the function and its complement.

POWER-SUPPLY CONNECTIONS

As shown in the schematic diagram above, it is recommended that −5.2 V be applied at V_{EE} with V_{CC} = Gnd.

SYSTEM LOGIC SPECIFICATIONS

The nominal output logic swing of 0.85 V then varies from a low state of $V_L = -1.60$ V to a high state of $V_H = -0.75$ V with respect to ground.

If Positive logic is used when reference is made to logical "0's" or "1's", then

$$\left.\begin{array}{l}\text{"0"} = -1.60\text{ V}\\ \text{"1"} = -0.75\text{ V}\end{array}\right\}\text{ typical}$$

Dynamic logic refers to a change of logic states. Dynamic "0" is a negative going voltage excursion and a dynamic "1" is a positive going voltage excursion.

CIRCUIT OPERATION

An internal bias of −1.175 V is applied to the "bias input" of the differential amplifier and the logic signals are applied to the "signal input". If a logical "0" is applied, the current through R_E is supplied by the internally biased transistor. A drop of 0.85 V occurs across R_{C2}. The OR output then is −1.60 V, or one V_{BE}-drop below 0.85 V. Since no current flows in the "signal input" transistor, the NOR output is a V_{BE}-drop below ground, or −0.75 V. When a logical "1" level is applied to the "signal input", the current through R_{C2} is switched to the "signal input" transistor and a drop of 0.85 V occurs across R_{C1}. The OR output then goes to −0.75 V and the NOR output goes to −1.60 V.

Note: Any unused input should be connected to V_{EE}.

BIAS VOLTAGE SOURCE

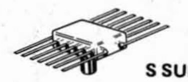
The bias voltage applied to the bias input is obtained from an internal regulated, temperature-compensated bias network. The temperature characteristics of the bias network compensate for any variations in circuit operating point over the temperature range or supply voltage changes, and insure that the threshold point is always in the center of the transfer characteristic curves.

MECL III INTEGRATED CIRCUITS MECL III

MC1600 series (0 to +75°C)

FEATURES

- Gate Switching Speeds of 1.0 ns
- Capability of Driving Terminated Lines with Impedance as Low as 50 Ohms
- Flip-Flop Toggle and Shifting Rate Greater Than 300 MHz
- Operation with Unused Inputs Left Open
- Multilayer Metalization for Optimum Performance
- New Packages with Improved Electrical and Thermal Characteristics
- Compatability with Low Cost MECL II



S SUFFIX
CASE 617

The requirement for digital systems with ever higher performance has increased the need for high-speed integrated circuits. The industry has recognized that the only economical way to obtain high operating system speed is through the use of emitter-coupled logic. As the result of considerable effort in research and development, Motorola offers a state-of-the-art, emitter-coupled logic family with sub-nanosecond local propagation delays – MECL III.

MECL III circuit design is similar to that used in the popular MECL II family. In the MECL III line, however, more advanced processing techniques are employed and the capability of driving low-impedance terminated lines is provided.

FUNCTIONS AND CHARACTERISTICS (V_{CC} = 0, V_{EE} = –5.2 V, T_A = 25°C)

Function	Type 0 to +75°C	DC Output Loading Factor Each Output	Propagation Delay t_{pd} ns typ	Total Power Dissipation mW typ
Dual 4-Input OR/NOR Gate	MC1660	90	1.1	110
Quad 2-Input NOR Gate	MC1662	90	1.1	220
Single Phase Type D Flip-Flop	MC1670	90	1.8	190

LOGIC DIAGRAMS

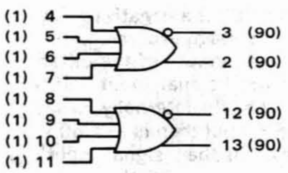
(V_{CC} = Gnd = Pins 1 and 14: V_{EE} = –5.2 V ±10% = Stud)

Loading Factors Listed Below Are dc Unterminated.

Numbers at ends of terminals denote pin numbers. Numbers in parenthesis denote loading.

GATES

MC1660
Dual 4-Input OR/NOR Gate

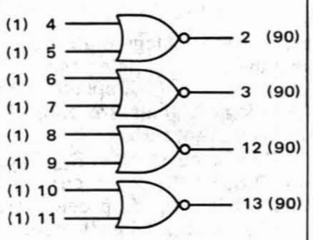


$3 = \overline{4+5+6+7}$

$2 = 4+5+6+7$

t_{pd} = 0.9 ns typ (510-ohm load)
1.1 ns typ (50-ohm load)
P_D = 110 mW typ/pkg (no load)

MC1662
Quad 2-Input NOR Gate

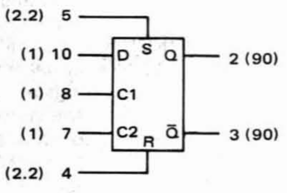


$2 = \overline{4+5}$

t_{pd} = 0.9 ns typ (510-ohm load)
1.1 ns typ (50-ohm load)
P_D = 220 mW typ/pkg (no load)

FLIP-FLOP

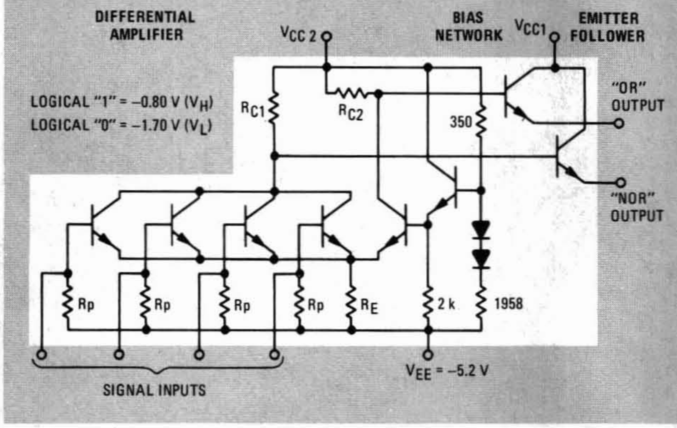
MC1670
Single Phase Type D Flip-Flop



f_{Tog} = 350 MHz typ
P_D = 190 mW typ/pkg (no load)

MECL III INTEGRATED CIRCUITS

BASIC HIGH INPUT IMPEDANCE MECL III GATE



MAXIMUM RATINGS

Characteristic	Symbol	Rating	Unit
Ratings above which device life may be impaired:			
Power Supply Voltage ($V_{CC} = 0$)	V_{EE}	−8	Vdc
Input Voltage ($V_{CC} = 0$)	V_{in}	0 to V_{EE}	Vdc
Output Source Current	I_o	40	mAdc
Storage Temperature Range	T_{stg}	−55 to +125	°C
Recommended maximum ratings above which performance may be degraded:			
Operating Temperature Range	T_A	0 to +75	°C
DC Fan-Out* (Gates and Flip-Flops)	n	90	–

*AC fan-out is limited by desired system performance.

FOR LOGICAL "1" INPUT,
"NOR" OUTPUT = −1.70 V
"OR" OUTPUT = −0.80 V

FOR LOGICAL "0" INPUT,
"NOR" OUTPUT = −0.80 V
"OR" OUTPUT = −1.70 V

CIRCUIT DESCRIPTION

The MECL III line of monolithic integrated logic circuits designed for extremely high speed system operation, is similar to and compatible with MECL II, but employs more advanced processing and design techniques.

The typical MECL III circuit consists of a differential-amplifier input with internal bias reference and with emitter-follower output to restore dc levels. High fan-out operation is possible because of the high-input impedance of the differential amplifier and the low-output impedance of the emitter followers. Power-supply noise is virtually eliminated by the nearly constant current drain of the differential amplifier, even during the transition period. Basic gate design provides for simultaneous output of both the function and its complement.

POWER-SUPPLY CONNECTIONS As shown in the schematic diagram above, it is recommended that −5.2 V be applied at V_{EE} with V_{CC} = Gnd.

SYSTEM LOGIC SPECIFICATIONS The nominal output logic swing of 0.90 V then varies from a low state of V_L = −1.70 V to a high state of V_H = −0.80 V with respect to ground.

If Positive logic is used when reference is made to logical "0's" or "1's", then

$$\left.\begin{array}{l}\text{"0"} = -1.70\ \text{V} \\ \text{"1"} = -0.80\ \text{V}\end{array}\right\}\ \text{typical}$$

Dynamic logic refers to a change of logic states. Dynamic "0" is a negative-going voltage excursion and a dynamic "1" is a positive-going voltage excursion.

CIRCUIT OPERATION An internal bias of −1.300 V is applied to the "bias input" of the differential amplifier and the logic signals are applied to the "signal input". If a logical "0" is applied, the current through R_E is supplied by the internally biased transistor. A drop of 0.90 V occurs across R_{C2}. The OR output then is −1.70 V, or one V_{BE}-drop below 0.90 V. Since no current flows in the "signal input" transistor, the NOR output is a V_{BE}-drop below ground, or −0.80 V. When a logical "1" level is applied to the "signal input", the current through R_{C2} is switched to the "signal input" transistor and a drop of 0.90 V occurs across R_{C1}. The OR output then goes to −0.80 V and the NOR output goes to −1.70 V. Note: all unused inputs are internally connected to V_{EE}.

BIAS VOLTAGE SOURCE The bias voltage applied to the bias input is obtained from an internal regulated, temperature-compensated bias network. The temperature characteristics of the bias network compensate for any variations in circuit operating point over the temperature range or supply voltage changes, and insure that the threshold point is always in the center of the transfer characteristic curves.

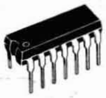
MHTL

INTEGRATED CIRCUITS

MHTL

MC660 Series (−30 to +75°C)

L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116

MHTL integrated circuits are especially designed to meet the requirements of industrial applications. Because of the outstanding noise immunity. MHTL circuits provide error-free operation in high noise environments far beyond the tolerance of other integrated circuit families. Multifunction packages and broad operating temperature range further tailor this device family to the industrial designer's requirements.

FUNCTIONS AND CHARACTERISTICS (V_{CC} = 15 V ±1.0 Vdc, T_A = 25°C)

Function	Type ③ Case 605C, 605 -30 to +75°C	Output Loading Factor Each Output	Propagation Delay t_{pd} ns typ	Power Dissipation mW typ/pkg
Expandable Dual 4-Input Gate (active pullup)	MC600L,P	10	110	88/26 ①
Expandable Dual 4-Input Gate (passive pullup)	MC661L,P	10	125	88/26 ①
Expandable Dual 4-Input Line Driver	MC662L,P	10	140	180/26 ①
Dual J-K Flip-Flop	MC663L,P	10	3.0 MHz ②	200
Master-Slave R-S Flip-Flop	MC664L,P	10	3.0 MHz ②	160
Triple Level Translator	MC665L,P	MDTL = 8 MTTL III = 5.5 MRTL = 5	40	83(DTL) 104(RTL)
Triple Level Translator	MC666L,P	10	75	105
Dual Monostable Multivibrator	MC667L,P	10	140	240
Quad 2-Input Gate (passive pullup)	MC668L,P	10	125	176/52 ①
Dual 4-Input Expander	MC669L,P	–	–	–
Triple 3-Input Gate (passive pullup)	MC670L,P	10	125	132/39 ①
Triple 3-Input Gate (active pullup)	MC671L,P	10	110	132/39 ①
Quad 2-Input Gate (active pullup)	MC672L,P	10	110	176/52 ①
Dual 2-Input AND-OR-INVERT Gate	MC673L,P	10	110	160/50 ①
Dual 2-Input AND-OR-INVERT Gate	MC674L,P	10	125	160/50 ①

① Inputs High/Input Low ② f_{Tog} ③ L suffix denotes Ceramic Package, P suffix denotes Plastic Package.

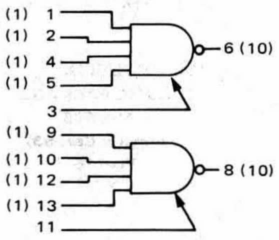
MAXIMUM RATINGS (T_A = 25°C)

Rating		Symbol	Value	Unit
Power Supply Voltage	Continuous Pulsed, < 1.0 s	V_{CC}	18 20	Vdc
Input Voltage	MC665 MC666 DTL RTL MC669 All Others	V_{in}	−1.0 to +18 −1 to +6 −4 to +4 −1.0 to +18 −1.0 to +18	Vdc
Output Current (into outputs)	MC662 MC663 MC664 MC669 All Others	–	60 28 26 – 30	mAdc
Input Reverse Current @ 18 V		I_R	0.5	mAdc
Forward Current (Individual) MC669		I_F	30	mAdc
Operating Temperature Range		T_A	−30 to +75	°C
Storage Temperature Range		T_{stg}	−55 to +125	°C

MHTL LOGIC DIAGRAMS

GATES

MC660
Expandable
Dual 4-Input NAND Gate
(active output pullup)

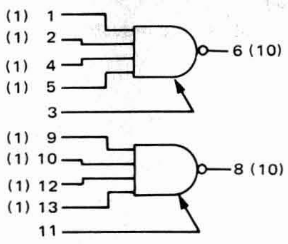


(1) 1
(1) 2
(1) 4
(1) 5
6 (10)
3
(1) 9
(1) 10
(1) 12
(1) 13
8 (10)
11

$6 = \overline{1 \cdot 2 \cdot 4 \cdot 5 \cdot [3]}$

t_{pd} = 110 ns typ
P_D = 88 mW typ/pkg (Inputs High)
26 mW typ/pkg (Input Low)

MC661
Expandable
Dual 4-Input NAND Gate
(passive output pullup)

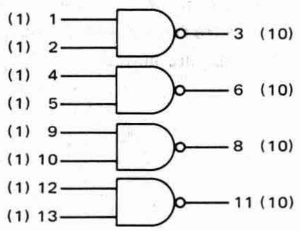


(1) 1
(1) 2
(1) 4
(1) 5
6 (10)
3
(1) 9
(1) 10
(1) 12
(1) 13
8 (10)
11

$6 = \overline{1 \cdot 2 \cdot 4 \cdot 5 \cdot [3]}$

t_{pd} = 125 ns typ
P_D = 88 mW typ/pkg (Inputs High)
26 mW typ/pkg (Input Low)

MC668
Quad 2-Input NAND Gate
(passive output pullup)

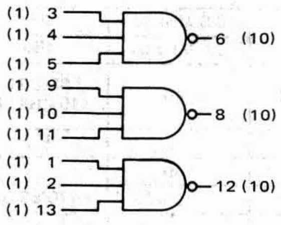


(1) 1
(1) 2
3 (10)
(1) 4
(1) 5
6 (10)
(1) 9
(1) 10
8 (10)
(1) 12
(1) 13
11 (10)

$3 = \overline{1 \cdot 2}$

t_{pd} = 125 ns typ
P_D = 176 mW typ/pkg (Inputs High)
52 mW typ/pkg (Input Low)

MC670
Triple 3-Input NAND Gate
(passive output pullup)

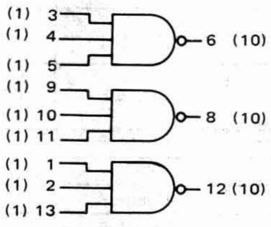


(1) 3
(1) 4
(1) 5
6 (10)
(1) 9
(1) 10
(1) 11
8 (10)
(1) 1
(1) 2
(1) 13
12 (10)

$6 = \overline{3 \cdot 4 \cdot 5}$

t_{pd} = 125 ns typ
P_D = 132 mW typ/pkg (Inputs High)
39 mW typ/pkg (Input Low)

MC671
Triple 3-Input NAND Gate
(active output pullup)

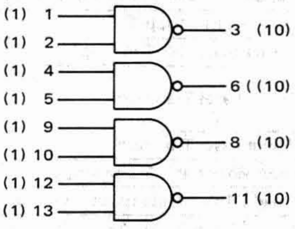


(1) 3
(1) 4
(1) 5
6 (10)
(1) 9
(1) 10
(1) 11
8 (10)
(1) 1
(1) 2
(1) 13
12 (10)

$6 = \overline{3 \cdot 4 \cdot 5}$

t_{pd} = 110 ns typ
P_D = 132 mW typ/pkg (Inputs High)
39 mW typ/pkg (Input Low)

MC672
Quad 2-Input NAND Gate
(active output pullup)

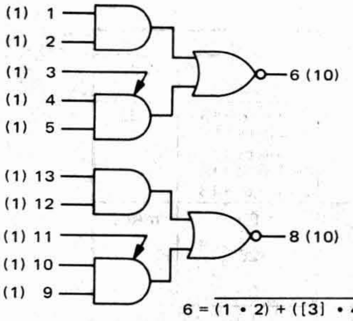


(1) 1
(1) 2
3 (10)
(1) 4
(1) 5
6 ((10)
(1) 9
(1) 10
8 (10)
(1) 12
(1) 13
11 (10)

$3 = \overline{1 \cdot 2}$

t_{pd} = 110 ns typ
P_D = 176 mW typ/pkg (Inputs High)
52 mW typ/pkg (Input Low)

MC673
Expandable
Dual 2-Input AND-OR-INVERT Gate

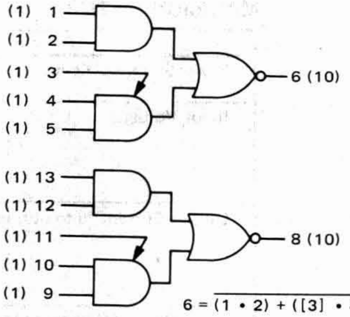


(1) 1
(1) 2
(1) 3
(1) 4
(1) 5
6 (10)
(1) 13
(1) 12
(1) 11
(1) 10
(1) 9
8 (10)

$6 = \overline{(1 \cdot 2) + ([3] \cdot 4 \cdot 5)}$

t_{pd} = 110 ns typ
P_D = 160 mW typ/pkg (Inputs High)
50 mW typ/pkg (Input Low)

MC674
Expandable
Dual 2-Input AND-OR-INVERT Gate



(1) 1
(1) 2
(1) 3
(1) 4
(1) 5
6 (10)
(1) 13
(1) 12
(1) 11
(1) 10
(1) 9
8 (10)

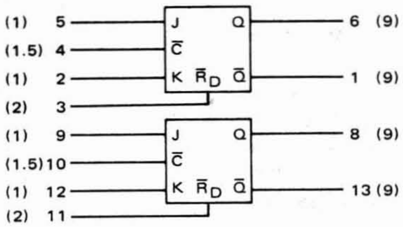
$6 = \overline{(1 \cdot 2) + ([3] \cdot 4 \cdot 5)}$

t_{pd} = 125 ns typ
P_D = 160 mW typ/pkg (Inputs High)
50 mW typ/pkg (Input Low)

Numbers at ends of terminals represent pin numbers.
Numbers in parenthesis indicate loading.
(V_{CC} = Pin 14, Gnd = Pin 7)

FLIP-FLOPS

MC663
Dual J-K Flip-Flop



(1) 5
(1.5) 4
(1) 2
(2) 3
J
C̄
K
R̄D
Q
Q̄
6 (9)
1 (9)
(1) 9
(1.5) 10
(1) 12
(2) 11
8 (9)
13 (9)

f_{Tog} = 3.0 MHz typ
P_D = 200 mW typ/pkg

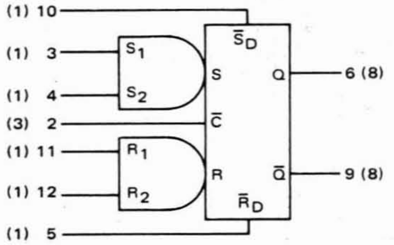
TRUTH TABLE

t_n		t_{n+1}	
J	K	Q	$\overline{Q}$
0	0	Q_n	$\overline{Q}_n$
1	0	1	0
0	1	0	1
1	1	$\overline{Q}_n$	Q_n

Direct input ($\overline{R}_D$) must be high.
0 = low state
1 = high state
t_n = time period prior to negative transition of clock pulse
t_{n+1} = time period subsequent to negative transition of clock pulse
Q_n = state of Q output in time period t_n

NOTE: A low state "0" at the direct reset $\overline{R}_D$ causes a low state "0" at the Q output and the complement at the $\overline{Q}$ output.

MC664
Master-Slave R-S Flip-Flop



(1) 10
(1) 3
(1) 4
(3) 2
(1) 11
(1) 12
(1) 5
S1
S2
R1
R2
S̄D
S
Q
C̄
R
Q̄
R̄D
6 (8)
9 (8)

f_{Tog} = 3.0 MHz typ
P_D = 160 mW typ/pkg

DIRECT INPUT OPERATION

$\overline{R}_D$	$\overline{S}_D$	Q	$\overline{Q}$
1	1	NC	NC
1	0	1	0
0	1	0	1
0	0	NA	NA

$\overline{C}$ must be Low
0 = low state
1 = high state
NC = No change
NA = Not allowed

CLOCKED OPERATION

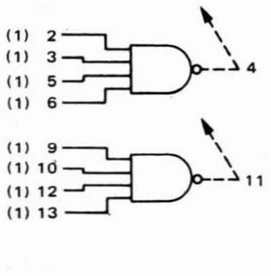
t_n				t_{n+1}
S_1	S_2	R_1	R_2	Q
0	X	0	X	Q_n
0	X	X	0	Q_n
X	0	0	X	Q_n
X	0	X	0	Q_n
0	X	1	1	0
X	0	1	1	0
1	1	0	X	1
1	1	X	0	1
1	1	1	1	U

Direct inputs ($\overline{R}_D$, $\overline{S}_D$) must be hign.

X = state of input does not affect state of the circuit
U = indeterminate state
t_n = time period prior to negative transition of clock pulse
t_{n+1} = time period subsequent to negative transition of clock pulse
Q_n = state of Q output in time period t_n

EXPANDER

MC669
Dual 4-Input Expander

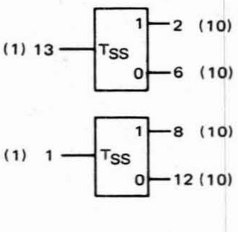


(1) 2
(1) 3
(1) 5
(1) 6
4
(1) 9
(1) 10
(1) 12
(1) 13
11

$4 = \overline{2 \cdot 3 \cdot 5 \cdot 6}$

MULTIVIBRATOR

MC667
Dual Monostable Multivibrator

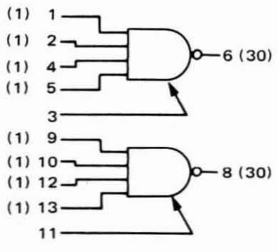


(1) 13
TSS
1
0
2 (10)
6 (10)
(1) 1
8 (10)
12 (10)

t_{pd} = 140 ns typ
P_D = 240 mW typ/pkg

DRIVER

MC662
Expandable
Dual 4-Input Line Driver
(active output pullup)



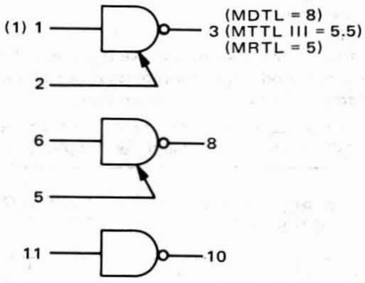
(1) 1
(1) 2
(1) 4
(1) 5
3
6 (30)
(1) 9
(1) 10
(1) 12
(1) 13
11
8 (30)

$6 = \overline{1 \cdot 2 \cdot 4 \cdot 5 \cdot [3]}$

t_{pd} = 140 ns typ
P_D = 180 mW typ/pkg (Inputs High)
26 mW typ/pkg (Input Low)

TRANSLATORS

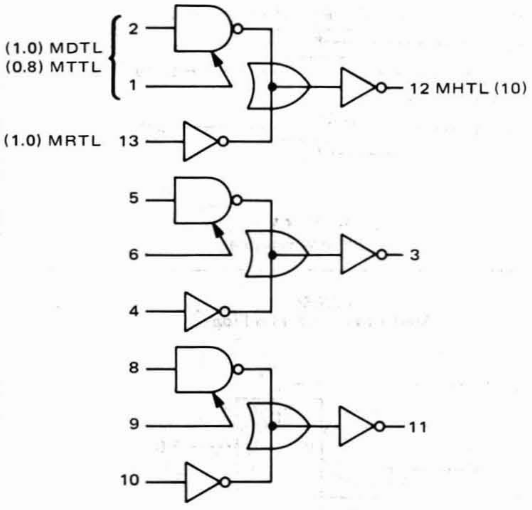
MC665
Triple Level Translator


(1) 1
3
(MDTL = 8)
(MTTL III = 5.5)
(MRTL = 5)
2
6
8
5
11
10

$3 = \overline{1 \cdot [2]}$

t_{pd} = 40 ns typ
P_D = 83 mW typ/pkg (DTL)
104 mW typ/pkg (RTL)

MC666
Triple Level Translator


2
(1.0) MDTL
(0.8) MTTL
1
12 MHTL (10)
(1.0) MRTL 13
5
6
3
4
8
9
11
10

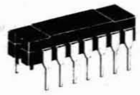
$12 = 2 \cdot [1] + 13$

t_{pd} = 75 ns typ
P_D = 105 mW typ/pkg

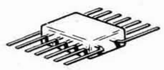
INTEGRATED CIRCUITS

MC5400 Series (–55 to +125°C)
MC7400 Series (0 to +70°C)

MC5400/MC7400 series integrated circuits comprise a family of transistor-transistor logic designed for general purpose digital applications. The family has a medium operating speed (15-30 MHz clock rate), good external noise immunity, high fan out, and the capability of driving capacitive loads of up to 600 pF.



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



F SUFFIX
CASE 609
TO-85

MAXIMUM RATINGS

Rating		Value	Unit
Power Supply Voltage		7.0	Vdc
Input Voltage		5.5	Vdc
Operating Temperature Range	MC5400 MC7400	–55 to +125 0 to +70	°C
Storage Temperature Range		–65 to +150	°C

FUNCTIONS AND CHARACTERISTICS (V_{CC} = 5.0 V, T_A = 25°C)

Function	Type ①		Case	Output Loading Factor Each Output	Propagation Delay t_{pd} ns typ	Power Dissipation mW typ/pkg
	–55°C to +125°C	0 to +70°C				
Quad 2-Input NAND Gate	MC5400F,L	MC7400F,L	609, 605C	10	13	40
Quad 2-Input NAND Gate (Open Collector Output)	MC5401F,L	MC7401F,L	609, 605C	10	35	40
Quad 2-Input NOR Gate	MC5402F,L	MC7402F,L	609, 605C	10	13	48
Triple 3-Input NAND Gate	MC5410F,L	MC7410F,L	609, 605C	10	13	30
Dual 4-Input NAND Gate	MC5420F,L	MC7420F,L	609, 605C	10	13	20
8-Input NAND Gate	MC5430F,L	MC7430F,L	609, 605C	10	13	10
Dual 4-Input NAND Buffer	MC5440F,L	MC7440F,L	609, 605C	30	13	50
Expandable Dual 2-Wide 2-Input AND-OR-INVERT Gate	MC5450F,L	MC7450F,L	609, 605C	10	13	28
Dual 2-Wide 2-Input AND-OR-INVERT Gate	MC5451F,L	MC7451F,L	609, 605C	10	13	28
Expandable 4-Wide 2-Input AND-OR-INVERT Gate	MC5453F,L	MC7453F,L	609, 605C	10	13	22
4-Wide 2-Input AND-OR-INVERT Gate	MC5454F,L	MC7454F,L	609, 605C	10	13	22
Dual 4-Input Expander for AND-OR-INVERT Gates	MC5460F,L	MC7460F,L	609, 605C	–	5.0	8.0
J-K Flip-Flop	MC5472F,L	MC7472F,L	609, 605C	10	30	40
Dual J-K Flip-Flop	MC5473F,L	MC7473F,L	609, 605C	10	30	80
Dual Type D Flip-Flop	MC5479F,L	MC7479F,L	609, 605C	10	16	84

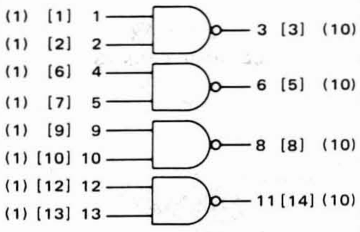
① F suffix denotes Flat Package, L suffix denotes Dual In-Line Ceramic Package.

MTTL LOGIC DIAGRAMS

Flat Package: V_{CC} = Pin 4, Gnd = Pin 11.
Dual In-Line Package: V_{CC} = Pin 14, Gnd = Pin 7 unless otherwise noted.

GATES

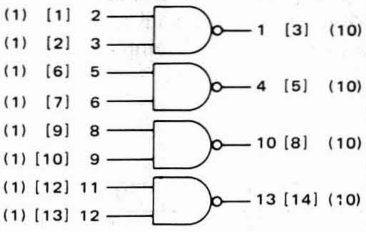
MC5400/MC7400
Quad 2-Input NAND Gate


(1) [1] 1
(1) [2] 2
3 [3] (10)
(1) [6] 4
(1) [7] 5
6 [5] (10)
(1) [9] 9
(1) [10] 10
8 [8] (10)
(1) [12] 12
(1) [13] 13
11 [14] (10)

$3 = \overline{1 \cdot 2}$

t_{pd} = 13 ns typ
P_D = 40 mW typ/pkg

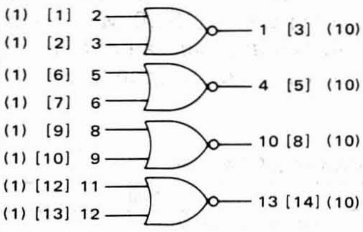
MC5401/MC7401
Quad 2-Input NAND Gate
(Open Collector Output)


(1) [1] 2
(1) [2] 3
1 [3] (10)
(1) [6] 5
(1) [7] 6
4 [5] (10)
(1) [9] 8
(1) [10] 9
10 [8] (10)
(1) [12] 11
(1) [13] 12
13 [14] (10)

$1 = \overline{2 \cdot 3}$

t_{pd} = 35 ns typ
P_D = 40 mW typ/pkg

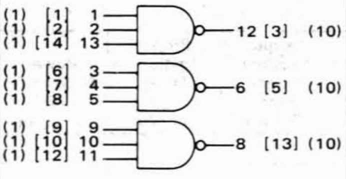
MC5402/MC7402
Quad 2-Input NOR Gate


(1) [1] 2
(1) [2] 3
1 [3] (10)
(1) [6] 5
(1) [7] 6
4 [5] (10)
(1) [9] 8
(1) [10] 9
10 [8] (10)
(1) [12] 11
(1) [13] 12
13 [14] (10)

$1 = \overline{2 + 3}$

t_{pd} = 13 ns typ
P_D = 48 mW typ/pkg

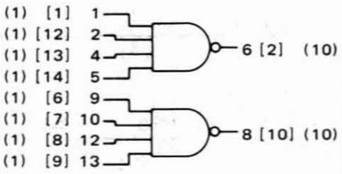
MC5410/MC7410
Triple 3-Input NAND Gate


(1) [1] 1
(1) [2] 2
(1) [14] 13
12 [3] (10)
(1) [6] 3
(1) [7] 4
(1) [8] 5
6 [5] (10)
(1) [9] 9
(1) [10] 10
(1) [12] 11
8 [13] (10)

$12 = \overline{1 \cdot 2 \cdot 13}$

t_{pd} = 13 ns typ
P_D = 30 mW typ/pkg

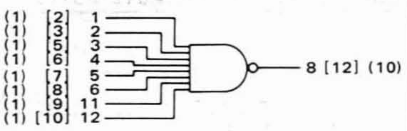
MC5420/MC7420
Dual 4-Input NAND Gate


(1) [1] 1
(1) [12] 2
(1) [13] 4
(1) [14] 5
6 [2] (10)
(1) [6] 9
(1) [7] 10
(1) [8] 12
(1) [9] 13
8 [10] (10)

$6 = \overline{1 \cdot 2 \cdot 4 \cdot 5}$

t_{pd} = 13 ns typ
P_D = 20 mW typ/pkg

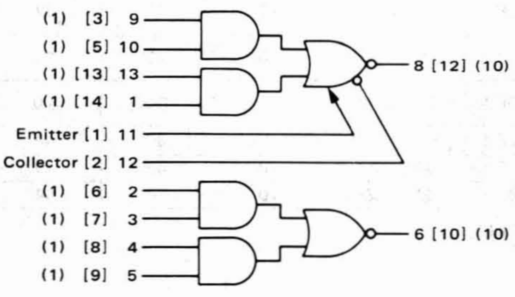
MC5430/MC7430
8-Input NAND Gate


(1) [2] 1
(1) [3] 2
(1) [5] 3
(1) [6] 4
(1) [7] 5
(1) [8] 6
(1) [9] 11
(1) [10] 12
8 [12] (10)

$8 = \overline{1 \cdot 2 \cdot 3 \cdot 4 \cdot 5 \cdot 6 \cdot 11 \cdot 12}$

t_{pd} = 13 ns typ
P_D = 10 mW typ/pkg

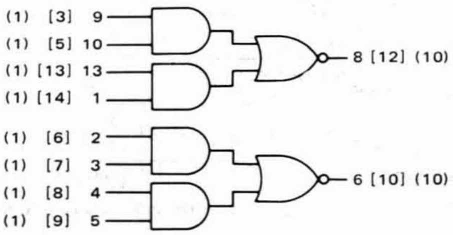
MC5450/MC7450
Expandable Dual 2-Wide 2-Input
AND-OR-INVERT Gate


(1) [3] 9
(1) [5] 10
(1) [13] 13
(1) [14] 1
8 [12] (10)
Emitter [1] 11
Collector [2] 12
(1) [6] 2
(1) [7] 3
(1) [8] 4
(1) [9] 5
6 [10] (10)

$8 = \overline{(9 \cdot 10) + (13 \cdot 1) + (\text{Expanders})}$

t_{pd} = 13 ns typ
P_D = 28 mW typ/pkg

MC5451/MC7451
Dual 2-Wide 2-Input
AND-OR-INVERT Gate


(1) [3] 9
(1) [5] 10
(1) [13] 13
(1) [14] 1
8 [12] (10)
(1) [6] 2
(1) [7] 3
(1) [8] 4
(1) [9] 5
6 [10] (10)

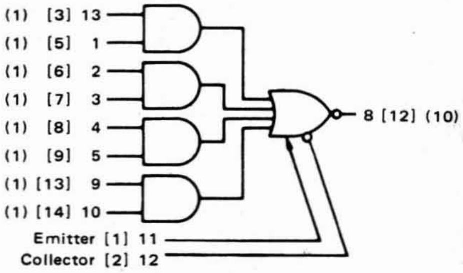
$8 = \overline{(9 \cdot 10) + (13 \cdot 1)}$

t_{pd} = 13 ns typ
P_D = 28 mW typ/pkg

Numbers at ends of terminals represent pin numbers for devices in the dual in-line package.
Numbers in brackets represent pin numbers for devices in the flat package.
Numbers in parenthesis indicate loading.
Logic equations are for devices in the dual in-line package.

GATES (continued)

MC5453/MC7453
Expandable 4-Wide 2-Input AND-OR-INVERT Gate

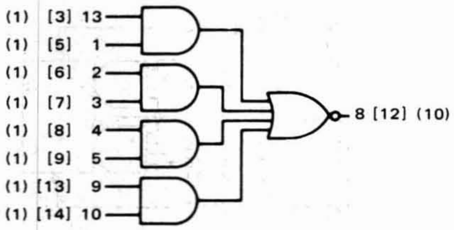


(1) [3] 13
(1) [5] 1
(1) [6] 2
(1) [7] 3
(1) [8] 4
(1) [9] 5
(1) [13] 9
(1) [14] 10
Emitter [1] 11
Collector [2] 12
8 [12] (10)

$$8 = \overline{(13 \cdot 1) + (2 \cdot 3) + (4 \cdot 5) + (9 \cdot 10) + (\text{Expanders})}$$

t_{pd} = 13 ns typ
P_D = 22 mW typ/pkg

MC5454/MC7454
4-Wide 2-Input AND-OR-INVERT Gate



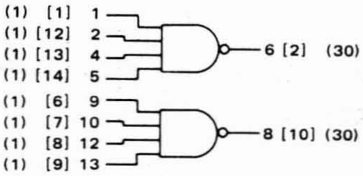
(1) [3] 13
(1) [5] 1
(1) [6] 2
(1) [7] 3
(1) [8] 4
(1) [9] 5
(1) [13] 9
(1) [14] 10
8 [12] (10)

$$8 = \overline{(13 \cdot 1) + (2 \cdot 3) + (4 \cdot 5) + (9 \cdot 10)}$$

t_{pd} = 13 ns typ
P_D = 22 mW typ/pkg

BUFFER

MC5440/MC7440
Dual 4-Input NAND Buffer



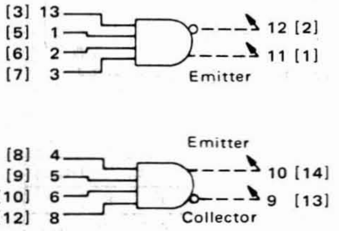
(1) [1] 1
(1) [12] 2
(1) [13] 4
(1) [14] 5
6 [2] (30)
(1) [6] 9
(1) [7] 10
(1) [8] 12
(1) [9] 13
8 [10] (30)

$$6 = \overline{1 \cdot 2 \cdot 4 \cdot 5}$$

t_{pd} = 13 ns typ
P_D = 50 mW typ/pkg

EXPANDER

MC5460/MC7460
Dual 4-Input Expander for AND-OR-INVERT Gates



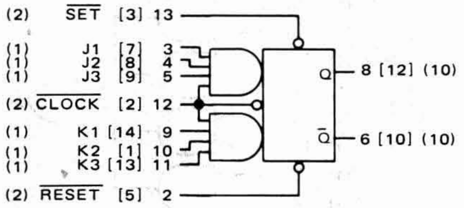
[3] 13
[5] 1
[6] 2
[7] 3
12 [2]
11 [1]
Emitter
Emitter
[8] 4
[9] 5
[10] 6
[12] 8
10 [14]
9 [13]
Collector

A maximum of 4 Expanders may be connected to the MC7450/MC5450 or MC7453/MC5453.

MTTL LOGIC DIAGRAMS

FLIP-FLOPS

MC5472/MC7472
J-K Flip-Flop



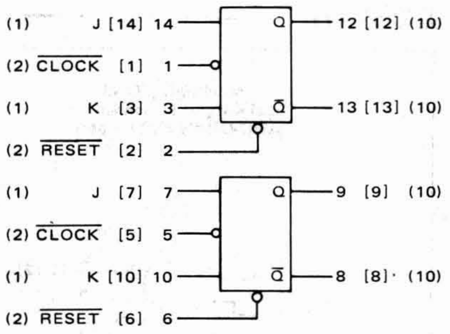
(2) SET [3] 13
(1) J1 [7] 3
(1) J2 [8] 4
(1) J3 [9] 5
(2) CLOCK [2] 12
(1) K1 [14] 9
(1) K2 [1] 10
(1) K3 [13] 11
(2) RESET [5] 2
Q
8 [12] (10)
Q̄
6 [10] (10)

t_n		t_{n+1}
J	K	Q
0	0	Q_n
0	1	0
1	0	1
1	1	$\overline{Q}_n$

$J = J1 \cdot J2 \cdot J3$
$K = K1 \cdot K2 \cdot K3$

f = 15 MHz
P_D = 40 mW typ/pkg

MC5473/MC7473
Dual J-K Flip-Flop



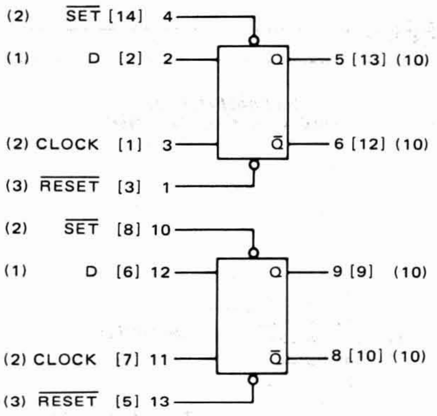
(1) J [14] 14
(2) CLOCK [1] 1
(1) K [3] 3
(2) RESET [2] 2
Q
Q̄
12 [12] (10)
13 [13] (10)
(1) J [7] 7
(2) CLOCK [5] 5
(1) K [10] 10
(2) RESET [6] 6
Q
Q̄
9 [9] (10)
8 [8] (10)

t_n		t_{n+1}
J	K	Q
0	0	Q_n
0	1	0
1	0	1
1	1	$\overline{Q}_n$

f = 15 MHz
P_D = 80 mW typ/pkg

V_{CC} = Pin 4, Gnd = Pin 11 for both packages.

MC5479/MC7479
Dual Type D Flip-Flop



(2) SET [14] 4
(1) D [2] 2
(2) CLOCK [1] 3
(3) RESET [3] 1
Q
Q̄
5 [13] (10)
6 [12] (10)
(2) SET [8] 10
(1) D [6] 12
(2) CLOCK [7] 11
(3) RESET [5] 13
Q
Q̄
9 [9] (10)
8 [10] (10)

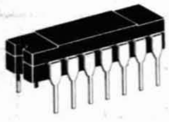
t_n	t_{n+1}	
D	Q	$\overline{Q}$
0	0	1
1	1	0

f = 30 MHz
P_D = 84 mW typ/pkg

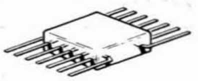
INTEGRATED CIRCUITS

MC400 Series (0 to +75°C)
MC500 Series (-55 to +125°C)

MTTL integrated circuits comprise a family of transistor-transistor logic designed for general purpose digital applications. The family has a medium operating speed (20 MHz clock rate), good external noise immunity, high fan out, and the capability of driving lines up to 600 pF capacitance.



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



F SUFFIX
CASE 609
TO-85

FUNCTIONS AND CHARACTERISTICS (V_{CC} = 5.0 V, T_A = 25°C)

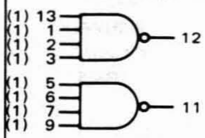
	Type ①		Output Loading Factor Each Output		Propagation Delay t_{pd} ns typ	Power Dissipation mW typ/pkg
Function	Case 609, 605C 0 to +75°C	Case 609, 605C -55 to +125°C	MC400 Series	MC500 Series		
Dual 4-Input NAND Gate	MC400 MC450	MC500 MC550	12 6	15 7	10	30
Expandable 4-Wide 2-2-2-3-Input AND-OR-INVERT Gate	MC401 MC451	MC501 MC551	12 6	15 7	12	30
8-Input NAND Gate	MC402 MC452	MC502 MC552	12 6	15 7	12	15
2-Wide 3-Input AND-OR-INVERT Gate with Gated Complement	MC403 MC453	MC503 MC553	12 6	15 7	11	35
Expandable 3-Wide 3-Input AND-OR-INVERT Gate	MC404 MC454	MC504 MC554	12 6	15 7	12	25
Expandable 2-Wide 4-Input AND-OR-INVERT Gate	MC405 MC455	MC505 MC555	12 6	15 7	12	20
Expandable 8-Input NAND Gate	MC406 MC456	MC506 MC556	12 6	15 7	18	15
Line Driver	MC407 MC457	MC507 MC557	12 6	15 7	25 @ 1000 pF Load	60
Quad 2-Input NAND Gate	MC408 MC458	MC508 MC558	12 6	15 7	10	60
4-Wide 3-2-2-3 Input Expander for AND-OR-INVERT Gates	MC409 MC459	MC509 MC559	12 6	15 7	–	–
Dual 4-Input Expander for AND-OR-INVERT Gates	MC410 MC460	MC510 MC560	12 6	15 7	–	–
Dual 4-Input Expander for NAND Gates	MC411 MC461	MC511 MC561	12 6	15 7	–	–
Triple 3-Input NAND Gate	MC412 MC462	MC512 MC562	12 6	15 7	10	45
R-S Flip-Flop	MC413 MC463	MC513 MC563	12 6	15 7	t_{on} = 15 ns t_{off} = 20 ns	30
Gated R-S Flip-Flop	MC414 MC464	MC514 MC564	12 6	15 7	t_{on} = 7.5 ns t_{off} = 20 ns	30
AND J-K Flip-Flop	MC415 MC465	MC515 MC565	12 6	15 7	t_{on} = 25 ns t_{off} = 13 ns	40
OR J-K Flip-Flop	MC416 MC466	MC516 MC566	12 6	15 7	t_{on} = 25 ns t_{off} = 13 ns	50
AND Input J-K Flip-Flop	MC417 MC467	MC517 MC567	12 6	15 7	20	95
Type D Flip-Flop	MC418 MC468	MC518 MC568	12 6	15 7	20	95
Expandable Dual 2-Wide 2-Input AND-OR-INVERT Gate	MC420 MC470	MC520 MC570	12 6	15 7	12	40
AC Coupled R-S Flip-Flop	MC421 MC471	MC521 MC571	12 6	15 7	18	30
Hex Inverter	MC425 MC475	MC525 MC575	12 6	15 7	10	90

① F suffix denoted Flat Package, L suffix denotes Dual In-Line Ceramic Package. (i.e., MC401F = Flat Package, MC401L = Dual In-Line Ceramic Package.)

MTTL I LOGIC DIAGRAMS

GATES

MC400/MC450
MC500/MC550
Dual 4-Input NAND Gate

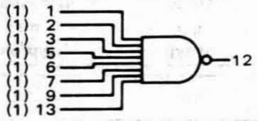


(1) 13
(1) 1
(1) 2
(1) 3
12
(1) 5
(1) 6
(1) 7
(1) 9
11

$12 = \overline{1 \cdot 2 \cdot 3 \cdot 13}$

t_{pd} = 10 ns typ
P_D = 30 mW typ/pkg

MC402/MC452
MC502/MC552
8-Input NAND Gate

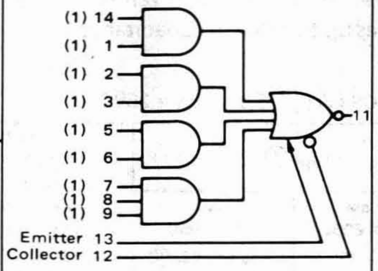


(1) 1
(1) 2
(1) 3
(1) 5
(1) 6
(1) 7
(1) 9
(1) 13
12

$12 = \overline{1 \cdot 2 \cdot 3 \cdot 5 \cdot 6 \cdot 7 \cdot 9 \cdot 13}$

t_{pd} = 12 ns typ
P_D = 15 mW typ/pkg

MC401/MC451
MC501/MC551
Expandable 4-Wide 2-2-2-3 Input AND-OR-INVERT Gate

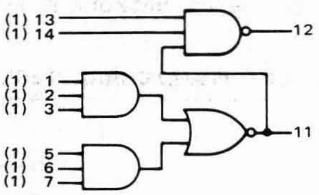


(1) 14
(1) 1
(1) 2
(1) 3
(1) 5
(1) 6
(1) 7
(1) 8
(1) 9
Emitter 13
Collector 12
11

$11 = \overline{(14 \cdot 1) + (2 \cdot 3) + (5 \cdot 6) + (7 \cdot 8 \cdot 9) + \ldots}$

t_{pd} = 12 ns typ
P_D = 30 mW typ/pkg

MC403/MC453
MC503/MC553
2-Wide 3-Input AND-OR-INVERT Gate with Gated Complement

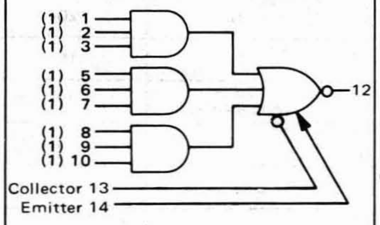


(1) 13
(1) 14
12
(1) 1
(1) 2
(1) 3
11
(1) 5
(1) 6
(1) 7

$12 = \overline{11 \cdot 13 \cdot 14}$
$11 = \overline{(1 \cdot 2 \cdot 3) + (5 \cdot 6 \cdot 7)}$

t_{pd} = 11 ns typ
P_D = 35 mW typ/pkg

MC404/MC454
MC504/MC554
Expandable 3-Wide 3-Input AND-OR-INVERT Gate

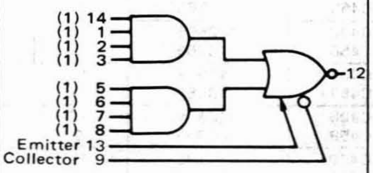


(1) 1
(1) 2
(1) 3
(1) 5
(1) 6
(1) 7
12
(1) 8
(1) 9
(1) 10
Collector 13
Emitter 14

$12 = \overline{(1 \cdot 2 \cdot 3) + (5 \cdot 6 \cdot 7) + (8 \cdot 9 \cdot 11) + \ldots}$

t_{pd} = 12 ns typ
P_D = 25 mW typ/pkg

MC405/MC455
MC505/MC555
Expandable 2-Wide 4-Input AND-OR-INVERT Gate

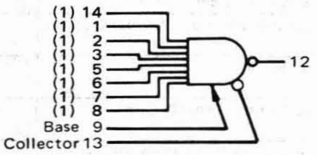


(1) 14
(1) 1
(1) 2
(1) 3
12
(1) 5
(1) 6
(1) 7
(1) 8
Emitter 13
Collector 9

$12 = \overline{(14 \cdot 1 \cdot 2 \cdot 3) + (5 \cdot 6 \cdot 7 \cdot 8) + \ldots}$

t_{pd} = 12 ns typ
P_D = 20 mW typ/pkg

MC406/MC456
MC506/MC556
Expandable 8-Input NAND Gate

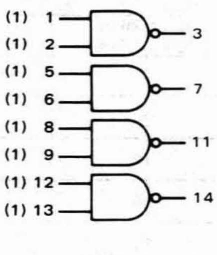


(1) 14
(1) 1
(1) 2
(1) 3
(1) 5
(1) 6
(1) 7
(1) 8
Base 9
Collector 13
12

$12 = \overline{1 \cdot 3 \cdot 5 \cdot 7 \cdot 8 \cdot 14 \cdot \ldots}$

t_{pd} = 18 ns typ
P_D = 15 mW typ/pkg

MC408/MC458
MC508/MC558
Quad 2-Input NAND Gate

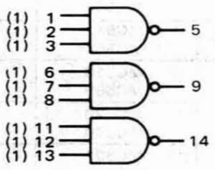


(1) 1
(1) 2
3
(1) 5
(1) 6
7
(1) 8
(1) 9
11
(1) 12
(1) 13
14

$3 = \overline{1 \cdot 2}$

t_{pd} = 10 ns typ
P_D = 60 mW typ/pkg

MC412/MC462
MC512/MC562
Triple 3-Input NAND Gate

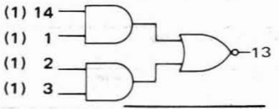


(1) 1
(1) 2
(1) 3
5
(1) 6
(1) 7
(1) 8
9
(1) 11
(1) 12
(1) 13
14

$5 = \overline{1 \cdot 2 \cdot 3}$

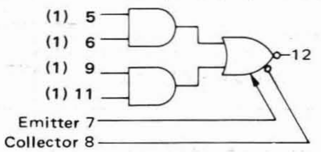
t_{pd} = 10 ns typ
P_D = 45 mW typ/pkg

MC420/MC470
MC520/MC570
Expandable Dual 2-Wide 2-Input AND-OR-INVERT Gate



(1) 14
(1) 1
(1) 2
(1) 3
13

$13 = \overline{(1 \cdot 14) + (2 \cdot 3)}$



(1) 5
(1) 6
(1) 9
(1) 11
12
Emitter 7
Collector 8

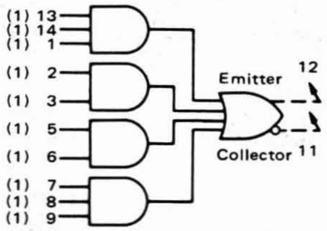
$12 = \overline{(5 \cdot 6) + (9 \cdot 11) + \ldots}$

t_{pd} = 12 ns typ
P_D = 40 mW typ/pkg

Numbers at ends of terminals represent pin numbers. Numbers in parenthesis indicate input loading factor. For output loading capability, see Functions and Characteristics Table. V_{CC} = Pin 4, Gnd = Pin 10.

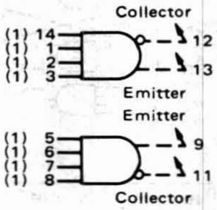
EXPANDERS

MC409/MC459
MC509/MC559
4-Wide 3-2-2-3 Input Expander
for AND-OR-INVERT Gates



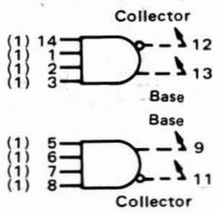
(1) 13
(1) 14
(1) 1
(1) 2
(1) 3
(1) 5
(1) 6
(1) 7
(1) 8
(1) 9
Emitter
12
Collector 11

MC410/MC460
MC510/MC560
Dual 4-Input Expander
for AND-OR-INVERT Gates



Collector
(1) 14
(1) 1
(1) 2
(1) 3
12
13
Emitter
Emitter
(1) 5
(1) 6
(1) 7
(1) 8
9
11
Collector

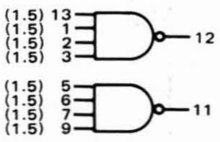
MC411/MC461
MC511/MC561
Dual 4-Input Expander
for NAND Gates



Collector
(1) 14
(1) 1
(1) 2
(1) 3
12
13
Base
Base
(1) 5
(1) 6
(1) 7
(1) 8
9
11
Collector

DRIVER

MC407/MC457
MC507/MC557
Dual 4-Input
Line Driver



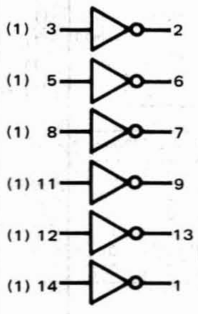
(1.5) 13
(1.5) 1
(1.5) 2
(1.5) 3
12
(1.5) 5
(1.5) 6
(1.5) 7
(1.5) 9
11

$12 = \overline{1 \cdot 2 \cdot 3 \cdot 13}$

t_{pd} = 25 ns typ
@ 1000 pF Load
P_D = 60 mW typ/pkg

INVERTER

MC425/MC475
MC525/MC575
Hex Inverter



(1) 3
2
(1) 5
6
(1) 8
7
(1) 11
9
(1) 12
13
(1) 14
1

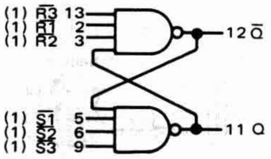
$2 = \overline{3}$

t_{pd} = 10 ns typ
P_D = 90 mW typ/pkg

MTTL I LOGIC DIAGRAMS

FLIP-FLOPS

MC413/MC463
MC513/MC563
R-S Flip-Flop



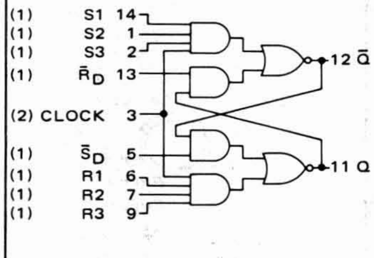
(1) $\overline{R3}$ 13
(1) $\overline{R1}$ 2
(1) $\overline{R2}$ 3
12 $\overline{Q}$
(1) $\overline{S1}$ 5
(1) $\overline{S2}$ 6
(1) $\overline{S3}$ 9
11 Q

$\overline{R}$	$\overline{S}$	Q_{n+1}	$\overline{Q}_{n+1}$
0	0	Not allowed	
0	1	0	1
1	0	1	0
1	1	Q_n	$\overline{Q}_n$

Where $\overline{R} = \overline{R1} \cdot \overline{R2} \cdot \overline{R3}$
$\overline{S} = \overline{S1} \cdot \overline{S2} \cdot \overline{S3}$

t_{on} = 15 ns typ
t_{off} = 20 ns typ
P_D = 30 mW typ/pkg

MC414/MC464
MC514/MC564
Gated R-S Flip-Flop



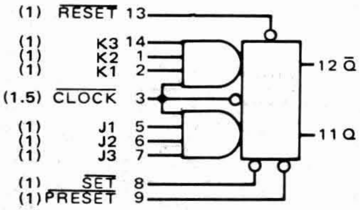
(1) S1 14
(1) S2 1
(1) S3 2
(1) $\overline{R}_D$ 13
(2) CLOCK 3
(1) $\overline{S}_D$ 5
(1) R1 6
(1) R2 7
(1) R3 9
12 $\overline{Q}$
11 Q

R_C	S_C	Q^{n+1}
0	0	Q^n
0	1	1
1	0	0
1	1	Indeterminate

Where $R_C = 6 \cdot 7 \cdot 9$
$S_C = 1 \cdot 2 \cdot 14$

t_{on} = 7.5 ns typ
t_{off} = 20 ns typ
P_D = 30 mW typ/pkg

MC415/MC465
MC515/MC565
AND J-K Flip-Flop



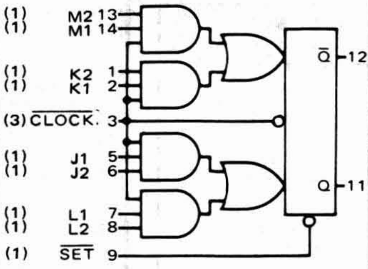
(1) $\overline{\text{RESET}}$ 13
(1) K3 14
(1) K2 1
(1) K1 2
(1.5) $\overline{\text{CLOCK}}$ 3
(1) J1 5
(1) J2 6
(1) J3 7
(1) $\overline{\text{SET}}$ 8
(1) $\overline{\text{PRESET}}$ 9
12 $\overline{Q}$
11 Q

J	K	Q_n	Q_{n+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

Where $J = J1 \cdot J2 \cdot J3$
$K = K1 \cdot K2 \cdot K3$

f = 25 MHz typ
P_D = 40 mW typ/pkg

MC416/MC466
MC516/MC566
OR J-K Flip-Flop



(1) M2 13
(1) M1 14
(1) K2 1
(1) K1 2
(3) $\overline{\text{CLOCK}}$ 3
(1) J1 5
(1) J2 6
(1) L1 7
(1) L2 8
(1) $\overline{\text{SET}}$ 9
$\overline{Q}$ 12
Q 11

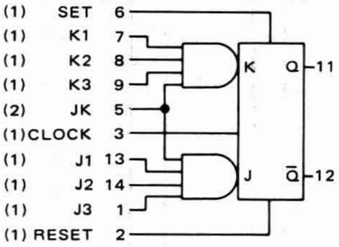
J	L	K	M	Q_n	Q_{n+1}
0	0	X	X	0	0
1	X	X	X	0	1
X	1	X	X	0	1
X	X	0	0	1	1
X	X	1	X	1	0
X	X	X	1	1	0

X = Don't Care

Where $J = J1 \cdot J2$
$L = L1 \cdot L2$
$K = K1 \cdot K2$
$M = M1 \cdot M2$

f = 25 MHz typ
P_D = 50 mW typ/pkg

MC417/MC467
MC517/MC567
AND Input J-K Flip-Flop

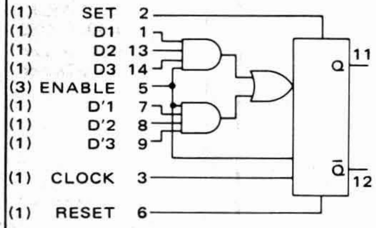


(1) SET 6
(1) K1 7
(1) K2 8
(1) K3 9
(2) JK 5
(1) CLOCK 3
(1) J1 13
(1) J2 14
(1) J3 1
(1) RESET 2
K
J
Q 11
$\overline{Q}$ 12

t_n		t_{n+1}	
J	K	Q	$\overline{Q}$
1	1	$\overline{Q}n$	Qn
0	1	0	1
1	0	1	0
0	0	Qn	$\overline{Q}n$

f = 25 MHz typ
P_D = 95 mW typ/pkg

MC418/MC468
MC518/MC568
Type D Flip-Flop



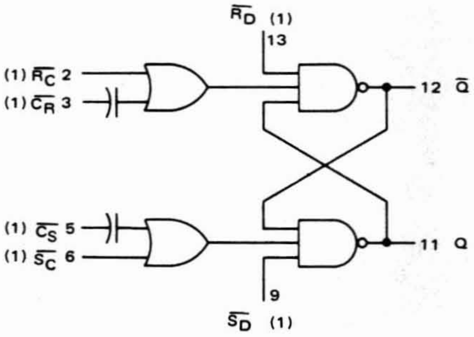
(1) SET 2
(1) D1 1
(1) D2 13
(1) D3 14
(3) ENABLE 5
(1) D'1 7
(1) D'2 8
(1) D'3 9
(1) CLOCK 3
(1) RESET 6
Q 11
$\overline{Q}$ 12

t_n		t_{n+1}	
D	D'	Q	$\overline{Q}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

f = 25 MHz typ
P_D = 95 mW typ/pkg

FLIP-FLOPS (continued)

MC421/MC471
MC521/MC571
AC Coupled R-S Flip-Flop


$\overline{R_D}$ (1)
13
(1) $\overline{R_C}$ 2
(1) $\overline{C_R}$ 3
12 $\overline{Q}$
(1) $\overline{C_S}$ 5
(1) $\overline{S_C}$ 6
11 Q
9
$\overline{S_D}$ (1)

$\overline{S}$	$\overline{R}$	Q^{n+1}
0	0	Not Allowed
0	1	1
1	0	0
1	1	Q^n

Where: $\overline{\overline{S_C} \cdot \overline{C_S}} = \overline{S}$

$\overline{\overline{R_C} \cdot \overline{C_R}} = \overline{R}$

f = 15 MHz typ

P_D = 30 mW typ/pkg

MAXIMUM RATINGS

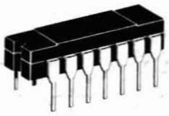
Rating	Value	Unit
Supply Voltage — Continuous MC500 Series MC400 Series	+8.0 +7.0	Vdc
Supply Operating Voltage Range	4.5 to 6.0	Vdc
Input Voltage	+5.5	Vdc
Output Voltage	+5.5	Vdc
Operating Temperature Range MC500 Series MC400 Series	-55 to +125 0 to +75	°C
Storage Temperature Range Ceramic Package	-65 to +200	°C
Maximum Junction Temperature MC500/550 Series MC400/450 Series	 +175 +150	°C
Thermal Resistance-Junction To Case (θ_{JC}) Ceramic Package	0.09	°C/mW
Thermal Resistance-Junction To Ambient (θ_{JA}) Ceramic Package	0.26	°C/mW

MTTL II INTEGRATED CIRCUITS MTTL II

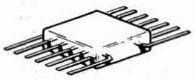
MC2000 Series (0 to +75°C)

MC2100 Series (−55 to +125°C)

MTTL II integrated circuits comprise a family of transistor-transistor logic designed for general purpose digital applications. The family has a high operating speed (30-50 MHz clock rate), good external noise immunity, high fan out, and the capability of driving capacitive loads of up to 600 pF.



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



F SUFFIX
CASE 609
TO-85

MAXIMUM RATINGS

Rating	Value	Unit
Supply Voltage—Continuous – MC2100 Series MC2000 Series	+8.0 +7.0	Vdc
Supply Operating Voltage Range	4.5 to 6.0	Vdc
Input Voltage	+5.5	Vdc
Output Voltage	+5.5	Vdc
Operating Temperature Range – MC2100 Series MC2000 Series	−55 to +125 0 to +75	°C
Storage Temperature Range – Ceramic Package	−65 to +200	°C
Maximum Junction Temperature – MC2100 Series MC2000 Series	+175 +150	°C
Thermal Resistance-Junction to Case (θ_{JC}) – Ceramic Package	0.09	°C/mW
Thermal Resistance-Junction to Ambient (θ_{JA}) – Ceramic Package	0.26	°C/mW

FUNCTIONS AND CHARACTERISTICS (V_{CC} = 5.0 V, T_A = 25°C)

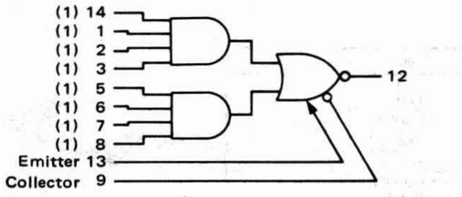
Function	Type ①		Output Loading Factor Each Output		Propagation Delay t_{pd} ns typ	Power Dissipation mW typ/pkg
	Case 609, 605C 0 to +75°C	Case 609, 605C -55 to +125°C	MC2000 Series	MC2100 Series		
Expandable 2-Wide 4-Input AND-OR-INVERT Gate	MC2000 MC2050	MC2100 MC2150	9 5	11 6	7.0	27
Quad 2-Input NAND Gate	MC2001 MC2051	MC2101 MC2151	9 5	11 6	6.0	88
4-Wide 3-2-2-3 Input Expander for AND-OR-INVERT Gates	MC2002 MC2052	MC2102 MC2152	9 5	11 6	–	28
Dual 4-Input NAND Gate	MC2003 MC2053	MC2103 MC2153	9 5	11 6	6.0	44
Expandable 4-Wide 2-2-2-3 Input AND-OR-INVERT Gate	MC2004 MC2054	MC2104 MC2154	9 5	11 6	7.0	36
8-Input NAND Gate	MC2005 MC2055	MC2105 MC2155	9 5	11 6	8.0	22
Dual 4-Input Expander for AND-OR-INVERT Gates	MC2006 MC2056	MC2106 MC2156	9 5	11 6	–	14
Triple 3-Input NAND Gate	MC2007 MC2057	MC2107 MC2157	9 5	11 6	6.0	66
AND J-K Flip-Flop	MC2009 MC2059	MC2109 MC2159	9 5	11 6	f = 30 MHz	40
OR J-K Flip-Flop	MC2010 MC2060	MC2110 MC2160	9 5	11 6	f = 30 MHz	50
Expandable Dual 2-Wide 2-Input AND-OR-INVERT Gate	MC2013 MC2063	MC2113 MC2163	9 5	11 6	7.0	58
AND J-K Flip-Flop	MC2025 MC2075	MC2125 MC2175	9 5	11 6	f = 50 MHz	50
OR J-K Flip-Flop	MC2026 MC2076	MC2126 MC2176	9 5	11 6	f = 50 MHz	60
OR J-K Flip-Flop	MC2028 MC2078	MC2128 MC2178	9 5	11 6	f = 35 MHz	60

① F suffix denotes Flat Package, L denotes Dual In-Line Ceramic Package.
(i.e., MC2000F = Flat Package, MC2100L = Dual In-Line Ceramic.)

MTTL II LOGIC DIAGRAMS

GATES

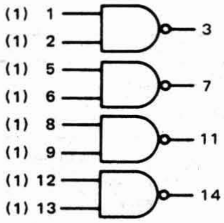
MC2000/MC2050 MC2100/MC2150 Expandable 2-Wide 4-Input AND-OR-INVERT Gate


(1) 14
(1) 1
(1) 2
(1) 3
(1) 5
(1) 6
(1) 7
(1) 8
Emitter 13
Collector 9
12

$12 = \overline{(14 \cdot 1 \cdot 2 \cdot 3) + (5 \cdot 6 \cdot 7 \cdot 8) + (\text{Expander})}$

t_{pd} = 7.0 ns typ
P_D = 27 mW typ/pkg

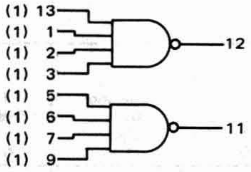
MC2001/MC2051 MC2101/MC2151 Quad 2-Input NAND Gate


(1) 1
(1) 2
(1) 5
(1) 6
(1) 8
(1) 9
(1) 12
(1) 13
3
7
11
14

$3 = \overline{1 \cdot 2}$
$7 = \overline{5 \cdot 6}$
$11 = \overline{8 \cdot 9}$
$14 = \overline{12 \cdot 13}$

t_{pd} = 6.0 ns typ
P_D = 88 mW typ/pkg

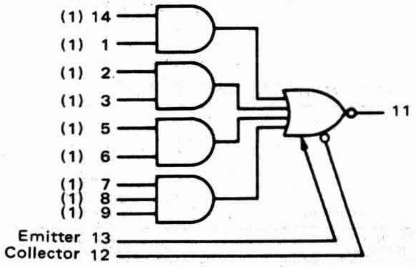
MC2003/MC2053 MC2103/MC2153 Dual 4-Input NAND Gate


(1) 13
(1) 1
(1) 2
(1) 3
(1) 5
(1) 6
(1) 7
(1) 9
12
11

$12 = \overline{1 \cdot 2 \cdot 3 \cdot 13}$
$11 = \overline{5 \cdot 6 \cdot 7 \cdot 9}$

t_{pd} = 6.0 ns typ
P_D = 44 mW typ/pkg

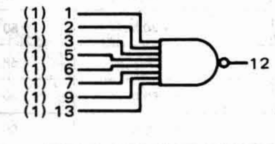
MC2004/MC2054 MC2104/MC2154 Expandable 4-Wide 2-2-2-3 Input AND-OR-INVERT Gate


(1) 14
(1) 1
(1) 2
(1) 3
(1) 5
(1) 6
(1) 7
(1) 8
(1) 9
Emitter 13
Collector 12
11

$11 = \overline{(14 \cdot 1) + (2 \cdot 3) + (5 \cdot 6) + (7 \cdot 8 \cdot 9) + (\text{Expander})}$

t_{pd} = 7.0 ns typ
P_D = 36 mW typ/pkg

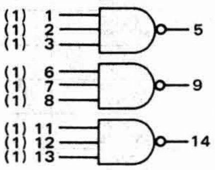
MC2005/MC2055 MC2105/MC2155 8-Input NAND Gate


(1) 1
(1) 2
(1) 3
(1) 5
(1) 6
(1) 7
(1) 9
(1) 13
12

$12 = \overline{1 \cdot 2 \cdot 3 \cdot 5 \cdot 6 \cdot 7 \cdot 9 \cdot 13}$

t_{pd} = 8.0 ns typ
P_D = 22 mW typ/pkg

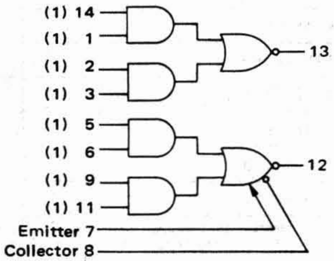
MC2007/MC2057 MC2107/MC2157 Triple 3-Input NAND Gate


(1) 1
(1) 2
(1) 3
(1) 6
(1) 7
(1) 8
(1) 11
(1) 12
(1) 13
5
9
14

$5 = \overline{1 \cdot 2 \cdot 3}$

t_{pd} = 6.0 ns typ
P_D = 66 mW typ/pkg

MC2013/MC2063 MC2113/MC2163 Expandable Dual 2-Wide 2-Input AND-OR-INVERT Gate


(1) 14
(1) 1
(1) 2
(1) 3
(1) 5
(1) 6
(1) 9
(1) 11
Emitter 7
Collector 8
13
12

$13 = \overline{(1 \cdot 14) + (2 \cdot 3)}$
$12 = \overline{(5 \cdot 6) + (9 \cdot 11) + (\text{Expander})}$

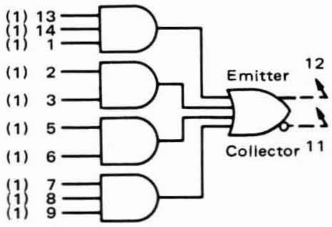
t_{pd} = 7.0 ns typ P_D = 58 mW typ/pkg

Numbers at ends of terminals represent pin numbers.
Numbers in parenthesis indicate input loading factor.
For output loading capability, see Functions and Characteristics table.

V_{CC} = Pin 4, Gnd = Pin 10.

EXPANDERS

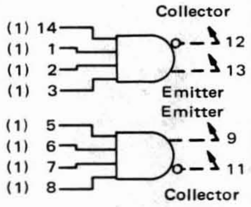
MC2002/MC2052 MC2102/MC2152 4-Wide 3-2-2-3 Input Expander for AND-OR-INVERT Gates



(1) 13
(1) 14
(1) 1
(1) 2
(1) 3
(1) 5
(1) 6
(1) 7
(1) 8
(1) 9
Emitter
12
Collector
11

P_D = 28 mW typ/pkg

MC2006/MC2056 MC2106/MC2156 Dual 4-Input Expander for AND-OR-INVERT Gates

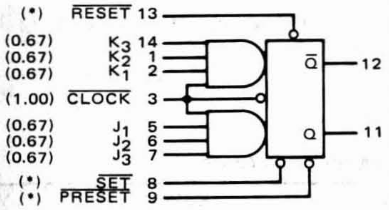


Collector
(1) 14
(1) 1
(1) 2
(1) 3
12
13
Emitter
Emitter
(1) 5
(1) 6
(1) 7
(1) 8
9
11
Collector

P_D = 14 mW typ/pkg

FLIP-FLOPS

MC2009/MC2059, MC2025/MC2075 MC2109/MC2159, MC2125/MC2175 AND J-K Flip-Flop



(•) $\overline{RESET}$ 13
(0.67) K_3 14
(0.67) K_2 1
(0.67) K_1 2
(1.00) $\overline{CLOCK}$ 3
(0.67) J_1 5
(0.67) J_2 6
(0.67) J_3 7
(•) $\overline{SET}$ 8
(•) $\overline{PRESET}$ 9
$\overline{Q}$
12
Q
11

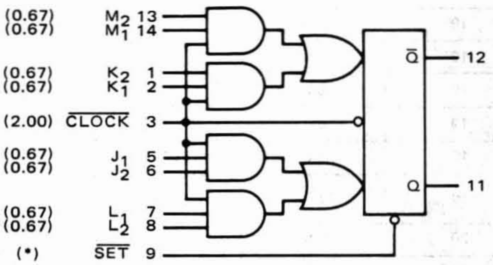
J	K	Q_n	Q_{n+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

$J = J_1 \cdot J_2 \cdot J_3$
$K = K_1 \cdot K_2 \cdot K_3$

MC2009 Series
•0.67
f = 30 MHz typ
P_D = 40 mW typ/pkg

MC2025 Series
•1.2
f = 50 MHz typ
P_D = 50 mW typ/pkg

MC2010/MC2060, MC2026/MC2076 MC2110/MC2160, MC2126/MC2176 OR J-K Flip-Flop



(0.67) M_2 13
(0.67) M_1 14
(0.67) K_2 1
(0.67) K_1 2
(2.00) $\overline{CLOCK}$ 3
(0.67) J_1 5
(0.67) J_2 6
(0.67) L_1 7
(0.67) L_2 8
(•) $\overline{SET}$ 9
$\overline{Q}$
12
Q
11

J	L	K	M	Q_n	Q_{n+1}
0	0	X	X	0	0
1	X	X	X	0	1
X	1	X	X	0	1
X	X	0	0	1	1
X	X	1	X	1	0
X	X	X	1	1	0

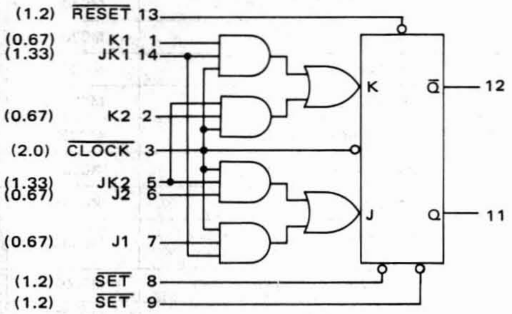
X = Don't Care

$J = J_1 \cdot J_2$
$L = L_1 \cdot L_2$
$K = K_1 \cdot K_2$
$M = M_1 \cdot M_2$

MC2010 Series
•0.67
f = 30 MHz typ
P_D = 50 mW typ/pkg

MC2026 Series
•1.2
f = 50 MHz typ
P_D = 60 mW typ/pkg

MC2028/MC2078 MC2128/MC2178 OR J-K FLIP-FLOP



(1.2) $\overline{RESET}$ 13
(0.67) K1 1
(1.33) JK1 14
(0.67) K2 2
(2.0) $\overline{CLOCK}$ 3
(1.33) JK2 5
(0.67) J2 6
(0.67) J1 7
(1.2) $\overline{SET}$ 8
(1.2) $\overline{SET}$ 9
K
$\overline{Q}$
12
J
Q
11

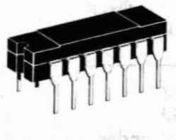
J1	J2	K1	K2	JK1	JK2	Q_{n+1}
X	X	X	X	0	0	Q_n
X	1	X	0	0	1	1
X	0	X	1	0	1	0
X	1	X	1	0	1	Q_n
1	X	0	X	1	0	1
0	X	1	X	1	0	0
1	X	1	X	1	0	Q_n
0	0	0	0	1	1	Q_n
X	1	0	0	1	1	1
1	X	0	0	1	1	1
0	0	X	1	1	1	0
0	0	1	X	1	1	0
1	X	1	X	1	1	Q_n
X	1	X	1	1	1	Q_n

X = Don't Care

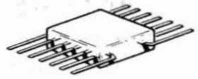
f = 35 MHz typ
P_D = 60 mW typ/pkg

MC3000 Series (0 to +75°C)

MTTL III integrated circuits comprise a family of transistor-transistor logic designed for general purpose digital applications. The family has a high operating speed (30-50 MHz clock rate), good external noise immunity, high fan out, and the capability of driving lines up to 600 pF capacitance.



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



F SUFFIX
CASE 607
(Formerly Case 83)
TO-86

MAXIMUM RATINGS

Rating	Value	Unit
Supply Voltage – Continuous	+7.0	Vdc
Supply Operating Voltage Range	4.5 to 5.5	Vdc
Input Voltage	+5.5	Vdc
Output Voltage	+5.5	Vdc
Operating Temperature Range	0 to +75	°C
Storage Temperature Range – Flat Package Plastic Package	−65 to +175 −55 to +125	°C °C

FUNCTIONS AND CHARACTERISTICS (V_{CC} = 5.0 V, T_A = 25°C)

Function	Type ①	Output Loading Factor Each Output	Propagation Delay t_{pd} ns/pF	Power Dissipation mW typ/pkg
Quad 2-Input NAND Gate	MC3000	10	6.0	88
Quad 2-Input AND Gate	MC3001	10	9.0	112
Quad 2-Input NOR Gate	MC3002	10	6.0	122
Quad 2-Input OR Gate	MC3003	10	9.0	150
Triple 3-Input NAND Gate	MC3005	10	6.0	66
Triple 3-Input AND Gate	MC3006	10	9.0	84
Dual 4-Input NAND Gate	MC3010	10	6.0	44
Single 8-Input NAND Gate	MC3015	10	8.0	22
Expandable Dual 2-Wide 2-Input AND-OR-INVERT Gate	MC3020	10	6.0	62.5
Dual 4-Input NAND Power Gate	MC3025	20	6.0	70
Dual 4-Input AND Power Gate	MC3026	20	9.0	90
Dual 3-Input 3-Output AND Series Terminated Line Driver	MC3028	•	9.0	56
Dual 3-Input 3-Output NAND Series Terminated Line Driver	MC3029	•	6.0	44
Dual 4-Input Expander for AND-OR-INVERT Gates	MC3030	••	•••	15
AND J-K Flip-Flops	MC3050	10	f = 40 MHz	80
AND Input $J\overline{J}$-$K\overline{K}$ Flip-Flop	MC3052	10	f = 40 MHz	75
Dual Type D Flip-Flop	MC3060	10	f = 30 MHz	120
Dual J-K Flip-Flop	MC3061	10	f = 50 MHz	100
Dual J-K Flip-Flop	MC3062	10	f = 50 MHz	100

① F suffix denotes Flat Package, L suffix denotes Dual In-Line Ceramic Package. (i.e., MC3000F = Flat Package, MC3000L = Ceramic Package.)

•Direct Output = 10 minus the number of resistor-terminated outputs being used.

••Full output loading factor of the expandable gate is maintained.

•••Δt_{pd} = +1.0 ns typ when added to the expandable AND-OR-INVERT Gate.
Δt_{pd}/pF = +1.0 ns/pF typ caused by additional capacitance at expansion points.

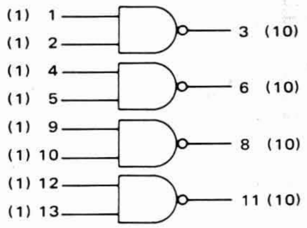
MTTL III LOGIC DIAGRAMS

Numbers at ends of terminals represent pin numbers.
Numbers in parenthesis indicate loading.

V_{CC} = Pin 14, Gnd = Pin 7.

GATES

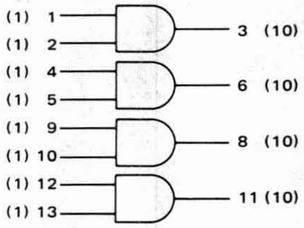
MC3000
Quad 2-Input NAND Gate


(1) 1
(1) 2
3 (10)
(1) 4
(1) 5
6 (10)
(1) 9
(1) 10
8 (10)
(1) 12
(1) 13
11 (10)

$3 = \overline{1 \cdot 2}$

t_{pd} = 6.0 ns typ
P_D = 88 mW typ/pkg

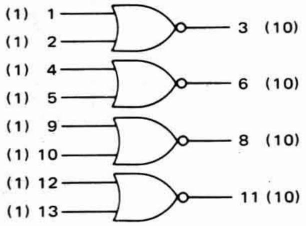
MC3001
Quad 2-Input AND Gate


(1) 1
(1) 2
3 (10)
(1) 4
(1) 5
6 (10)
(1) 9
(1) 10
8 (10)
(1) 12
(1) 13
11 (10)

$3 = 1 \cdot 2$

t_{pd} = 9.0 ns typ
P_D = 112 mW typ/pkg

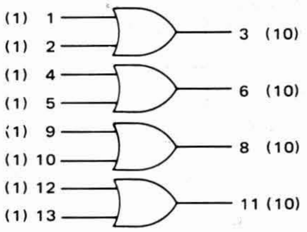
MC3002
Quad 2-Input NOR Gate


(1) 1
(1) 2
3 (10)
(1) 4
(1) 5
6 (10)
(1) 9
(1) 10
8 (10)
(1) 12
(1) 13
11 (10)

$3 = \overline{1 + 2}$

t_{pd} = 6.0 ns typ
P_D = 122 mW typ/pkg

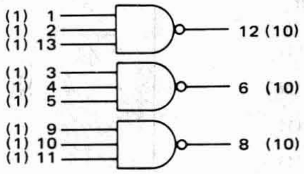
MC3003
Quad 2-Input OR Gate


(1) 1
(1) 2
3 (10)
(1) 4
(1) 5
6 (10)
(1) 9
(1) 10
8 (10)
(1) 12
(1) 13
11 (10)

$3 = 1 + 2$

t_{pd} = 9.0 ns typ
P_D = 150 mW typ/pkg

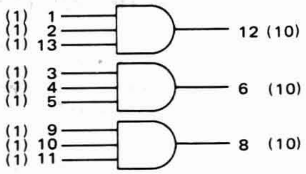
MC3005
Triple 3-Input NAND Gate


(1) 1
(1) 2
(1) 13
12 (10)
(1) 3
(1) 4
(1) 5
6 (10)
(1) 9
(1) 10
(1) 11
8 (10)

$12 = \overline{1 \cdot 2 \cdot 13}$

t_{pd} = 6.0 ns typ
P_D = 66 mW typ/pkg

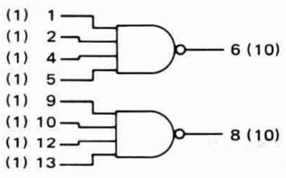
MC3006
Triple 3-Input AND Gate


(1) 1
(1) 2
(1) 13
12 (10)
(1) 3
(1) 4
(1) 5
6 (10)
(1) 9
(1) 10
(1) 11
8 (10)

$12 = 1 \cdot 2 \cdot 13$

t_{pd} = 9.0 ns typ
P_D = 84 mW typ/pkg

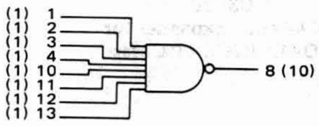
MC3010
Dual 4-Input NAND Gate


(1) 1
(1) 2
(1) 4
(1) 5
6 (10)
(1) 9
(1) 10
(1) 12
(1) 13
8 (10)

$6 = \overline{1 \cdot 2 \cdot 4 \cdot 5}$

t_{pd} = 6.0 ns typ
P_D = 44 mW typ/pkg

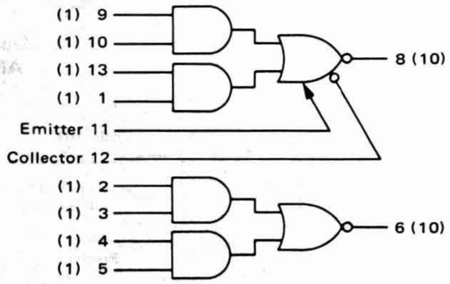
MC3015
8-Input NAND Gate


(1) 1
(1) 2
(1) 3
(1) 4
(1) 10
(1) 11
(1) 12
(1) 13
8 (10)

$8 = \overline{1 \cdot 2 \cdot 3 \cdot 4 \cdot 10 \cdot 11 \cdot 12 \cdot 13}$

t_{pd} = 8.0 ns typ
P_D = 22 mW typ/pkg

MC3020
Expandable Dual 2-Wide 2-Input AND-OR-INVERT Gate


(1) 9
(1) 10
(1) 13
(1) 1
8 (10)
Emitter 11
Collector 12
(1) 2
(1) 3
(1) 4
(1) 5
6 (10)

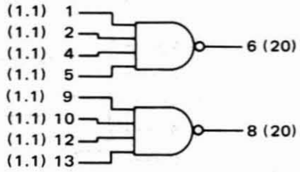
$8 = \overline{(9 \cdot 10) + (13 \cdot 1) + (\text{Expanders})}$

t_{pd} = 6.0 ns typ
P_D = 62.5 mW typ/pkg

MTTL III LOGIC DIAGRAMS

POWER GATES

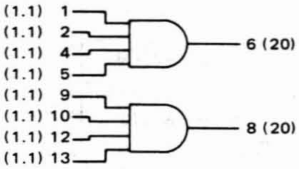
MC3025
Dual 4-Input NAND Power Gate


(1.1) 1
(1.1) 2
(1.1) 4
(1.1) 5
(1.1) 9
(1.1) 10
(1.1) 12
(1.1) 13
6 (20)
8 (20)

6 = $\overline{1 \cdot 2 \cdot 4 \cdot 5}$

t_{pd} = 6.0 ns typ
P_D = 70 mW typ/pkg

MC3026
Dual 4-Input AND Power Gate

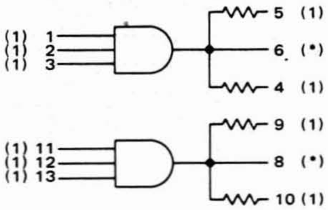

(1.1) 1
(1.1) 2
(1.1) 4
(1.1) 5
(1.1) 9
(1.1) 10
(1.1) 12
(1.1) 13
6 (20)
8 (20)

6 = 1 • 2 • 4 • 5

t_{pd} = 9.0 ns typ
P_D = 90 mW typ/pkg

LINE DRIVERS

MC3028
Dual 3-Input 3-Output AND Series Terminated Line Driver

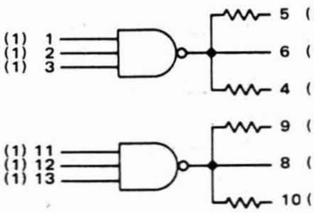

(1) 1
(1) 2
(1) 3
5 (1)
6 (*)
4 (1)
(1) 11
(1) 12
(1) 13
9 (1)
8 (*)
10 (1)

4, 5, 6, = 1 • 2 • 3

t_{pd} = 9.0 ns typ
P_D = 56 mW typ/pkg

*10 MINUS THE NUMBER OF RESISTOR-TERMINATED OUTPUTS BEING USED.

MC3029
Dual 3-Input 3-Output NAND Series Terminated Line Driver


(1) 1
(1) 2
(1) 3
5 (1)
6 (*)
4 (1)
(1) 11
(1) 12
(1) 13
9 (1)
8 (*)
10 (1)

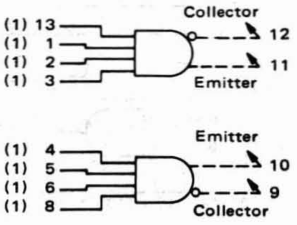
4, 5, 6 = $\overline{1 \cdot 2 \cdot 3}$

t_{pd} = 6.0 ns typ
P_D = 44 mW typ/pkg

*10 MINUS THE NUMBER OF RESISTOR-TERMINATED OUTPUTS BEING USED.

EXPANDER

MC3030
Dual 4-Input Expander for AND-OR-INVERT Gates


(1) 13
(1) 1
(1) 2
(1) 3
Collector
12
11
Emitter
(1) 4
(1) 5
(1) 6
(1) 8
Emitter
10
9
Collector

Full output loading factor of the expandable gate is maintained.

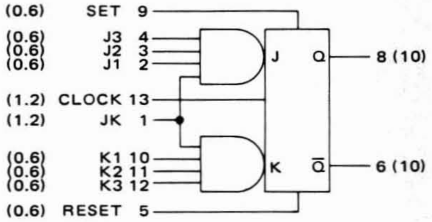
Δt_{pd} = +1.0 ns typ
When added to the expandable "AND-OR-INVERT" gate.

$\Delta t_{pd}/pF$ = +1.0 ns/pF typ
Caused by additional capacitance at expansion points.

P_D = 15 mW typ/pkg

FLIP-FLOPS

MC3050
AND J-K Flip-Flop



(0.6) SET 9
(0.6) J3 4
(0.6) J2 3
(0.6) J1 2
(1.2) CLOCK 13
(1.2) JK 1
(0.6) K1 10
(0.6) K2 11
(0.6) K3 12
(0.6) RESET 5
J
K
Q
$\overline{Q}$
8 (10)
6 (10)

J	K	Q_n	Q_{n+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

Where:

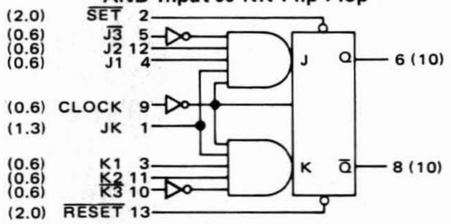
$J = J1 \cdot J2 \cdot J3 \cdot JK$

$K = K1 \cdot K2 \cdot K3 \cdot JK$

$f = 40$ MHz

$P_D = 80$ mW typ/pkg

MC3052
AND Input J$\overline{J}$-K$\overline{K}$ Flip-Flop



(2.0) $\overline{SET}$ 2
(0.6) $\overline{J3}$ 5
(0.6) J2 12
(0.6) J1 4
(0.6) CLOCK 9
(1.3) JK 1
(0.6) K1 3
(0.6) K2 11
(0.6) $\overline{K3}$ 10
(2.0) $\overline{RESET}$ 13
J
K
Q
$\overline{Q}$
6 (10)
8 (10)

J	K	Q_n	Q_{n+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

Where:

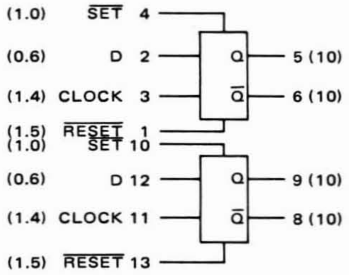
$J = J1 \cdot J2 \cdot \overline{J3} \cdot JK$

$K = K1 \cdot K2 \cdot \overline{K3} \cdot JK$

$f = 40$ MHz

$P_D = 75$ mW typ/pkg

MC3060
Dual Type D Flip-Flop



(1.0) $\overline{SET}$ 4
(0.6) D 2
(1.4) CLOCK 3
(1.5) $\overline{RESET}$ 1
(1.0) $\overline{SET}$ 10
(0.6) D 12
(1.4) CLOCK 11
(1.5) $\overline{RESET}$ 13
Q
$\overline{Q}$
5 (10)
6 (10)
9 (10)
8 (10)

D	Q_n	Q_{n+1}
0	0	0
0	1	0
1	0	1
1	1	1

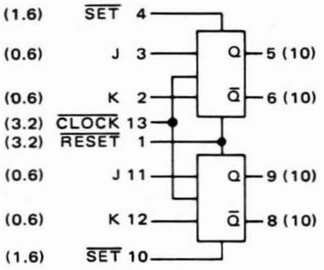
$Q_{n+1} = D_n$

$f = 30$ MHz

$P_D = 120$ mW typ/pkg

MC3061
Dual J-K Flip-Flop

J	K	Q_n	Q_{n+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0



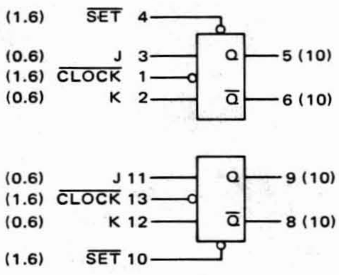
(1.6) $\overline{SET}$ 4
(0.6) J 3
(0.6) K 2
(3.2) $\overline{CLOCK}$ 13
(3.2) $\overline{RESET}$ 1
(0.6) J 11
(0.6) K 12
(1.6) $\overline{SET}$ 10
Q
$\overline{Q}$
5 (10)
6 (10)
9 (10)
8 (10)

$f = 50$ MHz

$P_D = 100$ mW typ/pkg

MC3062
Dual J-K Flip-Flop

J	K	Q_n	Q_{n+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0



(1.6) $\overline{SET}$ 4
(0.6) J 3
(1.6) $\overline{CLOCK}$ 1
(0.6) K 2
(0.6) J 11
(1.6) $\overline{CLOCK}$ 13
(0.6) K 12
(1.6) $\overline{SET}$ 10
Q
$\overline{Q}$
5 (10)
6 (10)
9 (10)
8 (10)

$f = 50$ MHz

$P_D = 100$ mW typ/pkg

MTTL COMPLEX FUNCTIONS MTTL

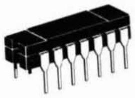
INTEGRATED CIRCUITS

MC4000 Series (0 to +75°C)

The MC4000 series of transistor-transistor logic (MTTL) complex functions is designed for general purpose digital applications in the medium to high-speed range, with typical clock frequencies to 30-40 MHz and typical propagation delay times of 5.0-10 ns per level of gating.

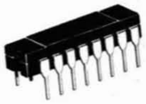
Each of the functions has been specified to allow use with all of the MTTL and MDTL families.

L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



P SUFFIX
PLASTIC PACKAGE
CASE 612

L SUFFIX
CERAMIC PACKAGE
CASE 620



INPUT and OUTPUT LOADING FACTORS with respect to MTTL and MDTL families

Family	MC4000 Input Loading Factor	MC4000 Output Loading Factor*
MC4000	1.0	11
MC400	1.0	10
MC2000	0.67	6
MC3000	0.7	8
MC7400	1.0	10
MC830	1.15**	12

Note: Differences in MC4000 series loading factors result from differences in specifications for each family.

*Unless open collector; see table below.

**Applies only when input is being driven by MDTL gate with 2.0 k ohm pullup resistor. Logic "1" state drive limitations of gates with 6.0 k ohm pullup resistors reduce drive capability to fan-out of 3.

FUNCTIONS AND CHARACTERISTICS (V_{CC} = 5.0 V, T_A = 25°C)

Function	Type①	Case	Output Loading Factor Each Output	Propagation Delay t_{pd} ns typ	Power Dissipation mW typ/pkg
Dual 4-Channel Data Selector	MC4000	605C	11	11	150
Dual Data Distributor	MC4002	605C	11	10.5	175
16-Bit Scratch Pad Memory Cell	MC4004	605C	I_{OL} = 40 mA Open Collector	Write mode: 25 Read mode: 15	250
16-Bit Scratch Pad Memory Cell	MC4005	605C	I_{OL} = 20 mA	Write mode: 25 Read mode: 15	250
Binary to One-of-Eight Line Decoder	MC4006	605C	11	14	100
Dual Binary to One-of-Four Line Decoder	MC4007	620	11	14	125
8-Bit Parity Tree	MC4008	605C	11	15 to 30	150
Dual 4-Bit Parity Tree	MC4010	605C	11	9.5 to 22	125
Interting/Non-Inverting One-of-Eight Decoder	MC4038	612	Open Collector I_{OL} = 20 mA	Address Time < 45 ns	240
Seven-Segment Character Generator	MC4039	612			240
Binary to Two-of-Eight Decoder	MC4040	612			200
Single-Error Hamming Code Detector and Generator	MC4041	612			240

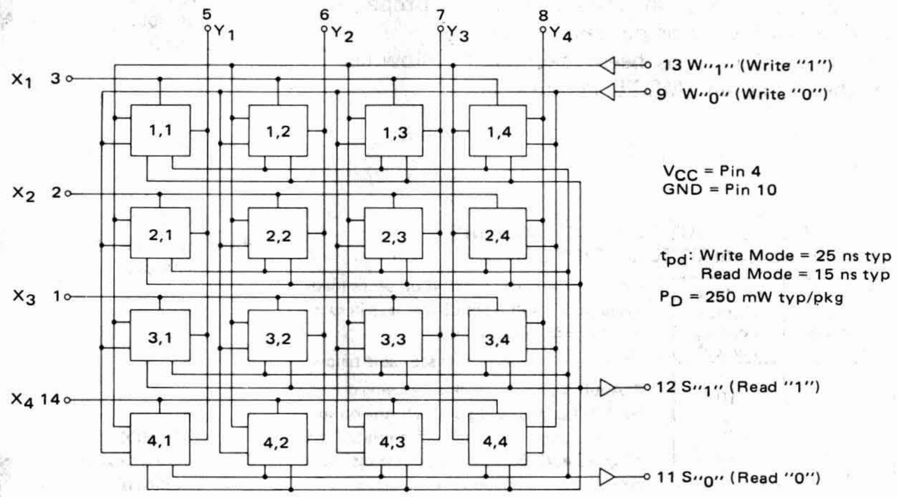
① L suffix denotes Dual In-Line Ceramic Package, P suffix denotes Dual In-Line Plastic Package. (i.e., MC4000L = Dual In-Line Ceramic Package, MC4038P = Dual In-Line Plastic Package.)

MTTL MC4000 SERIES LOGIC DIAGRAMS

Numbers at ends of terminals represent pin numbers.
Numbers in parenthesis indicate loading.

MEMORIES

MC4004, MC4005
16-Bit Scratch Pad Memory Cell

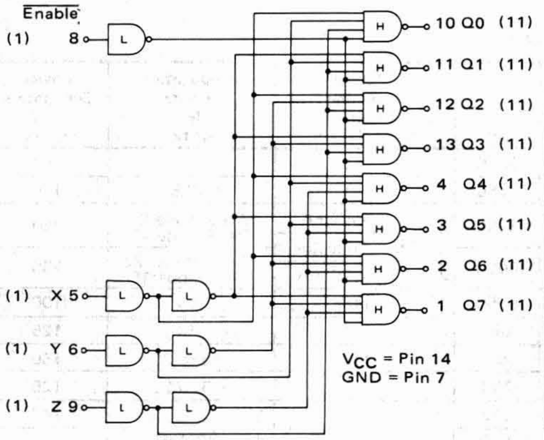

5 Y1
6 Y2
7 Y3
8 Y4
X1 3
X2 2
X3 1
X4 14
1,1
1,2
1,3
1,4
2,1
2,2
2,3
2,4
3,1
3,2
3,3
3,4
4,1
4,2
4,3
4,4
13 W"1" (Write "1")
9 W"0" (Write "0")
12 S"1" (Read "1")
11 S"0" (Read "0")

V_{CC} = Pin 4
GND = Pin 10

t_{pd}: Write Mode = 25 ns typ
Read Mode = 15 ns typ
P_D = 250 mW typ/pkg

DECODERS

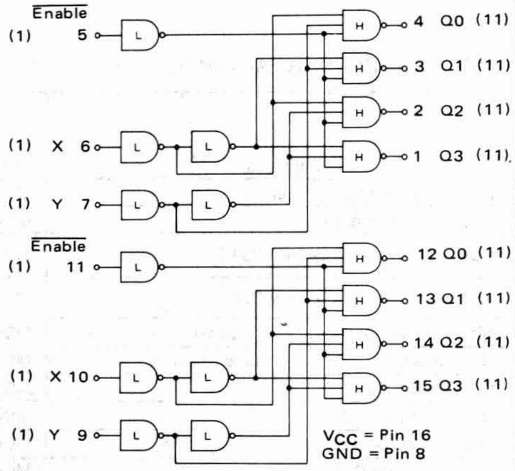
MC4006
Binary to 1-of-8 Line Decoder


Enable
(1) 8
L
H
10 Q0 (11)
11 Q1 (11)
12 Q2 (11)
13 Q3 (11)
4 Q4 (11)
3 Q5 (11)
2 Q6 (11)
1 Q7 (11)
(1) X 5
(1) Y 6
(1) Z 9

V_{CC} = Pin 14
GND = Pin 7

t_{pd} = 14 ns typ
P_D = 100 mW typ/pkg

MC4007
Dual Binary to 1-of-4 Line Decoder

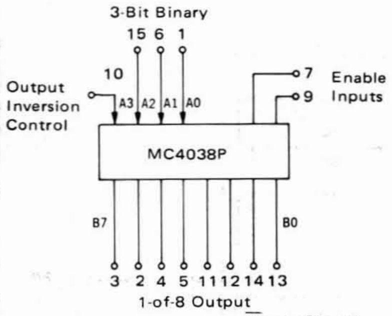

Enable
(1) 5
L
H
4 Q0 (11)
3 Q1 (11)
2 Q2 (11)
1 Q3 (11)
(1) X 6
(1) Y 7
Enable
(1) 11
12 Q0 (11)
13 Q1 (11)
14 Q2 (11)
15 Q3 (11)
(1) X 10
(1) Y 9

V_{CC} = Pin 16
GND = Pin 8

t_{pd} = 14 ns typ
P_D = 125 mW typ/pkg

DECODERS (continued)

MC4038
Inverting/Non-Inverting 1-of-8 Decoder

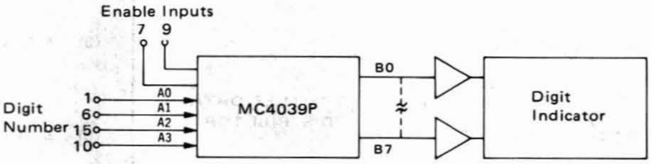

3-Bit Binary
15 6 1
10
Output Inversion Control
A3 A2 A1 A0
7 Enable
9 Inputs
MC4038P
B7
B0
3 2 4 5 11 12 14 13
1-of-8 Output

V_{CC} = Pin 16
GND = Pin 8

INPUT (A)				OUTPUT BIT NO. (B)							
3	2	1	0	7	6	5	4	3	2	1	0
0	0	0	0	0	1	1	1	1	1	1	1
0	0	0	1	1	0	1	1	1	1	1	1
0	0	1	0	1	1	0	1	1	1	1	1
0	0	1	1	1	1	1	0	1	1	1	1
0	1	0	0	1	1	1	1	0	1	1	1
0	1	0	1	1	1	1	1	1	0	1	1
0	1	1	0	1	1	1	1	1	1	0	1
0	1	1	1	1	1	1	1	1	1	1	0
1	0	0	0	1	0	0	0	0	0	0	0
1	0	0	1	0	1	0	0	0	0	0	0
1	0	1	0	0	0	1	0	0	0	0	0
1	0	1	1	0	0	0	1	0	0	0	0
1	1	0	0	0	0	0	0	1	0	0	0
1	1	0	1	0	0	0	0	0	1	0	0
1	1	1	0	0	0	0	0	0	0	1	0
1	1	1	1	0	0	0	0	0	0	0	1

P_D = 240 mW typ/pkg

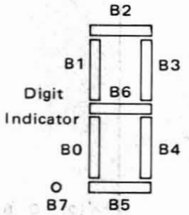
MC4039
7-Segment Character Generator


Enable Inputs
7 9
Digit Number
1
6
15
10
A0
A1
A2
A3
MC4039P
B0
B7
Digit Indicator

Output Bit	B0	B1	B2	B3	B4	B5	B6	B7
Pin No.	13	14	12	11	5	4	2	3

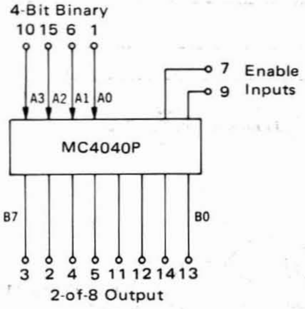
V_{CC} = Pin 16
GND = Pin 8

P_D = 240 mW typ/pkg


B2
B1
B3
Digit Indicator
B6
B0
B4
B7
B5

DIGIT	SEGMENTS ILLUMINATED	INPUT (A)				OUTPUT BIT NO. (B)							
		3	2	1	0	7	6	5	4	3	2	1	0
0	0,1,2,3,4,5	0	0	0	0	1	1	0	0	0	0	0	0
1	3,4	0	0	0	1	1	1	1	0	0	1	1	1
2	0,2,3,5,6	0	0	1	0	1	0	0	1	0	0	1	0
3	2,3,4,5,6	0	0	1	1	1	0	0	0	0	0	1	1
4	1,3,4,6	0	1	0	0	1	0	1	0	0	1	0	1
5	1,2,4,5,6	0	1	0	1	1	0	0	0	1	0	0	1
6	0,1,4,5,6	0	1	1	0	1	0	0	0	1	1	0	0
7	2,3,4	0	1	1	1	1	1	1	0	0	0	1	1
8	0,1,2,3,4,5,6	1	0	0	0	1	0	0	0	0	0	0	0
9	1,2,3,4,6	1	0	0	1	1	0	1	0	0	0	0	1
NONE		1	0	1	0	1	1	1	1	1	1	1	1
●	7 (Ext.)	1	0	1	1	0	1	1	1	1	1	1	1
–	6	1	1	0	0	1	0	1	1	1	1	1	1
NONE		1	1	0	1	1	1	1	1	1	1	1	1
NONE		1	1	1	0	1	1	1	1	1	1	1	1
NONE		1	1	1	1	1	1	1	1	1	1	1	1

MC4040
Binary to 2-of-8 Decoder

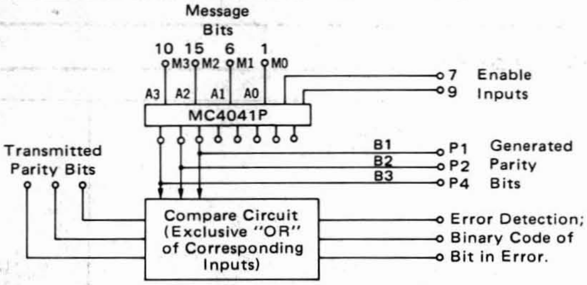

4-Bit Binary
10 15 6 1
A3 A2 A1 A0
7 Enable
9 Inputs
MC4040P
B7
B0
3 2 4 5 11 12 14 13
2-of-8 Output

V_{CC} = Pin 16
GND = Pin 8

INPUT (A)				OUTPUT BIT NO. (B)							
3	2	1	0	7	6	5	4	3	2	1	0
0	0	0	0	1	1	1	0	1	1	1	0
0	0	0	1	1	1	1	0	1	1	0	1
0	0	1	0	1	1	1	0	1	0	1	1
0	0	1	1	1	1	1	0	0	1	1	1
0	1	0	0	1	1	0	1	1	1	1	0
0	1	0	1	1	1	0	1	1	1	0	1
0	1	1	0	1	1	0	1	1	0	1	1
0	1	1	1	1	1	0	1	0	1	1	1
1	0	0	0	1	0	1	1	1	1	1	0
1	0	0	1	1	0	1	1	1	1	0	1
1	0	1	0	1	0	1	1	1	0	1	1
1	0	1	1	1	0	1	1	0	1	1	1
1	1	0	0	0	1	1	1	1	1	1	0
1	1	0	1	0	1	1	1	1	1	0	1
1	1	1	0	0	1	1	1	1	0	1	1
1	1	1	1	0	1	1	1	0	1	1	1

P_D = 200 mW typ/pkg

MC4041
Single-Error Hamming Code Detector and Generator


Message Bits
10 15 6 1
M3 M2 M1 M0
A3 A2 A1 A0
7 Enable
9 Inputs
MC4041P
Transmitted Parity Bits
B1
B2
B3
P1 Generated
P2 Parity
P4 Bits
Compare Circuit (Exclusive "OR" of Corresponding Inputs)
Error Detection; Binary Code of Bit in Error.

Output Bit	B0	B1	B2	B3	B4	B5	B6	B7
Pin No.	13	14	12	11	5	4	2	3

V_{CC} = Pin 16
GND = Pin 8

INPUT (A)				OUTPUT BIT NO. (B)							
3	2	1	0	7	6	5	4	3	2	1	0
0	0	0	0	1	1	1	1	1	1	1	0
0	0	0	1	0	0	1	1	1	0	0	1
0	0	1	0	0	0	1	0	0	1	0	1
0	0	1	1	1	1	1	0	0	0	1	0
0	1	0	0	0	0	0	1	0	0	1	1
0	1	0	1	1	1	0	1	0	1	0	0
0	1	1	0	1	1	0	0	1	0	0	0
0	1	1	1	0	0	0	0	1	1	1	1
1	0	0	0	0	0	0	0	0	0	0	1
1	0	0	1	1	1	0	0	0	1	1	0
1	0	1	0	1	1	0	1	1	0	1	0
1	0	1	1	0	0	0	1	1	1	0	1
1	1	0	0	1	1	1	0	1	1	0	0
1	1	0	1	0	0	1	0	1	0	1	1
1	1	1	0	0	0	1	1	0	1	1	1
1	1	1	1	1	1	1	1	0	0	0	0

Simple Parity: The outputs of bits 0, 6, and 7 provide parity check over the 4 message bits.

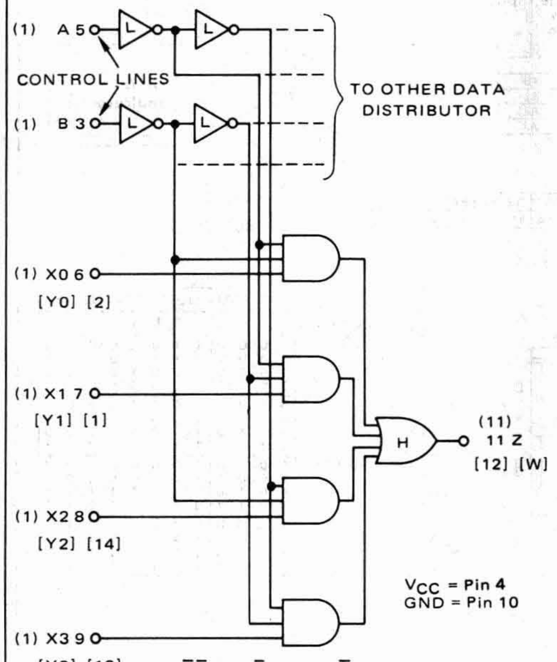
Hamming Detection and Correction: Bits 1, 2, and 3 perform the parity calculations necessary for Hamming Code generation or detection on 4 message bits. For greater than 4 bits per message, ROM's may be cascaded. In these cases, bits 4, 5, 6, and 7 perform the necessary parity calculations.

P_D = 240 mW typ/pkg

MTTL MC4000 SERIES LOGIC DIAGRAMS

DATA ROUTING FUNCTIONS

MC4000
Dual 4-Channel Data Selector
(½ of device shown)
[Numbers and symbols in brackets are for other half.]


(1) A 5
CONTROL LINES
(1) B 3
L
L
L
L
TO OTHER DATA DISTRIBUTOR
(1) X0 6
[Y0] [2]
(1) X1 7
[Y1] [1]
(1) X2 8
[Y2] [14]
(1) X3 9
H
(11)
11 Z
[12] [W]

V_{CC} = Pin 4
GND = Pin 10

[Y3] [13]

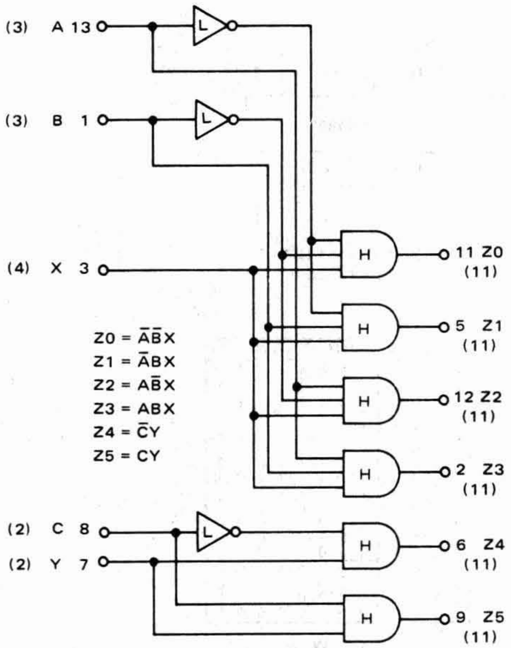
$Z = \bar{A}\bar{B}X0 + \bar{A}BX1 + A\bar{B}X2 + ABX3$

$W = \bar{A}\bar{B}Y0 + \bar{A}BY1 + A\bar{B}Y2 + ABY3$

t_{pd} = 11 ns typ

P_D = 150 mW typ/pkg

MC4002
Dual Data Distributor


(3) A 13
(3) B 1
(4) X 3
(2) C 8
(2) Y 7
L
L
L
H
H
H
H
H
H
11 Z0 (11)
5 Z1 (11)
12 Z2 (11)
2 Z3 (11)
6 Z4 (11)
9 Z5 (11)

$Z0 = \bar{A}\bar{B}X$
$Z1 = \bar{A}BX$
$Z2 = A\bar{B}X$
$Z3 = ABX$
$Z4 = \bar{C}Y$
$Z5 = CY$

t_{pd} = 10.5 ns typ

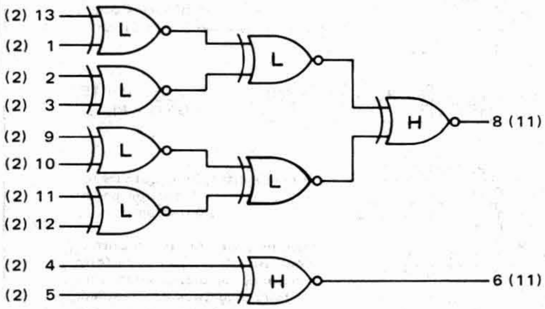
P_D = 175 mW typ/pkg

V_{CC} = Pin 4

GND = Pin 10

PARITY TREES

MC4008
8-Bit Parity Tree


(2) 13
(2) 1
(2) 2
(2) 3
(2) 9
(2) 10
(2) 11
(2) 12
(2) 4
(2) 5
L
L
L
L
L
L
H
H
8 (11)
6 (11)

t_{pd} = 15-30 ns typ

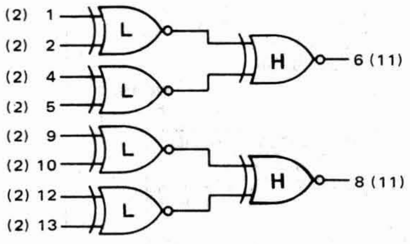
P_D = 150 mW typ/pkg

V_{CC} = Pin 14

GND = Pin 7

$8 = 1 \odot 2 \odot 3 \odot 9 \odot 10 \odot 11 \odot 12 \odot 13$
$6 = 4 \odot 5$
where $X \odot Y = \bar{X} \cdot \bar{Y} + X \cdot Y$

MC4010
Dual 4-Bit Parity Tree


(2) 1
(2) 2
(2) 4
(2) 5
(2) 9
(2) 10
(2) 12
(2) 13
L
L
L
L
H
H
6 (11)
8 (11)

t_{pd} = 9.5-22 ns typ

P_D = 125 mW typ/pkg

V_{CC} = Pin 14

GND = Pin 7

$6 = 1 \odot 2 \odot 4 \odot 5$

where $X \odot Y = \bar{X} \cdot \bar{Y} + X \cdot Y$

MDTL INTEGRATED CIRCUITS MDTL

MC830 Series (0 to +75°C)
MC930 Series (−55 to +125°)

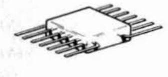
MDTL integrated circuits provide an excellent balance of speed, power dissipation, and noise immunity for general purpose digital applications. The line includes many new multi-function types. Additional logic power is provided by the "wired OR" capability of the basic MDTL gate.

MAXIMUM RATINGS

Rating	Value	Unit
Supply Voltage – Continuous	8.0	Vdc
Pulsed, < 1 second	12	
Output Current (into outputs) –		mAdc
Buffers, Power Gates – Continuous	150	
Pulsed, < 30 ms	300	
MC951/851, MC950/850 – Continuous	50	
MC950/850 – Pulsed, < 30 ms	100	
All other types	30	
Input Forward Current	−10	mAdc
Input Reverse Current –		mAdc
Buffers, Power Gates, MC950/850	5.0	
All other types	1.0	
Operating Temperature Range –		°C
MC930 Series	−55 to +125	
MC830 Series	0 to + 75	
Storage Temperature Range –		°C
Metal Can and Ceramic Package	−65 to +150	
Plastic Package	−55 to +125	

G SUFFIX
CASE 603
(Formerly Case 96A)
TO-100

P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116



F SUFFIX
CASE 607
(Formerly Case 83)
TO-86

P SUFFIX
PLASTIC PACKAGE
CASE 612

FUNCTIONS AND CHARACTERISTICS (V_{CC} = 5.0 Vdc, T_A = 25°C)

Function	Type ① 0 to +75°C	Case	Type ① −55 to +125°C	Case	Output Loading Factor Each Output	Propagation Delay t_{pd} ns typ	Total Power Dissipation mWtyp/pkg
Expandable Dual 4-Input NAND Gate	MC830	605,607	MC930	607	8	30	22
Expandable Dual 3-2 Input NAND Gate	MC830	603	MC930	603	8	30	22
Clocked Flip-Flop	MC831	603,605,607	MC931	603,607	7	40	55
Expandable Dual 4-Input Buffer	MC832	605,607	MC932	607	25	35	85
Expandable Dual 3-2 Input Buffer	MC832	603	MC932	603	25	35	85
Dual 4-Input Expander	MC833	605,607	MC933	607	–	–	–
Dual 4-3 Input Expander	MC833	603	MC933	603	–	–	–
Hex Inverter	MC834	605,607	MC934	607	8	30	66
Hex Inverter (without output resistors)	MC835	↓	MC935	↓	8	30	42
Hex Inverter	MC836	↓	MC936	↓	8	30	66
Hex Inverter	MC837	605,607	MC937	607	7	25	90
Decade Counter	MC838	↓	MC938	↓	8	30 MHz③	150
Divide-by-Sixteen Counter	MC839	↓	MC939	↓	8	30 MHz③	150
Hex Inverter (without input diodes)	MC840	↓	MC940	↓	8	30	66
Hex Inverter (without output resistors and input diodes)	MC841	↓	MC941	↓	8	30	42
Type D Flip-Flop Plus 2-Wide 2-Input AND-OR-INVERT Gate	MC842	605,607	MC942	607	9/11②	40	110
4-Input AND Driver with NOR Strobe	MC843	603	MC943	603	250 mA	80	50
Expandable Dual 4-Input Power Gate	MC844	605,607	MC944	607	27	30	65
Expandable Dual 3-2 Input Power Gate	MC844	603	MC944	603	27	30	65
Clocked Flip-Flop	MC845	603,605,607	MC945	603,607	12/10②	40	60
Quad 2-Input NAND Gate	MC846	605,607	MC946	607	8	30	44
Quad Inverter	MC846	603	MC946	603	8	30	44
Quad 2-Input Gate Expander	MC847	605,607	MC947	607	–	–	–
Clocked Flip-Flop	MC848	603,605,607	MC948	603,607	11/9②	40	70
Quad 2-Input NAND Gate (2 k pullup resistor)	MC849	605,607	MC949	607	7	25	66
Quad Inverter (2 k pullup resistor)	MC849	603	MC949	603	7	25	60
Pulse Triggered Binary	MC850	603,605,607	MC950	603,607	10/8②	15	50
Monostable Multivibrator	MC851	603,605,607	MC951	603,607	10	40	30
Dual J-K Flip-Flop (common clock and C_D, separate S_D)	MC852	605,607	MC952	607	12/10②	40	120
Dual J-K Flip-Flop (separate clock and S_D, no C_D)	MC853	605,607	MC953	607	12/10②	40	120
Dual J-K Flip-Flop (common clock and C_D, separate S_D, 2 k pullup resistor)	MC855	605,607	MC955	607	11/9②	40	140
Dual J-K Flip-Flop (separate clock and S_D, no C_D, 2 k pullup resistor)	MC856	↓	MC956	↓	11/9②	40	140
Quad 2-Input Buffers	MC857	↓	MC957	↓	25	35	170
Quad 2-Input NAND Power Gates	MC858	↓	MC958	↓	27	30	130
Expandable Dual 4-Input NAND Gate (2 k pullup resistor)	MC861	↓	MC961	↓	7	25	33
Expandable Dual 3-2 Input NAND Gate (2 k pullup resistor)	MC861	603	MC961	603	7	25	33
Triple 3-Input NAND Gate	MC862	605,607	MC962	607	8	30	33
Dual 2-Input NAND Gate plus Inverter	MC862	603	MC962	603	8	30	30
Triple 3-Input NAND Gate (2 k pullup resistor)	MC863	605,607	MC963	607	7	25	50
Dual 2-Input NAND Gate plus Inverter (2 k pullup resistor)	MC863	603	MC963	603	7	25	45
Dual 5-Input NAND Gates	MC1800	605,607	MC1900	607	8	30	22
Dual 5-Input NAND Gates (2 k pullup resistors)	MC1801	↓	MC1901	↓	7	25	33
Expandable 8-Input NAND Gates	MC1802	↓	MC1902	↓	8	30	11
Expandable 8-Input NAND Gates (2 k pullup resistor)	MC1803	↓	MC1903	↓	7	25	16.5
10-Input NAND Gates	MC1804	↓	MC1904	↓	8	30	11
10-Input NAND Gate (2 k pullup resistor)	MC1805	605,607	MC1905	607	7	25	16.5
Quad 2-Input AND Gates	MC1806	↓	MC1906	↓	8	35	72
Quad 2-Input AND Gates (2 k pullup resistors)	MC1807	↓	MC1907	↓	7	30	85
Quad 2-Input OR Gates	MC1808	↓	MC1908	↓	8	35	97
Quad 2-Input OR Gates (2 k pullup resistors)	MC1809	↓	MC1909	↓	7	30	115
Quad 2-Input NOR Gates	MC1810	605,607	MC1910	607	8	30	60
Quad 2-Input NOR Gates (2 k pullup resistors)	MC1811	↓	MC1911	↓	7	25	72
Quad 2-Input Exclusive OR Gates	MC1812	↓	MC1912	↓	8	40	120
Quad Latch	MC1813	612	–	–	7	35	220
Quad Latch	MC1814	605,607	MC1914	607	7	35	220

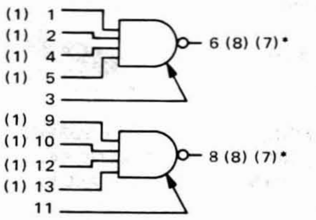
① G suffix denotes Metal Can, F suffix denotes Flat Package, P suffix denotes Plastic Package. (i.e., MC830G = Metal Can, MC830F = Flat Package, MC830P = Plastic Package)
② Fan-out for MC830 series type / Fan-out for MC930 series type.
③ Maximum counting Frequency

MDTL LOGIC DIAGRAMS

Numbers at ends of terminals represent pin numbers. Numbers in parenthesis indicate loading.
"G" Package: V_{CC} = pin 10, Gnd = pin 5 unless otherwise noted.
"F" and "P" Packages: V_{CC} = pin 14, Gnd = pin 7 unless otherwise noted.

GATES

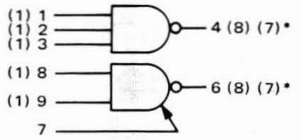
MC830F, MC830P, MC930F
MC861F, MC861P, MC961F
Expandable Dual 4-Input NAND Gate


(1) 1
(1) 2
(1) 4
(1) 5
3
6 (8) (7)*
(1) 9
(1) 10
(1) 12
(1) 13
11
8 (8) (7)*

$6 = \overline{1 \cdot 2 \cdot 4 \cdot 5 \cdot [3]}$

*Applies to MC861F, MC861P, MC961F

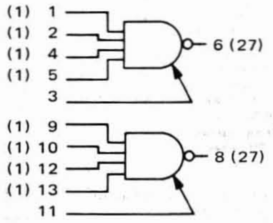
MC830G, MC930G
MC861G, MC961G
Expandable
Dual 3-2 Input NAND Gate


(1) 1
(1) 2
(1) 3
4 (8) (7)*
(1) 8
(1) 9
7
6 (8) (7)*

$4 = \overline{1 \cdot 2 \cdot 3}$

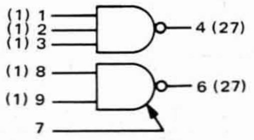
*Applies to MC861G, MC961G

MC844F, MC844P, MC944F
Expandable
Dual 4-Input Power NAND Gate


(1) 1
(1) 2
(1) 4
(1) 5
3
6 (27)
(1) 9
(1) 10
(1) 12
(1) 13
11
8 (27)

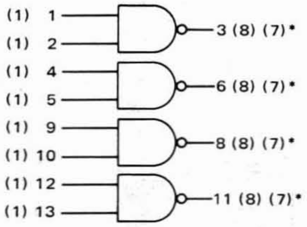
$6 = \overline{1 \cdot 2 \cdot 4 \cdot 5 \cdot [3]}$

MC844G, MC944G
Expandable
Dual 3-2 Input NAND Power Gate


(1) 1
(1) 2
(1) 3
4 (27)
(1) 8
(1) 9
7
6 (27)

$4 = \overline{1 \cdot 2 \cdot 3}$

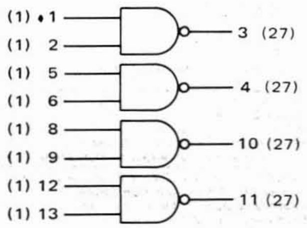
MC846F, MC846P, MC946F
MC849F, MC849P, MC949F
Quad 2-Input NAND Gate


(1) 1
(1) 2
3 (8) (7)*
(1) 4
(1) 5
6 (8) (7)*
(1) 9
(1) 10
8 (8) (7)*
(1) 12
(1) 13
11 (8) (7)*

$3 = \overline{1 \cdot 2}$

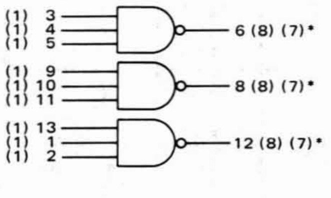
*Applies to MC849F, MC849P, MC949F

MC858F, MC858P, MC958F
Quad 2-Input NAND Power Gate


(1) 1
(1) 2
3 (27)
(1) 5
(1) 6
4 (27)
(1) 8
(1) 9
10 (27)
(1) 12
(1) 13
11 (27)

$3 = \overline{1 \cdot 2}$

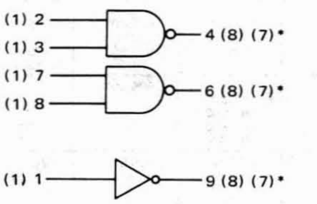
MC862F, MC862P, MC962F
MC863F, MC863P, MC963F
Triple 3-Input NAND Gate


(1) 3
(1) 4
(1) 5
6 (8) (7)*
(1) 9
(1) 10
(1) 11
8 (8) (7)*
(1) 13
(1) 1
(1) 2
12 (8) (7)*

$6 = \overline{3 \cdot 4 \cdot 5}$

*Applies to MC863F, MC863P, MC963F

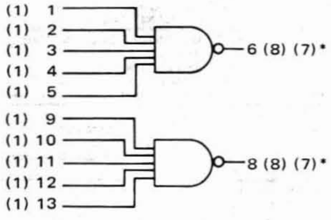
MC862G, MC962G
MC863G, MC963G
Dual 2-Input NAND Gate
Plus Inverter


(1) 2
(1) 3
4 (8) (7)*
(1) 7
(1) 8
6 (8) (7)*
(1) 1
9 (8) (7)*

$4 = \overline{2 \cdot 3}$
$6 = \overline{7 \cdot 8}$
$9 = \overline{1}$

*Applies to MC863G, MC963G

MC1800F, MC1800P, MC1900F
MC1801F, MC1801P, MC1901F
Dual 5-Input NAND Gate


(1) 1
(1) 2
(1) 3
(1) 4
(1) 5
6 (8) (7)*
(1) 9
(1) 10
(1) 11
(1) 12
(1) 13
8 (8) (7)*

$6 = \overline{1 \cdot 2 \cdot 3 \cdot 4 \cdot 5}$

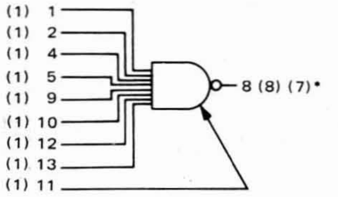
*Applies to MC1801F, MC1801P, MC1901F

(continued)

GATES (continued)

MC1802F, MC1802P, MC1902F
MC1803F, MC1803P, MC1903F

Expandable 8-Input NAND Gate

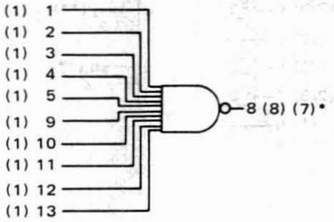

(1) 1
(1) 2
(1) 4
(1) 5
(1) 9
(1) 10
(1) 12
(1) 13
(1) 11
8 (8) (7)*

$8 = \overline{1 \cdot 2 \cdot 4 \cdot 5 \cdot 9 \cdot 10 \cdot 12 \cdot 13 \cdot [11]}$

*Applies to MC1803F, MC1803P, MC1903F

MC1804F, MC1804P, MC1904F
MC1805F, MC1805P, MC1905F

10-Input NAND Gate

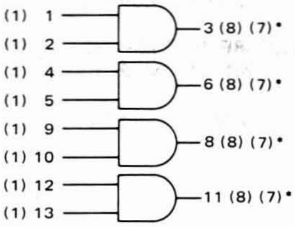

(1) 1
(1) 2
(1) 3
(1) 4
(1) 5
(1) 9
(1) 10
(1) 11
(1) 12
(1) 13
8 (8) (7)*

$8 = \overline{1 \cdot 2 \cdot 3 \cdot 4 \cdot 5 \cdot 9 \cdot 10 \cdot 11 \cdot 12 \cdot 13}$

*Applies to MC1805F, MC1805P, MC1905F

MC1806F, MC1806P, MC1906F
MC1807F, MC1807P, MC1907F

Quad 2-Input AND Gate

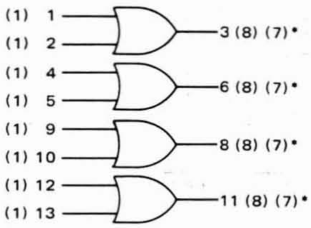

(1) 1
(1) 2
3 (8) (7)*
(1) 4
(1) 5
6 (8) (7)*
(1) 9
(1) 10
8 (8) (7)*
(1) 12
(1) 13
11 (8) (7)*

$3 = 1 \cdot 2$

*Applies to MC1807F, MC1807P, MC1907F

MC1808F, MC1808P, MC1908F
MC1809F, MC1809P, MC1909F

Quad 2-Input OR Gate

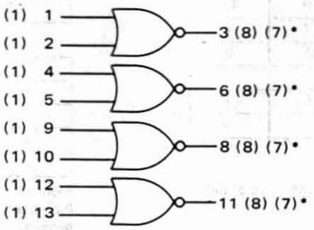

(1) 1
(1) 2
3 (8) (7)*
(1) 4
(1) 5
6 (8) (7)*
(1) 9
(1) 10
8 (8) (7)*
(1) 12
(1) 13
11 (8) (7)*

$3 = 1 + 2$

*Applies to MC1809F, MC1809P, MC1909F

MC1810F, MC1810P, MC1910F
MC1811F, MC1811P, MC1911F

Quad 2-Input NOR Gate

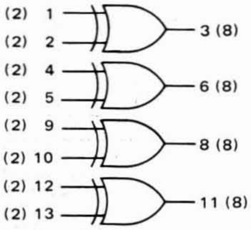

(1) 1
(1) 2
3 (8) (7)*
(1) 4
(1) 5
6 (8) (7)*
(1) 9
(1) 10
8 (8) (7)*
(1) 12
(1) 13
11 (8) (7)*

$3 = \overline{1 + 2}$

*Applies to MC1811F, MC1811P, MC1911F

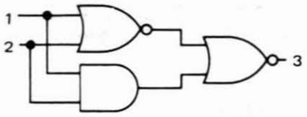
MC1812F, MC1812P, MC1912F

Quad 2-Input Exclusive OR Gate


(2) 1
(2) 2
3 (8)
(2) 4
(2) 5
6 (8)
(2) 9
(2) 10
8 (8)
(2) 12
(2) 13
11 (8)

$3 = 1 \cdot \overline{2} + \overline{1} \cdot 2$

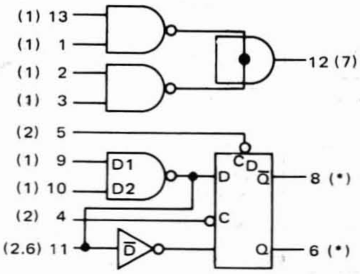
FUNCTIONAL LOGIC DIAGRAM



MULTIFUNCTION DEVICES

MC842F, MC842P, MC942F

Type D Flip-Flop Plus 2-Wide 2-Input AND-OR-INVERT Gate


(1) 13
(1) 1
(1) 2
(1) 3
12 (7)
(2) 5
(1) 9
(1) 10
(2) 4
(2.6) 11
D1
D2
D̄
C_D
D
Q̄
C
Q
8 (*)
6 (*)

$12 = \overline{(1 \cdot 13) + (2 \cdot 3)}$

t_n		t_{n+1}
D1 Pin 9	D2 Pin 10	Q Pin 6
1	1	1
0	X	0
X	0	0

SYNCHRONOUS TRUTH TABLES

t_n	t_{n+1}
$\overline{D}$ Pin 11	Q Pin 6
1	0
0	1

*For MC842F, and P = 9

*For MC942F = 11

Note that D can be set by D1, D2 or supplied by external means.

Asynchronous input, Direct Clear (C_D), overrides the synchronous inputs.

0 = Low state (More negative)
1 = High state (More positive)
X = State of the input does not affect the state of the circuit

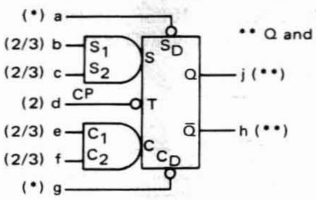
FLIP-FLOPS

MC831F, MC831G, MC831P
MC931F, MC931G

MC845F, MC845G, MC845P
MC945F, MC945G

MC848F, MC848G, MC848P
MC948F, MC948G

Clocked Flip-Flop



• S_D and C_D loading factor: ¾ for MC831/MC931 types
2 for other clocked flip-flops

•• Q and $\bar{Q}$ loading factor: 7 for MC831/MC931 types
12 for MC845 types
10 for MC945 types
11 for MC848 types
9 for MC948 types

PIN CONNECTIONS

Letter	a	b	c	d	e	f	g	h	j
"F" & "P" Pkgs.	10	3	4	2	12	11	5	9	6
"G" Pkg.	7	2	3	1	9	8	—	6	4

SYNCHRONOUS TRUTH TABLE

t_n				t_{n+1}
S_1	S_2	C_1	C_2	Q
0	X	0	X	Q_n
0	X	X	0	Q_n
X	0	0	X	Q_n
X	0	X	0	Q_n
0	X	1	1	0
X	0	1	1	0
1	1	0	X	1
1	1	X	0	1
1	1	1	1	U

0 — Low State (more negative)
1 — High State (more positive)
X — State of the input does not affect the state of the circuit.
U — Indeterminate State

J-K TRUTH TABLE
(Connect S_2 to $\bar{Q}$, C_2 to Q)

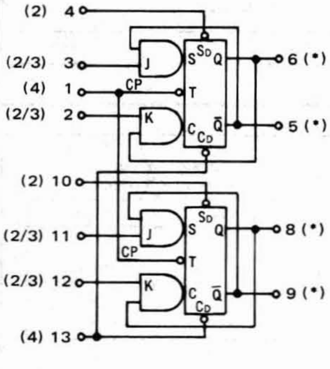
t_n		t_{n+1}
S_1	C_1	Q
0	0	Q_n
1	0	1
0	1	0
1	1	$\bar{Q}_n$

ASYNCHRONOUS TRUTH TABLE

S_D	C_D	Q	$\bar{Q}$
1	1	NC	NC
0	1	1	0
1	0	0	1
0	0	1	1

Asynchronous inputs, direct set (S_D) and direct clear (C_D), override the synchronous inputs; they are independent of all other inputs.

MC852F, MC852P, MC952F
MC855F, MC855P, MC955F
Dual J-K Flip-Flop



•Q and $\bar{Q}$ loading factor:
12 – MC852
10 – MC952
11 – MC855
9 – MC955

ASYNCHRONOUS TRUTH TABLE
MC952/MC852 and MC955/MC855

S_D	C_D	Q	$\bar{Q}$
1	1	NC	NC
0	1	1	0
1	0	0	1
0	0	1	1

ASYNCHRONOUS TRUTH TABLE
MC953/MC853 and MC956/MC856

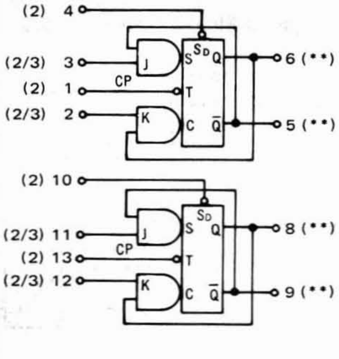
S_D	Q	$\bar{Q}$
1	NC	NC
0	1	0

J-K TRUTH TABLE
All Types

t_n		t_{n+1}
J	K	Q
0	0	Q_n
1	0	1
0	1	0
1	1	$\bar{Q}_n$

Asynchronous inputs, direct set (S_D) and direct clear (C_D), override the synchronous inputs: they are independent of all other inputs.

MC853F, MC853P, MC953F
MC856F, MC856P, MC956F
Dual J-K Flip-Flop

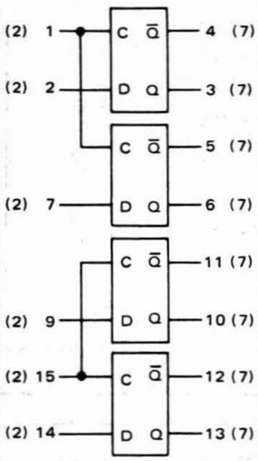


••Q and $\bar{Q}$ loading factor:
12 – MC853
10 – MC953
11 – MC856
9 – MC956

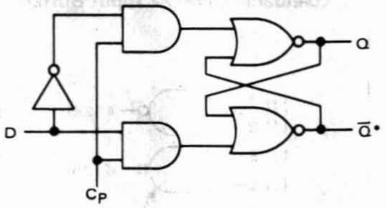
(continued)

FLIP-FLOPS (continued)

MC1813P
Quad Latch


(2) 1
C
Q̄
4 (7)
(2) 2
D
Q
3 (7)
C
Q̄
5 (7)
(2) 7
D
Q
6 (7)
C
Q̄
11 (7)
(2) 9
D
Q
10 (7)
(2) 15
C
Q̄
12 (7)
(2) 14
D
Q
13 (7)

FUNCTIONAL LOGIC DIAGRAM



Information present at the Data Input D is transferred to the Q output when the clock is high, and the Q output will follow the state of the Data input as long as the clock remains high. Information present at the Q output will be retained as the clock goes low until such time as the clock is permitted to go high.

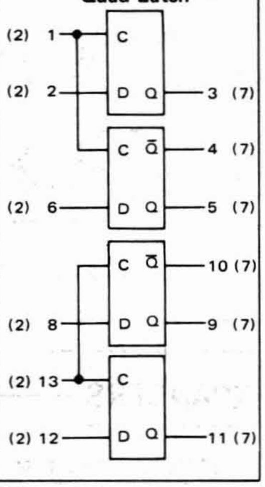
TRUTH TABLE

t_n	t_{n+1}	
D	Q	Q̄*
1	1	0
0	0	1

*As applicable
(see loading diagram)

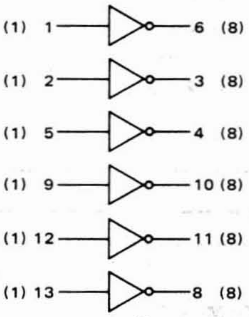
MC1813P: V_{CC} = Pin 16, Gnd = Pin 8

MC1814F, MC1814P,
MC1914F
Quad Latch


(2) 1
C
(2) 2
D
Q
3 (7)
C
Q̄
4 (7)
(2) 6
D
Q
5 (7)
C
Q̄
10 (7)
(2) 8
D
Q
9 (7)
(2) 13
C
(2) 12
D
Q
11 (7)

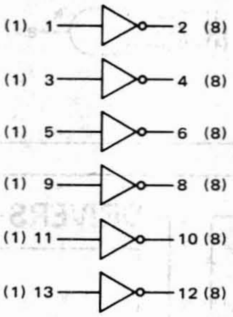
INVERTERS

MC834F, MC834P, MC934F
Hex Inverter


(1) 1
6 (8)
(1) 2
3 (8)
(1) 5
4 (8)
(1) 9
10 (8)
(1) 12
11 (8)
(1) 13
8 (8)

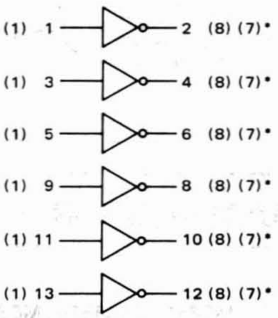
$6 = \bar{1}$

MC835F, MC835P, MC935F
Hex Inverter
(without output resistors)


(1) 1
2 (8)
(1) 3
4 (8)
(1) 5
6 (8)
(1) 9
8 (8)
(1) 11
10 (8)
(1) 13
12 (8)

$2 = \bar{1}$

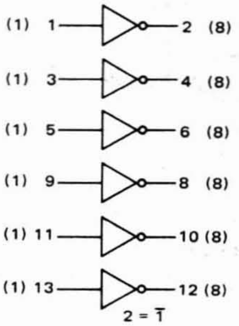
MC836F, MC836P, MC936F
MC837F, MC837P, MC937F
Hex Inverter


(1) 1
2 (8) (7)*
(1) 3
4 (8) (7)*
(1) 5
6 (8) (7)*
(1) 9
8 (8) (7)*
(1) 11
10 (8) (7)*
(1) 13
12 (8) (7)*

$2 = \bar{1}$

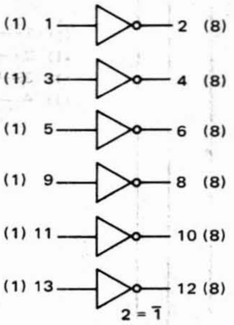
*Applies to MC837F, MC837P, MC937F

MC840F, MC840P, MC940F
Hex Inverter
(without input diodes)


(1) 1
2 (8)
(1) 3
4 (8)
(1) 5
6 (8)
(1) 9
8 (8)
(1) 11
10 (8)
(1) 13
12 (8)

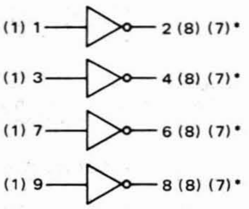
$2 = \bar{1}$

MC841F, MC841P, MC941F
Hex Inverter
(without output resistors and input diodes)


(1) 1
2 (8)
(1) 3
4 (8)
(1) 5
6 (8)
(1) 9
8 (8)
(1) 11
10 (8)
(1) 13
12 (8)

$2 = \bar{1}$

MC846G, MC946G
MC849G, MC949G
Quad Inverter


(1) 1
2 (8) (7)*
(1) 3
4 (8) (7)*
(1) 7
6 (8) (7)*
(1) 9
8 (8) (7)*

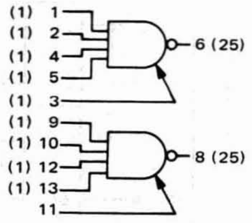
$2 = \bar{1}$

*Applies to MC849G, MC949G

MDTL LOGIC DIAGRAMS

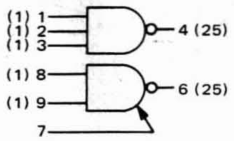
BUFFERS

MC832F, MC832P, MC932F
Expandable Dual 4-Input Buffer


(1) 1
(1) 2
(1) 4
(1) 5
(1) 3
6 (25)
(1) 9
(1) 10
(1) 12
(1) 13
11
8 (25)

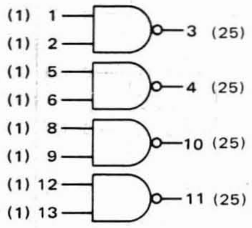
$6 = \overline{1 \cdot 2 \cdot 4 \cdot 5 \cdot [3]}$

MC832G, MC932G
Expandable Dual 3-2 Input Buffer


(1) 1
(1) 2
(1) 3
4 (25)
(1) 8
(1) 9
7
6 (25)

$4 = \overline{1 \cdot 2 \cdot 3}$

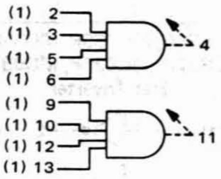
MC857F, MC857P, MC957F
Quad 2-Input Buffers


(1) 1
(1) 2
3 (25)
(1) 5
(1) 6
4 (25)
(1) 8
(1) 9
10 (25)
(1) 12
(1) 13
11 (25)

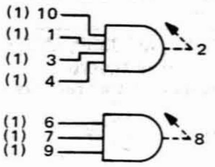
$3 = \overline{1 \cdot 2}$

EXPANDERS

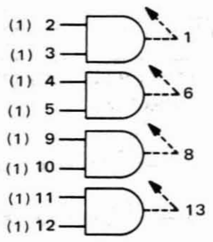
MC833F, MC833P, MC933F
Dual 4-Input Expander


(1) 2
(1) 3
(1) 5
(1) 6
4
(1) 9
(1) 10
(1) 12
(1) 13
11

MC833G, MC933G
Dual 4-3 Input Expander

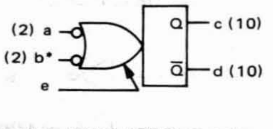

(1) 10
(1) 1
(1) 3
(1) 4
2
(1) 6
(1) 7
(1) 9
8

MC847F, MC847P, MC947F
Quad 2-Input Gate Expander


(1) 2
(1) 3
1
(1) 4
(1) 5
6
(1) 9
(1) 10
8
(1) 11
(1) 12
13

MULTIVIBRATOR

MC851F, MC851G, MC851P
MC951F, MC951G
Monostable Multivibrator


(2) a
(2) b*
e
Q
c (10)
Q̄
d (10)

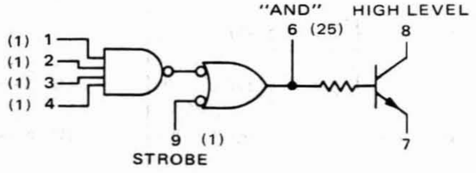
*Available in "F" & "P" Pkgs. only
"F" & "P" Pkgs: V_{CC} = pin 14, Gnd = pin 7
"G" Pkg: V_{CC} = pin 6, Gnd = pin 1

PIN CONNECTIONS

Letter	a	b	c	d	e
"F" & "P" Pkgs.	3	4	6	1	2
"G" Pkg.	9	—	10	7	8

DRIVERS

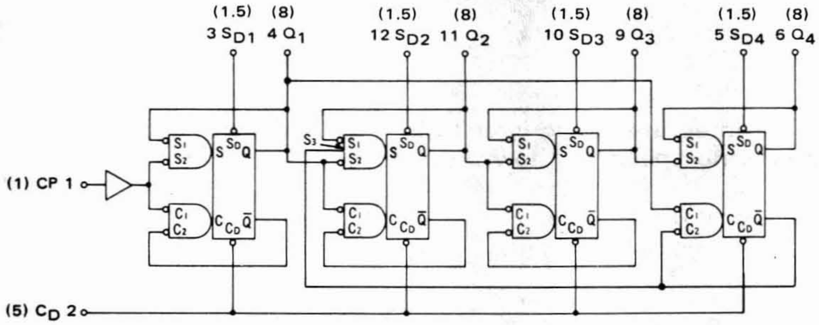
MC843G, MC943G
4-Input AND Driver with NOR Strobe


"AND"
6 (25)
HIGH LEVEL
8
(1) 1
(1) 2
(1) 3
(1) 4
9 (1)
STROBE
7

$\overline{8} = 1 \cdot 2 \cdot 3 \cdot 4 + \overline{9}$

COUNTERS

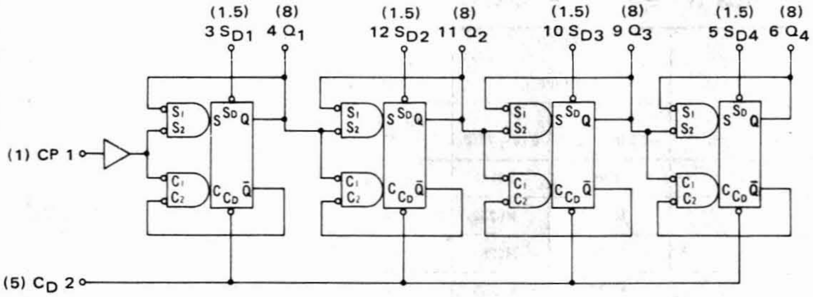
MC838F, MC838P, MC938F
Decade Counter


(1.5) (8)
3 S_{D1} 4 Q_1
(1.5) (8)
12 S_{D2} 11 Q_2
(1.5) (8)
10 S_{D3} 9 Q_3
(1.5) (8)
5 S_{D4} 6 Q_4
(1) CP 1
(5) C_D 2
S_1
S_2
S_3
C_1
C_2
S S_D Q
C C_D $\bar{Q}$

DECODING LOGIC

0	$\bar{Q}_1$	$\bar{Q}_2$	$\bar{Q}_3$	$\bar{Q}_4$
1	Q_1	$\bar{Q}_2$	$\bar{Q}_3$	$\bar{Q}_4$
2	$\bar{Q}_1$	Q_2	$\bar{Q}_3$	
3	Q_1	Q_2	$\bar{Q}_3$	
4	$\bar{Q}_1$	$\bar{Q}_2$	Q_3	
5	Q_1	$\bar{Q}_2$	Q_3	
6	$\bar{Q}_1$	Q_2	Q_3	
7	Q_1	Q_2	Q_3	
8	$\bar{Q}_1$			Q_4
9	Q_1			Q_4

MC839F, MC839P, MC939F
Divide-by-Sixteen Counter

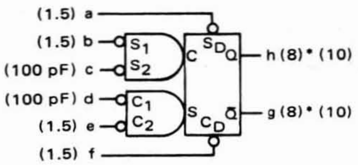

(1.5) (8)
3 S_{D1} 4 Q_1
(1.5) (8)
12 S_{D2} 11 Q_2
(1.5) (8)
10 S_{D3} 9 Q_3
(1.5) (8)
5 S_{D4} 6 Q_4
(1) CP 1
(5) C_D 2
S_1
S_2
C_1
C_2
S S_D Q
C C_D $\bar{Q}$

DECODING LOGIC

0	$\bar{Q}_1$	$\bar{Q}_2$	$\bar{Q}_3$	$\bar{Q}_4$
1	Q_1	$\bar{Q}_2$	$\bar{Q}_3$	$\bar{Q}_4$
2	$\bar{Q}_1$	Q_2	$\bar{Q}_3$	$\bar{Q}_4$
3	Q_1	Q_2	$\bar{Q}_3$	$\bar{Q}_4$
4	$\bar{Q}_1$	$\bar{Q}_2$	Q_3	$\bar{Q}_4$
5	Q_1	$\bar{Q}_2$	Q_3	$\bar{Q}_4$
6	$\bar{Q}_1$	Q_2	Q_3	$\bar{Q}_4$
7	Q_1	Q_2	Q_3	$\bar{Q}_4$
8	$\bar{Q}_1$	$\bar{Q}_2$	$\bar{Q}_3$	Q_4
9	Q_1	$\bar{Q}_2$	$\bar{Q}_3$	Q_4
10	$\bar{Q}_1$	Q_2	$\bar{Q}_3$	Q_4
11	Q_1	Q_2	$\bar{Q}_3$	Q_4
12	$\bar{Q}_1$	$\bar{Q}_2$	Q_3	Q_4
13	Q_1	$\bar{Q}_2$	Q_3	Q_4
14	$\bar{Q}_1$	Q_2	Q_3	Q_4
15	Q_1	Q_2	Q_3	Q_4

PULSE TRIGGERED BINARY

MC850F, MC850G, MC850P
MC950F, MC950G
Pulse Triggered Binary


(1.5) a
(1.5) b
(100 pF) c
(100 pF) d
(1.5) e
(1.5) f
S_1
S_2
C_1
C_2
C S_D Q
S C_D $\bar{Q}$
h (8)* (10)
g (8)* (10)

*Applies to MC950F, MC950G

"F" and "P" Packages: V_{CC} = pin 14, GND = pin 7
"G" Package: V_{CC} = Pin 10, GND = Pin 6

SYNCHRONOUS TRUTH TABLE

t_n				t_{n+1}
S_1	S_2	C_1	C_2	Q
0	0	0	0	U
1	X	1	X	Q_n
X	1	X	1	Q_n
0	1	1	0	Q_n
0	0	X	1	1
0	0	1	X	1
1	X	0	0	0
X	1	0	0	0

ASYNCHRONOUS TRUTH TABLE

S_D	C_D	Q	$\bar{Q}$
1	1	NC	NC
0	1	1	0
1	0	0	1
0	0	1	1

SINGLE TRIGGER TRUTH TABLE
(Pins S_2 and C_1 tied together)

t_n		t_{n+1}
S_1	C_2	Q
0	0	U
1	0	0
0	1	1
1	1	Q_n

0 = low state (more negative) 1 = high state (more positive)

X = don't care U = indeterminate state NC = no change

PIN CONNECTIONS

Letter	a	b	c	d	e	f	g	h
"F" & "P" Pkgs.	13	4	5	6	10	1	11	3
"G" Pkg.	9	3	4	5	7	1	8	2

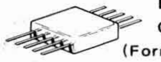
DTL INTEGRATED CIRCUITS DTL

MC200 series (−55 to +125°C)

MC250 series (0 to 75°C)

The DTL family of integrated logic circuits is characterized by moderate speed and low power dissipation.

G SUFFIX
CASE 602A
(Formerly Case 71A)



F SUFFIX
CASE 606
(Formerly Case 72)
TO-91

FUNCTIONS AND CHARACTERISTICS (V+ = 4 V, V− = −2 V, T_A = 25°C)

	TYPE ①		FAN-OUT		Propagation Delay		
FUNCTION	−55 to +125°C	0 to +75°C	MC200 SERIES	MC250 SERIES	t_{pd} ns typ	Power Dissipation mW typ	CASE
4-Input Gate NAND/NOR	MC201	MC251	5	4	30	6	602A, 606
3-Input Gate NAND/NOR	MC202	MC252	5	4	30	6	602A, 606
3-Input Power Gate NAND/NOR	MC204	MC254	20	12	40	30	602A, 606
Line Driver	MC205	MC255	20	12	55	50	602A, 606
Dual 2-Input Gate NAND/NOR	MC206	MC256	5	4	30	12	602A, 606
Dual 3-2 Input Gate NAND/NOR	MC207	MC257	5	4	30	12	602A, 606
Dual 3-2 Input Gate NAND/NOR	MC208	MC258	4	3	30	30	602A, 606
Clocked R-S Flip-Flop	MC209	MC259	8	6	60	16	602A, 606
Clocked R-S Flip-Flop (Pulse Triggered Binary)	MC210	MC260	8	6	60	16	602A, 606
Dual 3-Input Gate NAND/NOR	MC212	MC262	5	4	30	12	602A, 606
Dual 3-Input Gate NAND/NOR	MC213	MC263	4	3	30	30	602A, 606
			V_R (Volts)		t_{rr} (ns)		
6-Input Gate AND (Expander)	MC203	MC253	8	8	4	—	602A, 606
Dual 3-Input Gate AND (Expander)	MC215	MC265	8	8	4	—	602A, 606
Dual 3-Input Diode Array	MC217	MC267	8	8	4	—	602A, 606

① G suffix denotes Metal Can, F suffix denotes Flat Package. (i.e., MC201G = Metal Can, MC201F = Flat Package.)

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Input Voltage	V_{in}	8	Vdc
Power Supply Voltage	V_{CC}	8	Vdc
Input Forward Current	I_F	30	mAdc
Operating Temperature — MC200 Series MC250 Series	T_A	−55 to +125 0 to +75	°C
Storage Temperature	T_{stg}	−65 to +175	°C

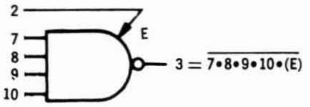
Note: Ratings apply to most devices, refer to applicable data sheet for specific information.

DTL LOGIC DIAGRAMS

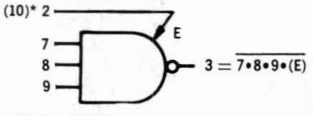
Numbers at ends of terminals represent pin numbers. Inputs have a fan-in of 1 unless otherwise noted. For fan-out capability, see Functions and Characteristics table. (V+ = pin 6, V− = pin 5 unless otherwise noted. Gnd = 1.)

GATES

MC201, MC251
4-Input Gate NAND/NOR

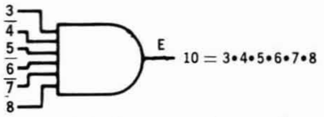

2
7
8
9
10
E
$3 = \overline{7\cdot8\cdot9\cdot10\cdot(E)}$

MC202, MC252
MC204, MC254
3-Input Gate NAND/NOR


(10)* 2
7
8
9
E
$3 = \overline{7\cdot8\cdot9\cdot(E)}$

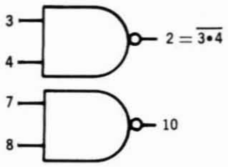
*MC204, MC254
Fan-in = 2 for MC204, MC254

MC203, MC253
6-Input Gate AND
(Expander)

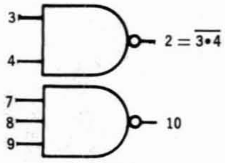

3
4
5
6
7
8
E
$10 = 3\cdot4\cdot5\cdot6\cdot7\cdot8$

Note: No power supply connection.

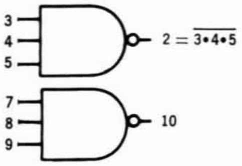
MC206, MC256
Dual 2-Input Gate NAND/NOR


3
4
$2 = \overline{3\cdot4}$
7
8
10

MC207, MC257
MC208, MC258
Dual 3-2 Input Gate NAND/NOR

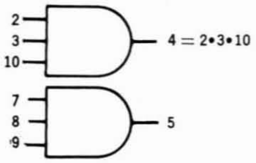

3
4
$2 = \overline{3\cdot4}$
7
8
9
10

MC212, MC262
MC213, MC263
Dual 3-Input Gate NAND/NOR


3
4
5
$2 = \overline{3\cdot4\cdot5}$
7
8
9
10

Note: No V− connection.

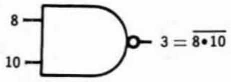
MC215, MC265
Dual 3-Input Gate AND
(Expander)


2
3
10
$4 = 2\cdot3\cdot10$
7
8
9
5

Note: No power supply connection.

DRIVERS

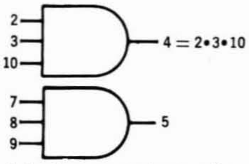
MC205, MC255
Line Driver


8
10
$3 = \overline{8\cdot10}$

Fan-in = 2

DIODE ARRAYS

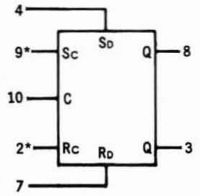
MC217, MC267
Dual Diode Array


2
3
10
$4 = 2\cdot3\cdot10$
7
8
9
5

Note: No power supply connection.

FLIP-FLOPS

MC209, MC259
Clocked R-S Flip-Flop


4
9*
10
2*
7
Sc
SD
Q
8
C
Rc
RD
Q
3

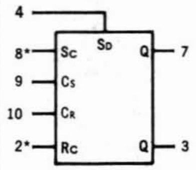
CLOCKED SET-RESET		
Sc	Rc	Q
0	0	?
0	1	1
1	0	0
1	1	No Change

DIRECT SET-RESET		
SD	RD	Q
0	0	‡
0	1	1
1	0	0
1	1	No Change

*Fan-In = 0.75 for MC209, 1 for MC259

‡Both Q and $\overline{Q}$ in 1 state until either SD or CD rises.

MC210, MC260 Clocked R-S Flip-Flop (Pulse Triggered Binary)


4
8*
9
10
2*
Sc
SD
Cs
CR
Rc
Q
7
Q
3

Sc	Cs	CR	Rc	Q	$\overline{Q}$
1	X	1	X	NC	NC
X	1	X	1	NC	NC
1	X	X	1	NC	NC
0	0	X	1	1	0
0	0	1	X	1	0
1	X	0	0	0	1
X	1	0	0	0	1
0	0	0	0	U	U

*Fan-in = 0.7

Low level on SD overrides other inputs and results in high level on Q.
0 on pins Cs or CR means transition to low level.
X = don't care.
NC = no change.
U = indeterminate state.

MRTL

MEDIUM POWER INTEGRATED CIRCUITS

MRTL

MC700 series (+15 to +55°C)
MC800 series (0 to +75 and 0 to +100°C)
MC900 series (–55 to +125°C)

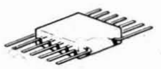
The MRTL family of resistor-transistor logic offers the industry's broadest line of digital circuits. Devices in this section are medium-power circuits; low-power mW MRTL circuits are also available. The medium-power MC700-Series devices have loading factors normalized for compatibility with the low-power (mW MRTL) devices for ease in mixing the two power levels in a system. Exceptional economy is provided by the UNIBLOC dual in-line plastic package.

G SUFFIX
CASE 601
(Formerly Case 96)
TO-99

G SUFFIX
CASE 603
(Formerly Case 96A)
TO-100

P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116

F SUFFIX
CASE 606
(Formerly Case 72)
TO-91



F SUFFIX
CASE 607
(Formerly Case 83)
TO-86

FUNCTIONS AND CHARACTERISTICS

(V_{CC} = 3.0 V ±10% for MC900 Series and MC800F,G Series; 3.6 V ±10% for MC800P Series and MC700 Series, T_A = 25°C)

Function	Type ① MC700 Series +15 to +55°C	Case	Type ① MC800 Series 0 to +75°C	Case	Type ① MC800 Series 0 to +100°C	Case	Type ① MC900 Series –55 to +125°C	Case	Fan-Out Each Output with mW MRTL	Fan-Out Each Output with MRTL	Propagation Delay t_{pd} ns typ	Total Power Dissipation mW typ MC700 Series & MC800P Series	Total Power Dissipation mW typ MC800F,G Series & MC900 Series
Buffer	MC700	601,606			MC800	601,606	MC900	601,606	80	25	20	25/50 ②	16/45 ②
Counter Adapter	MC701	601			MC801	601	MC901	601	16	5	22	80	55
R-S Flip-Flop	MC702	601			MC802	601	MC902	601	13	4	14	32	22
3-Input NOR Gate	MC703	601,606			MC803	601,606	MC903	601,606	16	5	12	28/7.5 ②	19/5.0 ②
Half Adder	MC704	601,606			MC804	601,606	MC904	601,606	16	5	14	65	45
Half-Shift Register	MC705	601,606			MC805	601,606	MC905	601,606	13	4	22	75	53
Half-Shift Register (w/o inverter)	MC706	↓			MC806	↓	MC906	↓	13	4	22	52	36
4-Input NOR Gate	MC707	↓			MC807	↓	MC907	↓	16	5	12	30/7.5 ②	19/5.0 ②
Dual 2-Input NOR Gate	MC714	↓			MC814	↓	MC914	↓	16	5	12	50/15 ②	38/10 ②
Dual 3-Input NOR Gate	MC715	603,605,606	MC815	605	MC815	603,606	MC915	603,606	16	5	12	55/15 ②	38/10 ②
J-K Flip-Flop			MC816	605	MC816	601,606	MC916	601,606	–	3	35	91/79 ③	62/54 ③
J-K Flip-Flop	MC723	601,605,606							10	–	35	91/79 ③	–
Quad 2-Input NOR Gate	MC724	605,607	MC824	605	MC824	607	MC924	607	16	5	12	100/30 ②	76/20 ②
Dual 4-Input NOR Gate	MC725	605,607	MC825	↓	MC825	607	MC925	607	16	5	12	60/15 ②	38/10 ②
J-K Flip-Flop	MC726	603,605,606	MC826	↓	MC826	603,606	MC926	603,606	16	5	35	100/86 ③	130/65 ③
Quad Inverter	MC727	603,606			MC827	603,606	MC927	603,606	16	5	12	87/30 ②	76/20 ②
5-Input NOR Gate	MC729	601,606			MC829	601,606	MC929	601,606	16	5	12	33/7.5 ②	19/5.0 ②
Quad Exclusive OR Gate	MC771	605,607	MC871	605	MC871	607	MC971	607	16	5	12	87	72
J-K Flip-Flop	MC774	601			MC874	601	MC974	601	16	5	35	100/86 ③	130/65 ③
Dual Half-Adder	MC775	605,607	MC875	605	MC875	607	MC975	607	16	5	20	120	90
1 J-K Flip-Flop, 1 Expander, 2 Buffers	MC779	605	MC879	605					–	–	–	166/169④	–
Dual Half-Shift Register	MC783	605,607	MC883	↓	MC883	607	MC983	607	13	4	22	140	110
Dual Half-Shift Register (w/inverter)	MC784	↓	MC884	↓	MC884	↓	MC984	↓	13	4	22	100	75
Quad 2-Input Expander	MC785	↓	MC885	↓	MC885	↓	MC985	↓	–	–	12	20/– ②	17/– ②
Dual 4-Input Expander	MC786	↓	MC886	↓	MC886	↓	MC986	↓	–	–	12	20/– ②	17/– ②
1 J-K Flip-Flop, 1 Inverter, 2 Buffers	MC787	605	MC887	605					–	–	–	163 /177④	–
Dual 3-Input Buffer, non inverting	MC788	605,607	MC888	↓	MC888	607	MC988	607	80	25	24	145/56 ②	128/42 ②
Hex Inverter	MC789	↓	MC889	↓	MC889	↓	MC989	↓	16	5	12	130/15 ②	76/20 ②
Dual J-K Flip-Flop	MC790	↓	MC890	↓	MC890	↓	MC990	↓	10	3	35	182/158③	124/108③
Dual J-K Flip-Flop	MC791	↓	MC891	↓	MC891	↓	MC991	↓	16	5	40	190/160③	155/130③
Triple 3-Input NOR Gate	MC792	605,607	MC892	605	MC892	607	MC992	607	16	5	12	82/24 ②	57/15 ②
Dual Full Adder	MC796	↓	MC896	↓	MC896	↓	MC996	↓	13	4	60	84	70
Dual Full Subtractor	MC797	↓	MC897	↓	MC897	↓	MC997	↓	13	4	60	84	70
Dual Buffer	MC799	603,605,606	MC899	↓	MC899	603,606	MC999	603,606	80	25	20	50/100 ②	32/90 ②
Hex Expander	MC9719	605,607	MC9819	↓	MC9819	607	MC9919	607	–	–	12	13/– ②	13/– ②

① G Suffix denotes Metal Can, F suffix denotes Flat Package, P suffix denotes Plastic Package. (i.e., MC715G = Metal Can, MC715F = Flat Package, MC715P = Plastic Package.)
② Inputs High/Inputs Low
③ Only Clock Inputs High/Inputs Low
④ Only Clock Input high on flip-flop, other element Inputs High/Inputs Low

MAXIMUM RATINGS (T_A = 25°C)

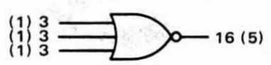
Rating	Symbol	Value	Unit
Input Voltage	–	±4	Vdc
Power Supply Voltage (Pulsed ≤1 second)	–	+12	Vdc
Operating Temperature Range	T_A		°C
MC900 Series		–55 to +125	
MC800F,G Series		0 to +100	
MC800P Series		0 to +75	
MC700 Series		+15 to +55	
Storage Temperature Range	T_{stg}		°C
Metal Can, Flat Package		–65 to +150	
Plastic Package		–55 to +125	

MRTL LOGIC DIAGRAMS

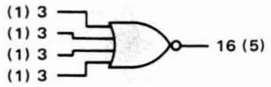
Number at end of terminal indicates loading for MC700 Series. Number in parenthesis indicates loading for MC800 Series and MC900 Series. Pin numbers vary with package type; see data sheet for details.

GATES

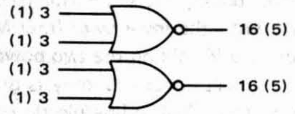
MC703, MC803, MC903
3-Input NOR Gate



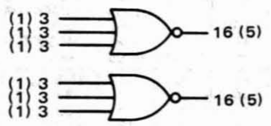
MC707, MC807, MC907
4-Input NOR Gate


(1) 3
(1) 3
(1) 3
(1) 3
16 (5)

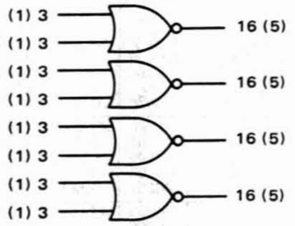
MC714, MC814, MC914
Dual 2-Input NOR Gate


(1) 3
(1) 3
16 (5)
(1) 3
(1) 3
16 (5)

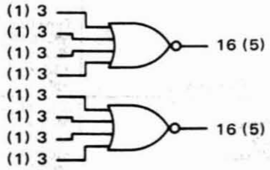
MC715, MC815, MC915
Dual 3-Input NOR Gate


(1) 3
(1) 3
(1) 3
16 (5)
(1) 3
(1) 3
(1) 3
16 (5)

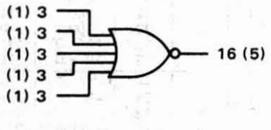
MC724, MC824, MC924
Quad 2-Input NOR Gate


(1) 3
(1) 3
16 (5)
(1) 3
(1) 3
16 (5)
(1) 3
(1) 3
16 (5)
(1) 3
(1) 3
16 (5)

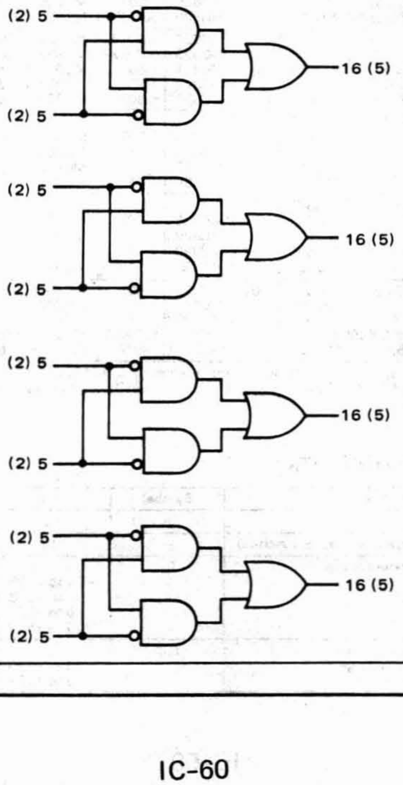
MC725, MC825, MC925
Dual 4-Input NOR Gate


(1) 3
(1) 3
(1) 3
(1) 3
16 (5)
(1) 3
(1) 3
(1) 3
(1) 3
16 (5)

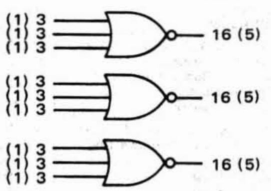
MC729, MC829, MC929
5-Input NOR Gate


(1) 3
(1) 3
(1) 3
(1) 3
(1) 3
16 (5)

MC771, MC871, MC971
Quad Exclusive OR Gate

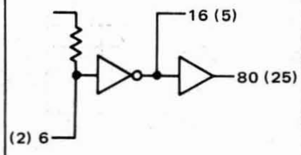

(2) 5
(2) 5
16 (5)
(2) 5
(2) 5
16 (5)
(2) 5
(2) 5
16 (5)
(2) 5
(2) 5
16 (5)

MC792, MC892, MC992
Triple 3-Input NOR Gate

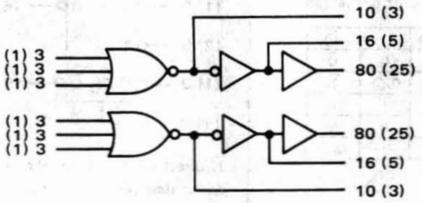

(1) 3
(1) 3
(1) 3
16 (5)
(1) 3
(1) 3
(1) 3
16 (5)
(1) 3
(1) 3
(1) 3
16 (5)

BUFFERS

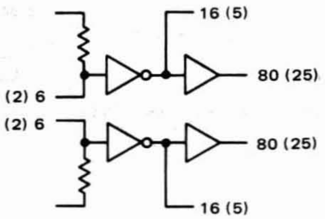
MC700, MC800, MC900
Buffer



MC788, MC888, MC988
Dual 3-Input Buffer

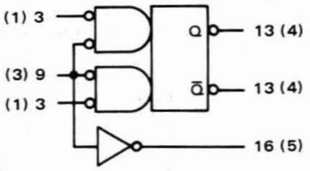

(1) 3
(1) 3
(1) 3
10 (3)
16 (5)
80 (25)
(1) 3
(1) 3
(1) 3
80 (25)
16 (5)
10 (3)

MC799, MC899, MC999
Dual Buffer

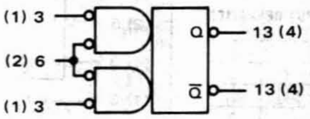

16 (5)
(2) 6
80 (25)
(2) 6
80 (25)
16 (5)

HALF-SHIFT REGISTERS

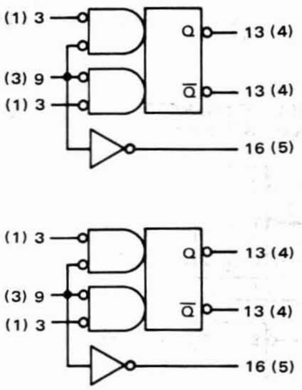
MC705, MC805, MC905
Half-Shift Register


(1) 3
Q
13 (4)
(3) 9
Q̄
13 (4)
(1) 3
16 (5)

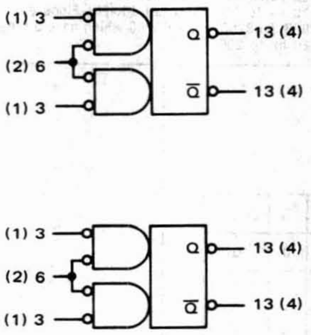
MC706, MC806, MC906
Half-Shift Register
(without inverter)


(1) 3
Q
13 (4)
(2) 6
Q̄
13 (4)
(1) 3

MC783, MC883, MC983
Dual Half-Shift Register

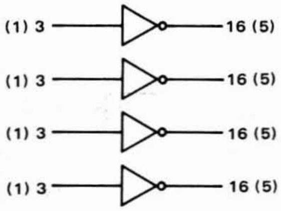

(1) 3
Q
13 (4)
(3) 9
Q̄
13 (4)
(1) 3
16 (5)
(1) 3
Q
13 (4)
(3) 9
Q̄
13 (4)
(1) 3
16 (5)

MC784, MC884, MC984
Dual Half-Shift Register
(without inverter)

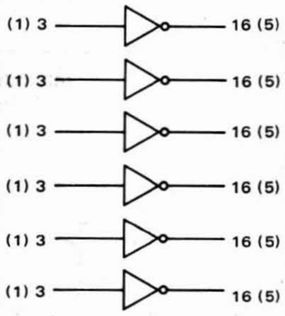

(1) 3
Q
13 (4)
(2) 6
Q̄
13 (4)
(1) 3
(1) 3
Q
13 (4)
(2) 6
Q̄
13 (4)
(1) 3

INVERTERS

MC727, MC827, MC927
Quad Inverter


(1) 3
16 (5)
(1) 3
16 (5)
(1) 3
16 (5)
(1) 3
16 (5)

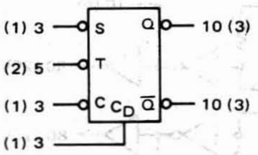
MC789, MC889, MC989
Hex Inverter


(1) 3
16 (5)
(1) 3
16 (5)
(1) 3
16 (5)
(1) 3
16 (5)
(1) 3
16 (5)
(1) 3
16 (5)

MRTL LOGIC DIAGRAMS

FLIP-FLOPS

MC723, MC816, MC916
J-K Flip-Flop

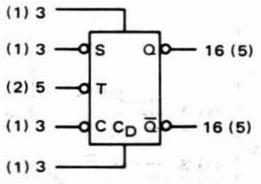

(1) 3
(2) 5
(1) 3
(1) 3
S
T
C
C_D
Q
$\overline{Q}$
10 (3)
10 (3)

CLOCKED INPUT OPERATION①

t_n②		t_{n+1}②	
S	C	Q	$\overline{Q}$
1	1	Q_n③	$\overline{Q}_n$
1	0	1	0
0	1	0	1
0	0	$\overline{Q}_n$	Q_n③

1. Direct input (C_D) must be low.
2. The time period prior to the negative transition of the clock pulse is denoted t_n and the time period subsequent to this transition is denoted t_{n+1}.
3. Q_n is the state of the Q output in the time period t_n.

MC726, MC826, MC926
J-K Flip-Flop


(1) 3
(1) 3
(2) 5
(1) 3
(1) 3
S
T
C
C_D
Q
$\overline{Q}$
16 (5)
16 (5)

CLOCKED INPUT OPERATION ①

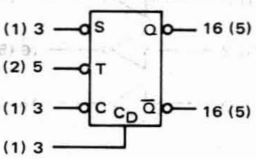
t_n②		t_{n+1}②	
S	C	Q	$\overline{Q}$
1	1	Q_n③	$\overline{Q}_n$
1	0	1	0
0	1	0	1
0	0	$\overline{Q}_n$	Q_n③

DIRECT INPUT OPERATION ①

S_D	C_D	Q	$\overline{Q}$
0	0	⑤	⑤
1	0	1	0
0	1	0	1
1	1	0	0

1. Direct inputs (C_D and S_D) must be low.
2. The time period prior to the negative transition of the clock pulse is denoted t_n and the time period subsequent to this transition is denoted t_{n+1}.
3. Q_n is the state of the Q output in the time period t_n.
4. Clock (T) to remain unchanged.
5. The output state will not change when the input state goes from $S_D = \overline{C}_D$ to $S_D = C_D = 0$. The output state cannot be predetermined in the case where the input goes from $S_D = C_D = 1$ to $S_D = C_D = 0$.

MC774, MC874, MC974
J-K Flip-Flop

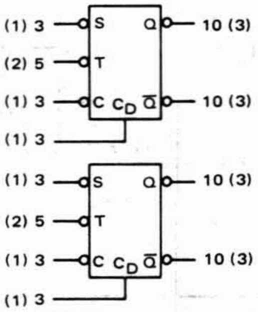

(1) 3
(2) 5
(1) 3
(1) 3
S
T
C
C_D
Q
$\overline{Q}$
16 (5)
16 (5)

CLOCKED INPUT OPERATION①

t_n②		t_{n+1}②	
S	C	Q	$\overline{Q}$
1	1	Q_n③	$\overline{Q}_n$
1	0	1	0
0	1	0	1
0	0	$\overline{Q}_n$	Q_n③

1. Direct input (C_D) must be low.
2. The time period prior to the negative transition of the clock pulse is denoted t_n and the time period subsequent to this transition is denoted t_{n+1}.
3. Q_n is the state of the Q output in the time period t_n.

MC790, MC890, MC990
Dual J-K Flip-Flop


(1) 3
(2) 5
(1) 3
(1) 3
(1) 3
(2) 5
(1) 3
(1) 3
S
T
C
C_D
Q
$\overline{Q}$
10 (3)
10 (3)
S
T
C
C_D
Q
$\overline{Q}$
10 (3)
10 (3)

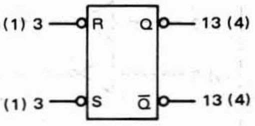
CLOCKED INPUT OPERATION①

t_n②		t_{n+1}②	
S	C	Q	$\overline{Q}$
1	1	Q_n③	$\overline{Q}_n$
1	0	1	0
0	1	0	1
0	0	$\overline{Q}_n$	Q_n③

1. Direct input (C_D) must be low.
2. The time period prior to the negative transition of the clock pulse is denoted t_n and the time period subsequent to this transition is denoted t_{n+1}.
3. Q_n is the state of the Q output in the time period t_n.

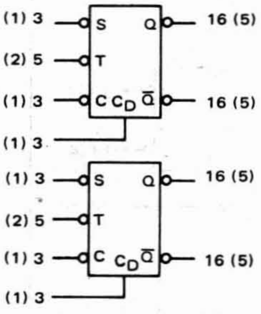
NOTE:
Clock pulse fall time must be within the range of 10 ns to 100 ns on all J-K Flip-Flops except MC926, MC826F, and MC826G which have a range of 10 ns to 200 ns.

MC702, MC802, MC902
R-S Flip-Flop


(1) 3
(1) 3
R
S
Q
$\overline{Q}$
13 (4)
13 (4)

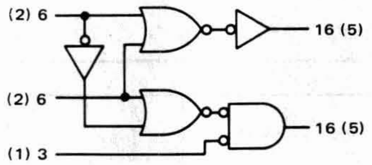
R	S	Q_{n+1}
0	0	Q_n
0	1	1
1	0	0
1	1	0

MC791, MC891, MC991
Dual J-K Flip-Flop


(1) 3
(2) 5
(1) 3
(1) 3
(1) 3
(2) 5
(1) 3
(1) 3
S
T
C
C_D
Q
$\overline{Q}$
16 (5)
16 (5)
S
T
C
C_D
Q
$\overline{Q}$
16 (5)
16 (5)

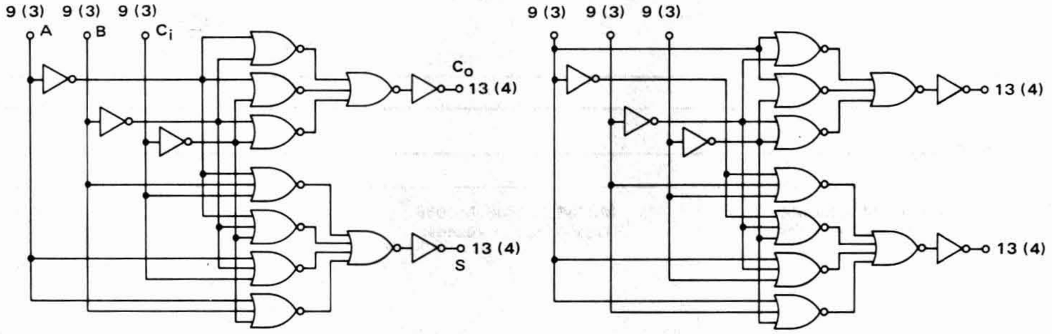
COUNTER ADAPTER

MC701, MC801, MC901
Counter Adapter


(2) 6
(2) 6
(1) 3
16 (5)
16 (5)

FULL ADDER

MC796, MC896, MC996
Dual Full Adder


9 (3)
9 (3)
9 (3)
A
B
C_i
C_o
13 (4)
13 (4)
S
9 (3)
9 (3)
9 (3)
13 (4)
13 (4)

TRUTH TABLE

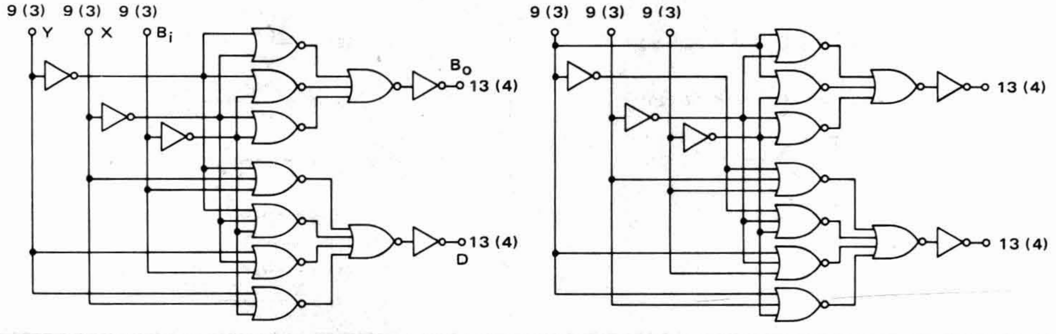
Input Logic Level			Output Logic Level	
A	B	C_i	S	C_o
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

FULL SUBTRACTOR

MC797, MC897, MC997
Dual Full Subtractor

TRUTH TABLE

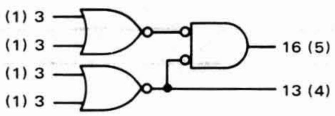
Input Logic Level			Output Logic Level	
X	Y	B_i	D	B_o
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1


9 (3)
9 (3)
9 (3)
Y
X
B_i
B_o
13 (4)
13 (4)
D
9 (3)
9 (3)
9 (3)
13 (4)
13 (4)

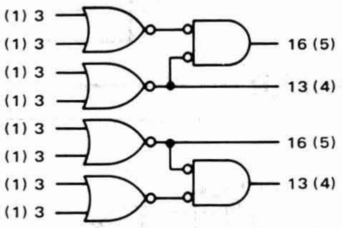
MRTL LOGIC DIAGRAMS

HALF ADDERS

MC704, MC804, MC904
Half Adder

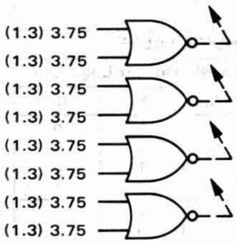

(1) 3
(1) 3
(1) 3
(1) 3
16 (5)
13 (4)

MC775, MC875, MC975
Dual Half Adder

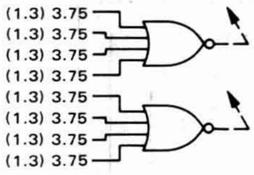

(1) 3
(1) 3
(1) 3
(1) 3
(1) 3
(1) 3
(1) 3
(1) 3
16 (5)
13 (4)
16 (5)
13 (4)

EXPANDERS

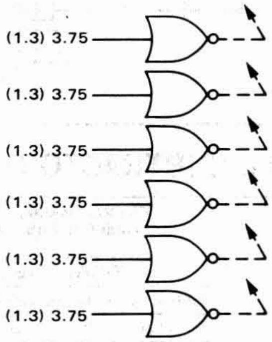
MC785, MC885, MC985
Quad 2-Input Expander


(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75

MC786, MC886, MC986
Dual 4-Input Expander

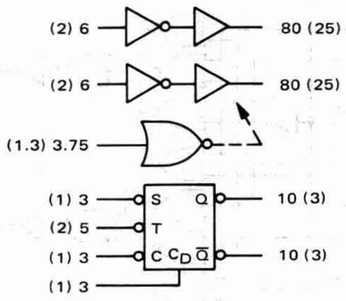

(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75

MC9719, MC9819, MC9919
Hex Expander

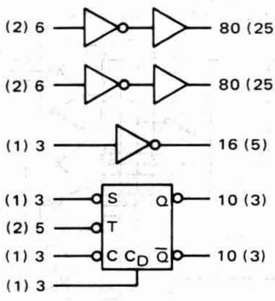

(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75
(1.3) 3.75

MULTIFUNCTION DEVICES

MC779, MC879
(1 J-K Flip-Flop, 1 Expander, 2 Buffers)


(2) 6
80 (25)
(2) 6
80 (25)
(1.3) 3.75
(1) 3
S
Q
10 (3)
(2) 5
T
(1) 3
C
C_D
$\overline{Q}$
10 (3)
(1) 3

MC787, MC887
(1 J-K Flip-Flop, 1 Inverter, 2 Buffers)


(2) 6
80 (25)
(2) 6
80 (25)
(1) 3
16 (5)
(1) 3
S
Q
10 (3)
(2) 5
T
(1) 3
C
C_D
$\overline{Q}$
10 (3)
(1) 3

mW MRTL

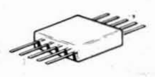
MC708 series (+15 to +55°C)
MC808 series (0 to +75°C)
MC908 series (−55 to +125°C)

The MRTL family of resistor-transistor logic offers the industry's broadest line of digital circuits. Devices in this section are low-power mW MRTL circuits; medium-power MRTL circuits are described separately. Added flexibility for system design is provided in the MC700 series of devices, some of which are listed in the medium-power MRTL section. The latter are specified with milliwatt-normalized loading factors to permit combining of medium and low-power devices. This facilitates the design of systems with optimum speed and power dissipation. Exceptional economy is provided by the UNIBLOC dual in-line plastic package.

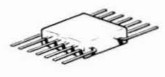
G SUFFIX
CASE 601
(Formerly Case 96)
TO-99

G SUFFIX
CASE 603
(Formerly Case 96A)
TO-100

P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116



F SUFFIX
CASE 606
(Formerly Case 72)
TO-91



F SUFFIX
CASE 607
(Formerly Case 83)
TO-86

FUNCTIONS AND CHARACTERISTICS

(V_{CC} = 3.0 V ±10% for MC908 Series, 3.6 V ±10% for MC808 Series and MC708 Series; T_A = 25°C)

Function	Type ① MC708 Series +15 to +55°C	Type ① MC808 Series 0 to +75°C	Case	Type ① MC908 Series −55 to +125°C	Case	Output Loading Factor Each Output All Series	Propagation Delay t_{pd} ns typ	Total Power Dissipation ② mW typ/pkg MC708 Series & MC808 Series	Total Power Dissipation ② mW typ/pkg MC908 Series
Half Adder	MC708	MC808	601,606	MC908	601,606	4	60	19/12.5	14/8.5
2-Input Buffer	MC709	MC809	↓	MC909	↓	30	57	7.0/23	5.5/16
Dual 2-Input NOR Gate	MC710	MC810	↓	MC910	↓	4	27	10/2.5	8.0/1.0
4-Input OR/NOR Gate	MC711	MC811	↓	MC911	↓	4	60	8.0/5.5	6.0/3.5
Half Adder	MC712	MC812	↓	MC912	↓	4	66	15.5/10.5	11.5/5.5
Type D Flip-Flop	MC713	MC813	601,606	MC913	601,606	3	75	24/17.5③	17.5/13 ③
Quad 2-Input NOR Gate	MC717	MC817	605,607	MC917	607	4	27	20/5.0	16/2.5
Dual 3-Input NOR Gate	MC718	MC818	603,605,606	MC918	603,606	4	27	12/2.5	9.5/1.0
Dual 4-Input NOR Gate	MC719	MC819	605,607	MC919	607	4	27	13/2.5	11/1.0
J-K Flip-Flop	MC720	MC820	601,606	MC920	601,606	2	50	20.5/14.5④	15.5/10 ④
Dual 2-Input Gate Expander	MC721	MC821	601,606	MC921	601,606	–	27	3.0/–	3.0/–
J-K Flip-Flop	MC722	MC822	603,605,606	MC922	603,606	4	70	24/20 ④	17.5/13 ④
5-Input NOR Gate	MC728	MC828	601,606	MC928	601,606	4	27	7.5/1.0	6.5/0.5
Dual J-K Flip-Flop	MC776	MC876	605,607	MC976	607	2	50	41/29 ④	31/20 ④
Dual Type D Flip-Flop	MC778	MC878	605,607	MC978	607	3	60	48/35 ③	35/26 ③
Dual Buffer	MC781	MC881	601	MC981	601	30	57	14/46	11/32
J-K Flip-Flop	MC782	MC882	601	MC982	601	2	80	23/21 ④	15/13 ④
Triple 3-Input NOR Gate	MC793	MC893	605,607	MC993	607	4	27	18/3.5	14/2.0
Dual 2-Input Buffer	MC798	MC898	↓	MC998	↓	30	57	14/46	11/32
Hex Inverter	MC9718	MC9818	↓	MC9918	↓	4	27	7.0/3.0	7.0/3.0
Hex Expander	MC9720	MC9820	605,607	MC9920	607	–	12	30/–	30/–
Quad 2-Input Expander	MC9721	MC9821	605,607	MC9921	607	–	27	20/–	20/–

① G suffix denotes Metal Can, F suffix denotes Flat Package, P suffix denotes Plastic Package.
(i.e., MC718G = Metal Can, MC718F = Flat Package, MC718P = Plastic Package.)

② Inputs High/Inputs Low unless otherwise noted.

③ Direct Set and Direct Clear Low, All other Inputs High/All Inputs Low.

④ Only Clock Input High/All Inputs Low

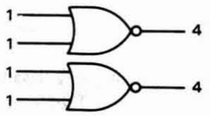
MAXIMUM RATINGS (T_A = 25°C)

Rating	Symbol	Value	Unit
Input Voltage	–	±4	Vdc
Power Supply Voltage (Pulsed ≦ 1 second)	–	+12	Vdc
Operating Temperature Range	T_A		°C
MC908 Series		−55 to +125	
MC808 Series		0 to +75	
MC708 Series		+15 to +55	
Storage Temperature Range	T_{stg}		°C
Metal Can, Flat Package		−65 to +150	
Plastic Package		−55 to +125	

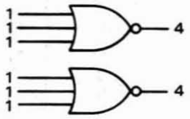
mW MRTL LOGIC DIAGRAMS

GATES

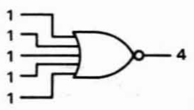
MC710, MC810, MC910
Dual 2-Input NOR Gate



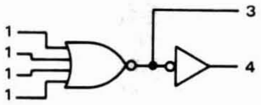
MC718, MC818, MC918
Dual 3-Input NOR Gate



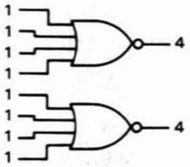
MC728, MC828, MC928
5-Input NOR Gate



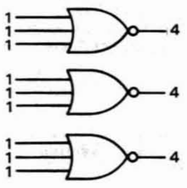
MC711, MC811, MC911
4-Input OR/NOR Gate



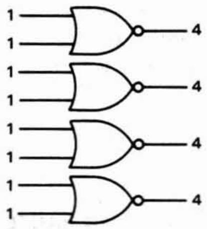
MC719, MC819, MC919
Dual 4-Input NOR Gate


1
1
1
1
1
1
1
1
4
4

MC793, MC893, MC993
Triple 3-Input NOR Gate

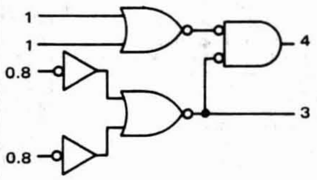

1
1
1
1
1
1
1
1
1
4
4
4

MC717, MC817, MC917
Quad 2-Input NOR Gate

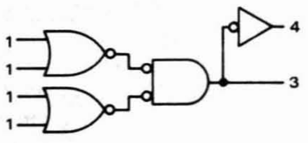

1
1
1
1
1
1
1
1
4
4
4
4

HALF ADDERS

MC708, MC808, MC908
Half Adder



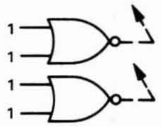
MC712, MC812, MC912
Half Adder



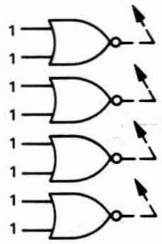
Numbers at end of terminals indicate loading.
Pin numbers vary with package type; see data sheet for details.

EXPANDERS

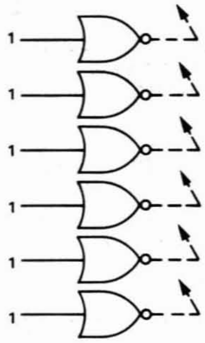
MC721, MC821, MC921
Dual 2-Input Expander



MC9721, MC9821, MC9921
Quad 2-Input Expander

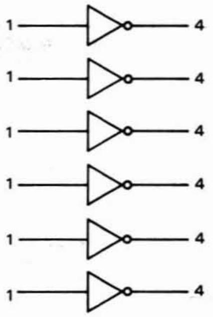


MC9720, MC9820, MC9920
Hex Expander



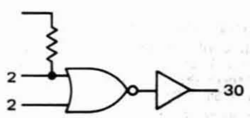
INVERTER

MC9718, MC9818, MC9918
Hex Inverter

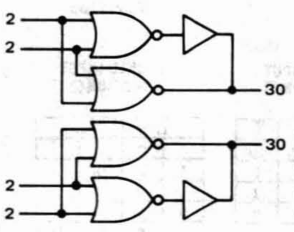

1
4
1
4
1
4
1
4
1
4
1
4

BUFFERS

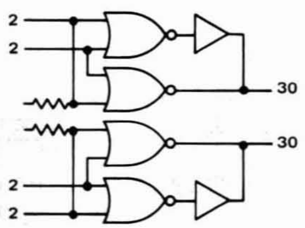
MC709, MC809, MC909
Buffer



MC781, MC881, MC981
Dual Buffers

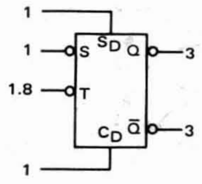


MC798, MC898, MC998
Dual Buffers



FLIP-FLOPS

MC713, MC813, MC913
Type D Flip-Flop



DIRECT INPUT OPERATION ①

S_D	C_D	Q	$\bar{Q}$
0	0	②	②
1	0	1	0
0	1	0	1
1	1	0	0

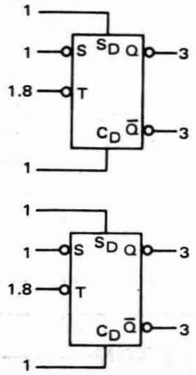
CLOCKED INPUT OPERATION ③

t_n	t_{n+1}	
S	Q	$\bar{Q}$
1	1	0
0	0	1

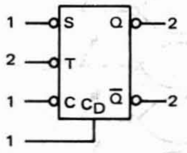
1. Clock (T input) must be high.
2. The output state will not change when the input state goes from $S_D = \bar{C}_D$ to $S_D = C_D = 0$. The output state cannot be predetermined in the case where the input goes from $S_D = C_D = 1$ to $S_D = C_D = 0$.
3. Direct inputs (S_D and C_D) must be low.

0 = low state
1 = high state
t_n = time period prior to negative transition of clock pulse
t_{n+1} = time period subsequent to negative transition of clock pulse

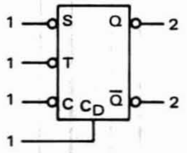
MC778, MC878, MC978
Dual Type D Flip-Flop



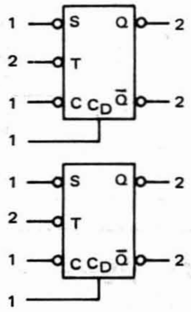
MC720, MC820, MC920
J-K Flip-Flop



MC782, MC882, MC982
J-K Flip-Flop



MC776, MC876, MC976
Dual J-K Flip-Flop



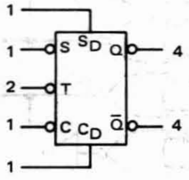
CLOCKED INPUT OPERATION

t_n		t_{n+1}	
S	C	Q	$\bar{Q}$
1	1	Q_n	$\bar{Q}_n$
1	0	1	0
0	1	0	1
0	0	$\bar{Q}_n$	Q_n

Direct input (C_D) must be low.
0 = low state
1 = high state
t_n = time period prior to negative transition of clock pulse.
t_{n+1} = time period subsequent to negative transition of clock pulse.
Q_n = state of Q output in time period t_n.

NOTE:
Clock pulse fall time must be within the range of 10 ns to 100 ns on all J-K Flip-Flops.

MC722, MC822, MC922
J-K Flip-Flop



DIRECT INPUT OPERATION ①

S_D	C_D	Q	$\bar{Q}$
0	0	②	②
1	0	1	0
0	1	0	1
1	1	0	0

CLOCKED INPUT OPERATION ③

t_n		t_{n+1}	
S	C	Q	$\bar{Q}$
1	1	Q_n	$\bar{Q}_n$
1	0	1	0
0	1	0	1
0	0	$\bar{Q}_n$	Q_n

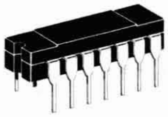
1. Clock (T) to remain unchanged.
2. The output state will not change when the input state goes from $S_D = \bar{C}_D$ to $S_D = C_D = 0$. The output state cannot be predetermined in the case where the input goes from $S_D = C_D = 1$ to $S_D = C_D = 0$.
3. Direct inputs (S_D and C_D) must be low.

0 = low state
1 = high state
t_n = time period prior to negative transition of clock pulse
t_{n+1} = time period subsequent to negative transition of clock pulse
Q_n = state of Q output in time period t_n

MC1124L

QUAD TYPE T FLIP-FLOP

The MC1124L is a MOS monolithic circuit consisting of four toggle-mode flip-flops with Q and $\overline{Q}$ outputs available. A push-pull buffer circuit on the Q line may be driven by a separate power supply, and requires no standby power when driving capacitive loads. It may be used in frequency synthesis applications such as organ circuits, digital dividers, counters, and similar applications.

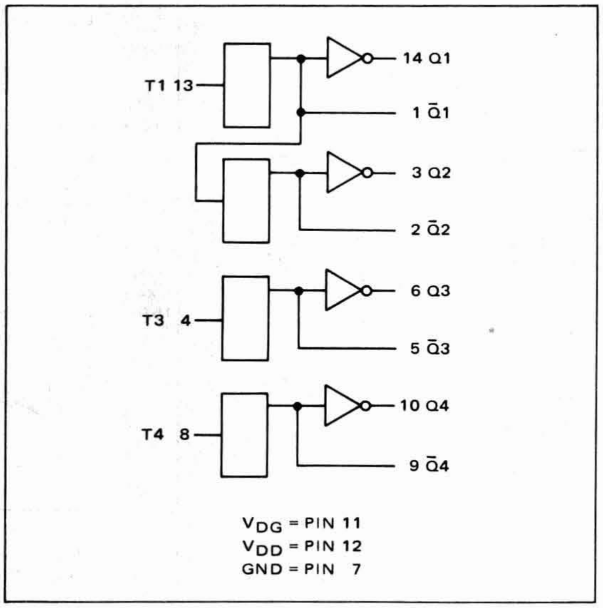


L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Binary Supply Voltage	V_{DG}	-40 to +0.3	Vdc
Buffer Supply Voltage	V_{DD}	-40 to +0.3	Vdc
Trigger Input Voltage	V_{in}	-30 to +0.3	Vdc
Operating Temperature Range	T_A	0 to +75	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

BLOCK DIAGRAM



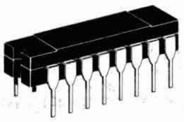
Features:

- DC to Greater than 1.0 MHz Operation
- Noise Immunity = 1.0 V or Greater
- Typical Power Dissipation = 25 mW/flip-flop
- Gate Protection on All Inputs

MC1150L

8-CHANNEL MULTIPLEX SWITCH

The MC1150L monolithic multiplex switch contains a one-of-eight decoder plus an output inhibit control. The circuit is constructed with P-channel enhancement mode MOS devices. It is designed for use in analog and digital applications such as A to D conversion and instrumentation signal routing.



L SUFFIX
CERAMIC PACKAGE
CASE 620

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Gate Supply Voltage *	V_{GG}	-35.0 to +0.3	Vdc
Drain Supply Voltage *	V_{DD}	-35.0 to +0.3	Vdc
Input Voltage *	V_{in}	-30.0 to +0.3	Vdc
Operating Temperature Range	T_A	0 to +75	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

* Referenced to V_{SS} (Pin 8).

Features:

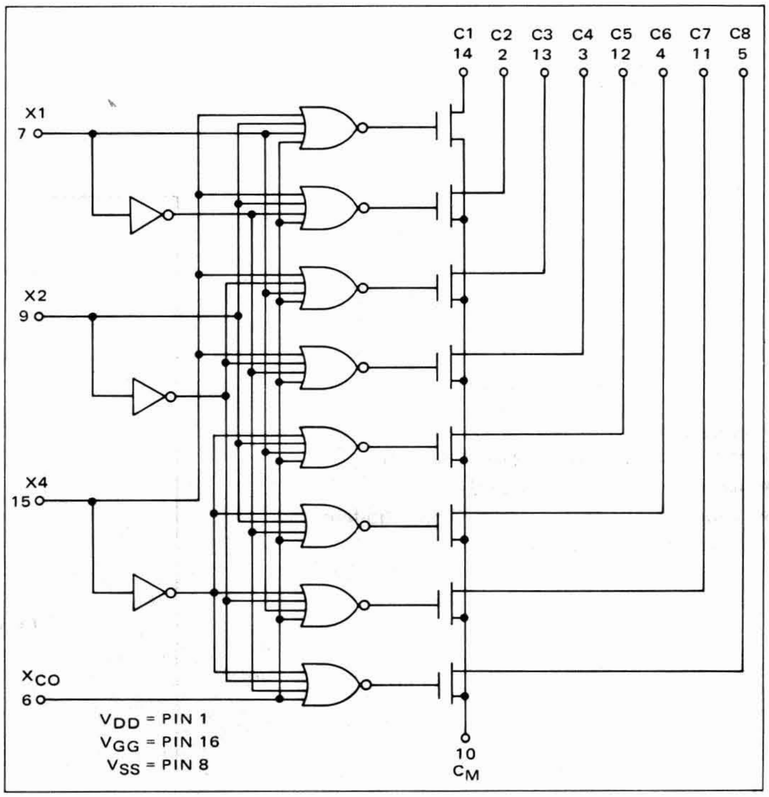
- High On/Off Resistance Ratio
- Zero Offset Voltage
- All Channel Blanking
- Diode Protection on All Inputs
- Low Leakage and Power Consumption

TRUTH TABLE**

DATA IN				CHANNEL "ON"
X1	X2	X4	X_{CO}	
–	–	–	1	OFF
0	0	0	0	C1
1	0	0	0	C2
0	1	0	0	C3
1	1	0	0	C4
0	0	1	0	C5
1	0	1	0	C6
0	1	1	0	C7
1	1	1	0	C8

** Using negative logic.

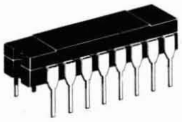
BLOCK DIAGRAM



MC1151L

2-OF-8 CHANNEL MULTIPLEX SWITCH

The MC1151L monolithic multiplex switch contains a single decoder selecting two of eight channel outputs, plus an output inhibit control. The circuit is constructed with P-channel enhancement mode MOS devices. It is designed for use in analog and digital applications such as A to D conversion and instrumentation signal routing.



L SUFFIX
CERAMIC PACKAGE
CASE 620

MAXIMUM RATINGS

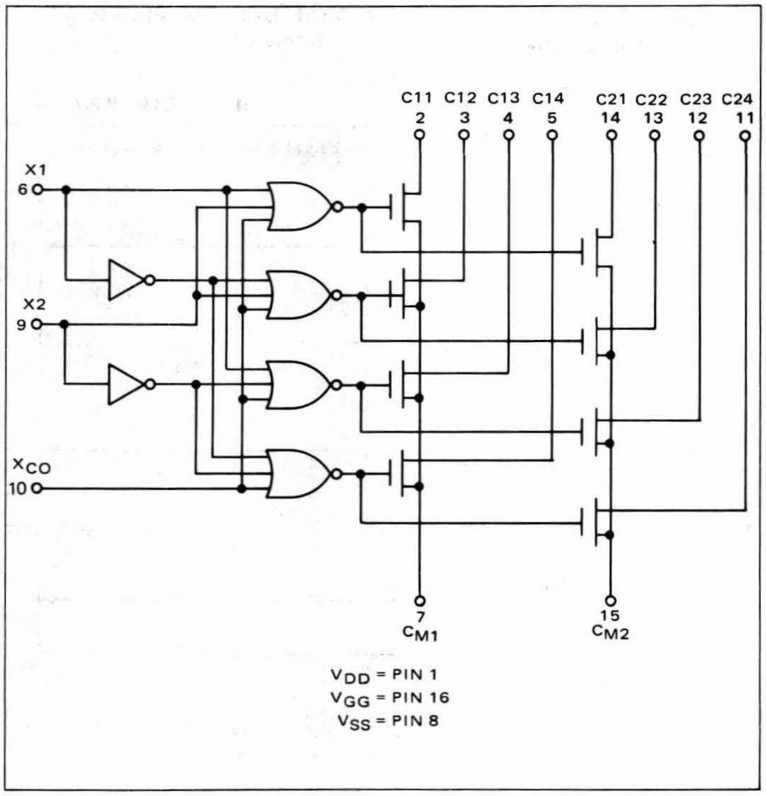
Rating	Symbol	Value	Unit
Gate Supply Voltage *	V_{GG}	-35.0 to +0.3	Vdc
Drain Supply Voltage *	V_{DD}	-35.0 to +0.3	Vdc
Input Voltage *	V_{in}	-30.0 to +0.3	Vdc
Operating Temperature Range	T_A	0 to +75	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

*Referenced to V_{SS} (Pin 8).

Features:

- High On/Off Resistance Ratio
- Zero Offset Voltage
- All Channel Blanking
- Diode Protection on All Inputs
- Low Leakage and Power Consumption

BLOCK DIAGRAM



TRUTH TABLE **

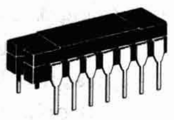
DATA IN			CHANNEL "ON"
X1	X2	X_{CO}	
–	–	1	OFF
0	0	0	C11, C21
1	0	0	C12, C22
0	1	0	C13, C23
1	1	0	C14, C24

**Using negative logic.

MC1170L

64-BIT RANDOM ACCESS MEMORY

The MC1170 MOS memory is constructed with P-channel enhancement mode devices in a single monolithic structure. It has been designed for use in systems with access time of 500 ns or less. The memory is organized as 16 words of 4 bits each. Input addressing is binary. This device lends itself to use in small buffer memories, and is easily interfaced with bipolar circuitry.



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

MAXIMUM RATINGS

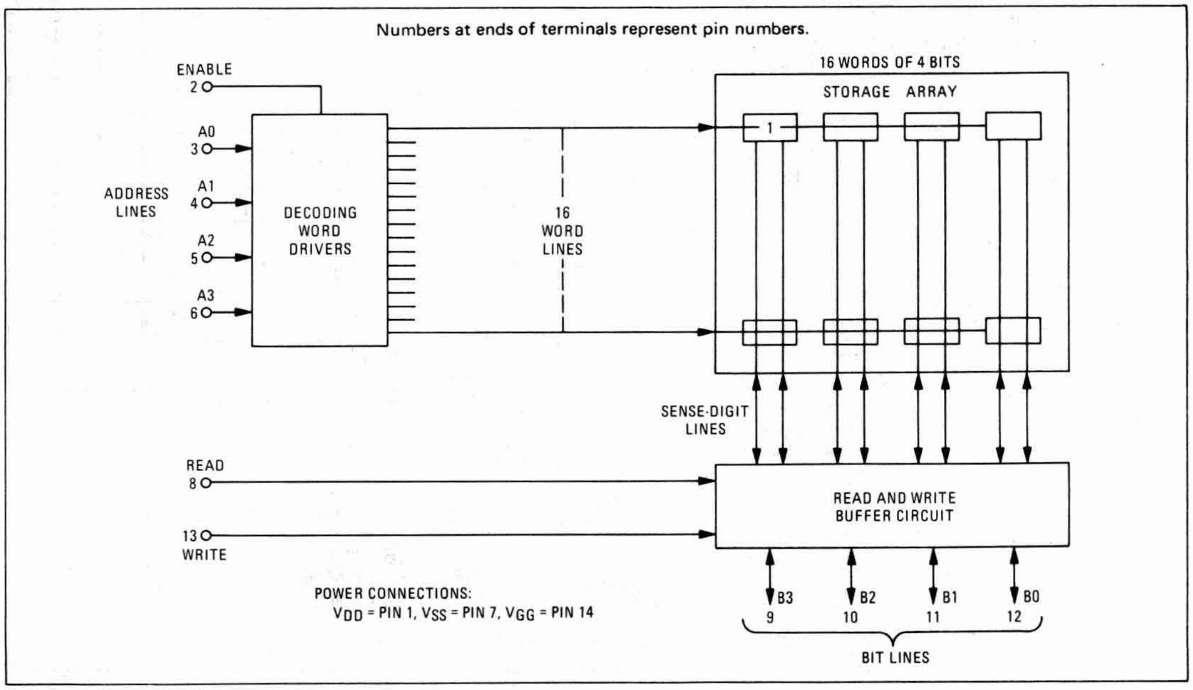
Rating	Symbol	Value	Unit
Gate Supply Voltage *	V_{GG}	-35.0 to +0.3	Vdc
Drain Supply Voltage *	V_{DD}	-35.0 to +0.3	Vdc
Input Voltage *	V_{in}	-30.0 to +0.3	Vdc
Operating Temperature Range	T_A	0 to +75	°C
Storage Temperature Range	T_{stg}	-65 to +150	°C

*Referenced to V_{SS} (Pin 7).

Features:

- Binary Addressing
- Enable Line for Address Expansion
- Single-Phase Clock
- Input Diode Protection
- Buffered Bit Lines
- Capable of dc Operation
- Wired "ORing" of Bit Lines to Expand Memory Size

BLOCK DIAGRAM



Numbers at ends of terminals represent pin numbers.

ENABLE
2
A0
3
ADDRESS LINES
A1
4
A2
5
A3
6
DECODING WORD DRIVERS
16 WORD LINES
16 WORDS OF 4 BITS
STORAGE ARRAY
1
SENSE-DIGIT LINES
READ
8
13
WRITE
READ AND WRITE BUFFER CIRCUIT
B3
9
B2
10
B1
11
B0
12
BIT LINES

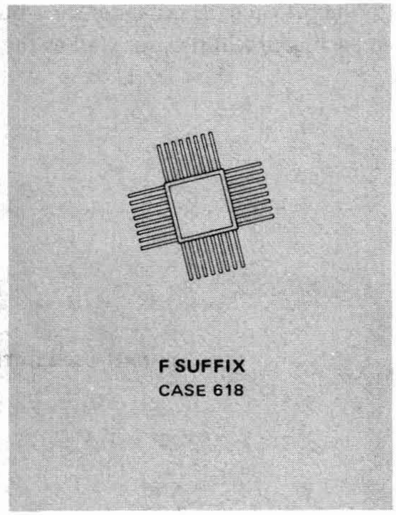
POWER CONNECTIONS:
V_{DD} = PIN 1, V_{SS} = PIN 7, V_{GG} = PIN 14

SPECIAL LOGIC PRODUCTS
for
CUSTOM · APPLICATIONS

XC157

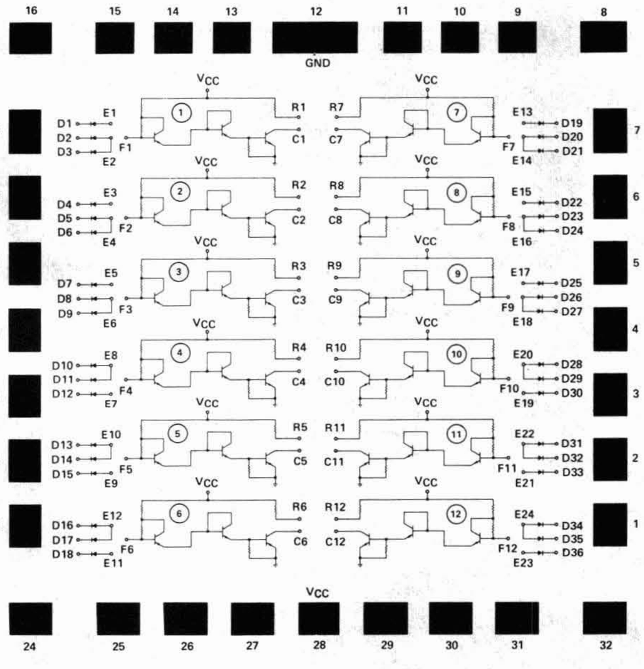
12-GATE ARRAY

with custom second layer of metalization



F SUFFIX
CASE 618

The XC157 is a monolithic 12-gate array developed to introduce a form of custom MSI. This array also serves as a vehicle for establishing customer-supplier interfaces which will ultimately lead toward more complex MSI and LSI systems. Each gate is intraconnected with a first layer of metalization but contains uncommitted input logic diodes and output load resistors for increased design flexibility. The diode and load resistor intraconnections and the subsequent gate-to-gate interconnections are made with your custom-designed second layer of metalization.


16
15
14
13
12
11
10
9
8
GND
VCC
17
18
19
20
21
22
23
7
6
5
4
3
2
1
D1
D2
D3
E1
E2
F1
R1
C1
R7
C7
E13
E14
F7
D19
D20
D21
D4
D5
D6
E3
E4
F2
R2
C2
R8
C8
E15
E16
F8
D22
D23
D24
D7
D8
D9
E5
E6
F3
R3
C3
R9
C9
E17
E18
F9
D25
D26
D27
D10
D11
D12
E8
E7
F4
R4
C4
R10
C10
E20
E19
F10
D28
D29
D30
D13
D14
D15
E10
E9
F5
R5
C5
R11
C11
E22
E21
F11
D31
D32
D33
D16
D17
D18
E12
E11
F6
R6
C6
R12
C12
E24
E23
F12
D34
D35
D36
①
②
③
④
⑤
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⑩
⑪
⑫
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32

CHIP SCHEMATIC

XC177

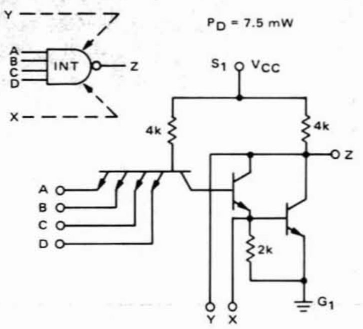
25-GATE ARRAY

with two custom layers of metalization

The XC177 is a monolithic 25-gate array that extends the logic capability of the customized metal approach for MSI-LSI. The gating intraconnections and the gate-to-gate interconnections of the compatible TTL-DTL gates are made by two custom layers of metalization. Each of the gates may be used as an internal gate, an external gate, a gate expander, or a buss output gate. This versatile set of gates allows you to choose the role that each gate will play, as well as the logic function design of the entire array.

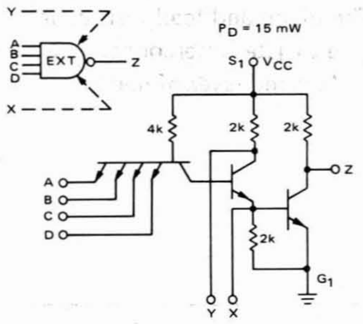
GATE FUNCTION OPTIONS

INTERNAL NAND GATE


Y
A
B
C
D
INT
Z
X
P_D = 7.5 mW
S1 Vcc
4k
4k
2k
Z
A
B
C
D
Y
X
G1

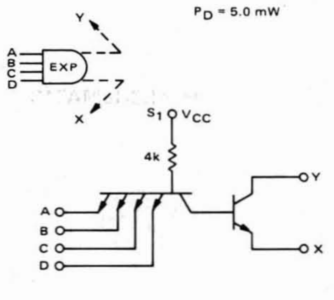
Use to perform logic within chip.

EXTERNAL NAND GATE


Y
A
B
C
D
EXT
Z
X
P_D = 15 mW
S1 Vcc
4k
2k
2k
Z
A
B
C
D
2k
G1
Y
X

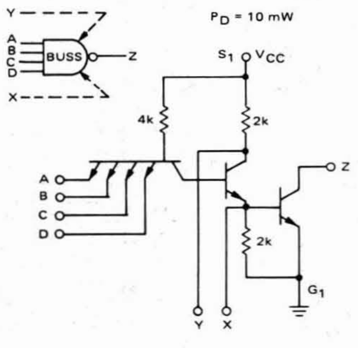
Use when interfacing with external circuitry for improved drive capability.

GATE EXPANDER


Y
A
B
C
D
EXP
X
P_D = 5.0 mW
S1 Vcc
4k
Y
A
B
C
D
X

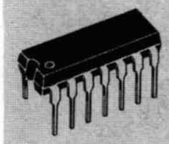
Use to perform the AND-OR-INVERT function.

BUSS OUTPUT NAND GATE

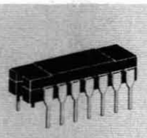

Y
A
B
C
D
BUSS
Z
X
P_D = 10 mW
S1 Vcc
4k
2k
Z
A
B
C
D
2k
G1
Y
X

Use to accomplish the Wired-OR function with minimum power dissipation.

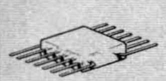
XC177 (continued)



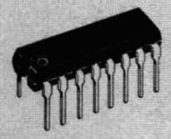
P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116



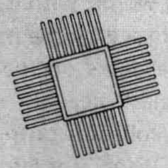
L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



F SUFFIX
CASE 607
(Formerly Case 83)
TO-86



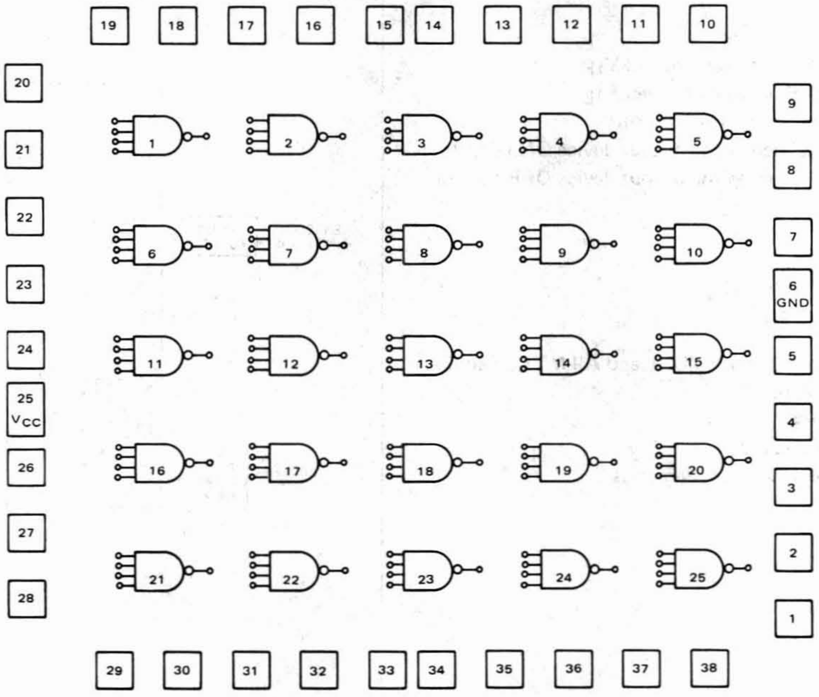
P SUFFIX
PLASTIC PACKAGE
CASE 612



F SUFFIX
CASE 618

LOGIC LAYOUT SHEET

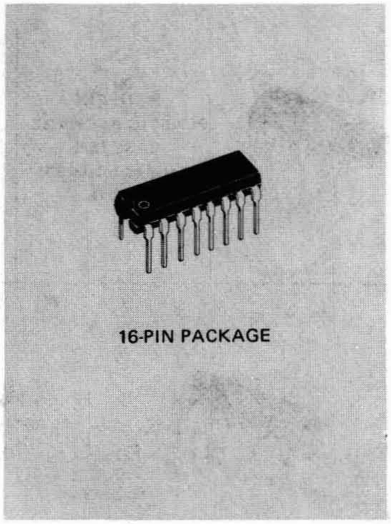
To describe complete function for custom metalization, label each gate as INT, EXT, EXP, or BUSS (as defined under "Gate Function Options"). Complete logic symbols with expander nodes where required, and show gate-to-gate interconnections along with gate-to-bonding pad interconnections desired. Bonding pads are committed to package pinouts as shown on the data sheet.



19 18 17 16 15 14 13 12 11 10
20
21
22
23
24
25 VCC
26
27
28
9
8
7
6 GND
5
4
3
2
1
1 2 3 4 5
6 7 8 9 10
11 12 13 14 15
16 17 18 19 20
21 22 23 24 25
29 30 31 32 33 34 35 36 37 38

XC170

128-BIT READ ONLY MEMORY


16-PIN PACKAGE

The XC170 is a monolithic 128-bit Read Only Memory that can be programmed for custom requirements. The basic organization of this memory is 16 eight-bit words, with each bit initially in the logical "1" storage state established by the metal intraconnection. By removing appropriate metal links on the device metalization, these bits can be changed to the logical "0" state to meet specific program requirements. Open collector outputs on each buffered bit line allow multiple "Wired ORing" for large memory arrays.

Logic Definitions:

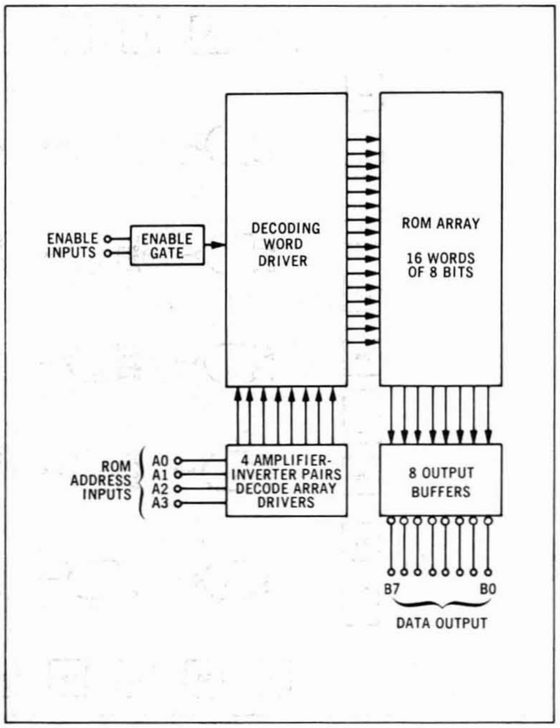
Inputs (Address and Enable):
- Logical "1" is defined as an applied V_{IH}
- Logical "0" is defined as an applied V_{IL}

Outputs (Data from Stored Bit Pattern):
- Logical "1" is defined as the output device ON (V_{OL})
- Logical "0" is defined as the output device OFF (Open)

Features:

- Logic Levels Compatible with MDTL and All MTTL Families
- Address Times < 45 ns
- Outputs Sink 20 mA
- Output Capacitance < 6.0 pF at 1.5 V
- "Wired OR" Capability to 64 Memories

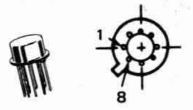
BLOCK DIAGRAM


ENABLE INPUTS
ENABLE GATE
DECODING WORD DRIVER
ROM ARRAY
16 WORDS OF 8 BITS
ROM ADDRESS INPUTS
A0
A1
A2
A3
4 AMPLIFIER-INVERTER PAIRS DECODE ARRAY DRIVERS
8 OUTPUT BUFFERS
B7
B0
DATA OUTPUT

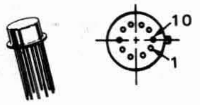
APPLICATION SELECTOR GUIDE

LINEAR integrated circuits offer the design engineer a variety of functions for analog applications. This line includes operational, differential, high frequency, power, and sense amplifiers, voltage regulators, a dual stereo preamplifier, and a dual chroma demodulator – devices are available in a broad selection of operating characteristics and packaging.

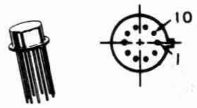
LINEAR IC PACKAGES



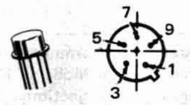
CASE 601 (TO-99)
(formerly CASE 96)
Suffix G after type number



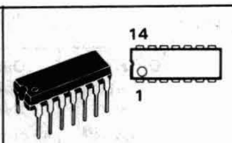
CASE 602A
(formerly CASE 71A)
Suffix G after type number



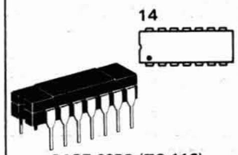
CASE 602B
(formerly CASE 71)
Suffix G after type number



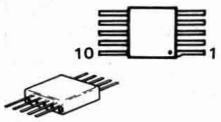
CASE 602C
(formerly CASE 89)
Suffix G after type number



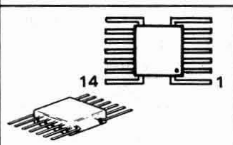
CASE 605 (TO-116)
(formerly CASE 93)
Suffix P after type number



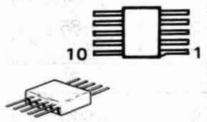
CASE 605C (TO-116)
Suffix L after type number



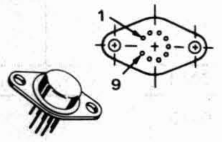
CASE 606 (TO-91)
(formerly CASE 72)
Suffix F after type number



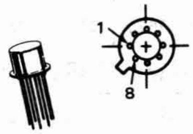
CASE 607 (TO-86)
(formerly CASE 83)
Suffix F after type number



CASE 608
(formerly CASE 73)
Suffix F after type number



CASE 614
Suffix R after type number



CASE 619
Suffix G after type number

At a Glance

OPERATIONAL AMPLIFIERS

TYPE				Open Loop Voltage Gain (A_{VOL})	Output Voltage Swing (V_{out}, V_p)	Common Mode Rejection Ratio (CM_{rej}, dB)
Temperature Range						
–55 to +125°C	Case	0 to +75°C	Case			
MC1520	602A, 606	–	–	1,500	± 4.0	–90
MC1530	602B, 606	**MC1430**	602B, 605, 605C, 606	5,000	± 5.0	–75
MC1531	602B, 606	**MC1431**	602B, 605, 605C, 606	3,500	± 5.0	–65
MC1533	602B, 605C, 606	**MC1433**	602B, 605, 605C, 606	60,000*	± 12	–100
MC1535**	602B, 607	**MC1435****	602B, 605, 605C, 607	7,000	± 3.6	–90
MC1537**	605C	**MC1437****	605, 605C	45,000	± 14	–100
MC1539	601	**MC1439**	601	**MC1539** 120,000 **MC1439** 100,000	± 14	–110
MCH1539†	619	**MCH1439**†	619	**MCH1539** 120,000 **MCH1439** 100,000	± 13	–110
MC1709	601, 605C, 606	**MC1709C**	601, 605, 605C, 606	45,000	± 14	–90
MC1712	601, 605C, 606	**MC1712C**	601, 605, 605C, 606	3,600	± 5.3	–100

*Adjustable **Dual †Hybrid

HIGH FREQUENCY AMPLIFIERS

TYPE	Temperature	Case	Small-Signal Voltage Gain (A_V, dB)	Bandwidth (MHz)	Noise Figure (dB)	Comments
MC1110	–55 to +125°C	602C	26② @ 100 MHz	300②	4.0 @ 100 MHz	High stability through low internal feedback for RF-IF applications.
MC1509	–55 to +125°C	608	40	40	4.5μV (5Hz-10MHz)①	Ideal for wideband video applications.
MC1510	–55 to +125°C	601, 608	40	40	4.5μV (5Hz-10MHz)①	
MC1545	–55 to +125°C	602A 605C, 607	18	75	25μV (5Hz-10MHz)①	Useful as a gated wideband amplifier, video switch, sense amplifier, multiplexer, modulator, FSK circuit, limiter, AGC circuit or pulse amplifier.
MC1550	–55 to +125°C	602B 606	26 @ 60 MHz	200②	5.0 @ 60 MHz	Constant input impedance over entire AGC range. RF-IF amplifier for communications equipment.
MC1552	–55 to +125°C	602B	34	40	5.0 @ 30 MHz	Three stage direct coupled common emitter cascade circuit with series feedback achieving extremely stable gain.
MC1553	–55 to +125°C	602B	52	35	5.0 @ 30 MHz	Same as MC1552 except higher gain.

① Noise Voltage referred to input

② Useful transducer power gain

APPLICATION SELECTOR GUIDE (continued)

POWER AMPLIFIERS

TYPE	Temperature	Case	Output Power (W)	Voltage Gain (A_v, V/V)	Total Harmonic Distortion (%)	Comments
MC1524	−55 to +125°C	602B	1.0	38	0.6	Complementary output, low standby current drain.
MC1554	−55 to +125°C	602B	1.0	10, 18, 36	0.4	Capable of single or split supply operation.

DIFFERENTIAL AMPLIFIERS

TYPE	Temperature	Case	Differential Voltage Gain (A_{dd}, dB)	Output Voltage Swing (V_{out}, V_{p-p})	Common Mode Rejection (CM_{rej}, dB)	Differential Input Impedance (Z_{in}, kΩ)	Comments
MC1429	0 to +75°C	602B	38	6.0	−75	40	Darlington inputs (high impedance).
MC1519	−55 to +125°C	602B	73	14	−89	2.6	NPN inputs, PNP outputs, 1 MHz BW.
MC1525	−55 to +125°C	602B	43	8.0	−85	3.0	Conventional differential inputs, high gain, built-in temperature compensated current source.
MC1526	−55 to +125°C	602B	36	8.0	−85	70	Same as MC1525 except Darlington inputs.
MC1529	−55 to +125°C	602B	38	6.0	−75	50	Same as MC1429—specified over full temperature range.

SENSE AMPLIFIERS

TYPE				Input Threshold (V_{th}, mVdc)	Voltage Gain (A_V, V/V)	Response Time (t_R, ns)	Comments
TEMPERATURE RANGE							
−55 to +125°C	Case	0 to +75°C	Case				
MC1514	605C	MC1414	605, 605C	21.5/18.5 ①	1700†	40	A dual differential comparator for level detection, low level sensing, and memory applications.
MC1540	602B, 605C 606	MC1440	602B, 605 605C, 606	17	85	20	Designed to detect bipolar differential signals derived by a core memory with cycle times as short as 0.5 μs.
MC1541	605C, 607	MC1441	605, 605C 607	17	85	30/15 ②	A dual-channel gated sense amplifier with separate wide band differential input amplifiers.
MC1710	601, 605C, 606	MC1710C	601, 605, 605C, 606	0	1700†	40	A differential comparator providing high accuracy and fast response time.
MC1711	602A, 605C, 606	MC1711C	602A, 605, 605C, 606	0	1500†	40	A dual differential comparator providing high accuracy and fast response time.

① −55°C/+125°C ② Diff. Mode/Com. Mode †A_{VOL}

STEREO PREAMPLIFIERS

TYPE	Temperature Temperature	Case	Open Loop Voltage Gain (A_{VOL})	Input Offset Voltage (mV)	Output Voltage Swing (V_{rms})	Channel Separation (dB)	Comments
MC1303	0 to +75°C	605, 605C	10,000	1.5	5.5	70	Two amplifiers on a single monolithic chip.

CHROMA DEMODULATORS

TYPE	Temperature	Case	Reference Voltage Range (V_{p-p})	Undistorted Output (V_{p-p})	Chroma Signal (V_{p-p})	Comments
MC1325	0 to +70°C	605, 605C	2.0-10	4.0	3.5	. . designed for color TV to demodulate the Chroma Signal.

VOLTAGE REGULATORS

TYPE				Max Input Voltage (Vdc)	Lead Current Range (mAdc)		Power Dissipation (Watts) ①		Output Impedance (mΩ typ)
TEMPERATURE RANGE									
−55 to +125°C	Case	0 to +75°C	Case		G Pkg.	R Pkg.	G Pkg.	R Pkg.	
MC1560	602A, 614	MC1460	602A, 614	20	250	600	1.8	10	15-25
MC1561	602A, 614	MC1461	602A, 614	35	250	600	1.8	17.5	20-35

Comments

A very unique and versatile series of voltage regulators with excellent load regulation, excellent transient response and thermal stability, and high ripple rejection.

① T_C = +25°C

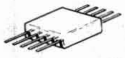
OPERATIONAL AMPLIFIERS

MC1430F,G,L,P (0 to +75°C)
MC1530F,G (−55 to +125°C)

. . . the MC1430 and MC1530 operational amplifiers are identical circuits specified over different temperature ranges. These devices are useful in a wide range of applications such as summing amplifiers and integrators and may be used for phase shifting, signal conditioning, and multiplexing as well as a variety of other analog functions. Primary features include:

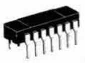
- Open Loop Gain = 5000 typical
- Output Voltage Swing = ±5 V typical @ 6 V Supply
- Low Output Impedance – 25 ohms typical

Operating characteristics are dependent on external feedback components.



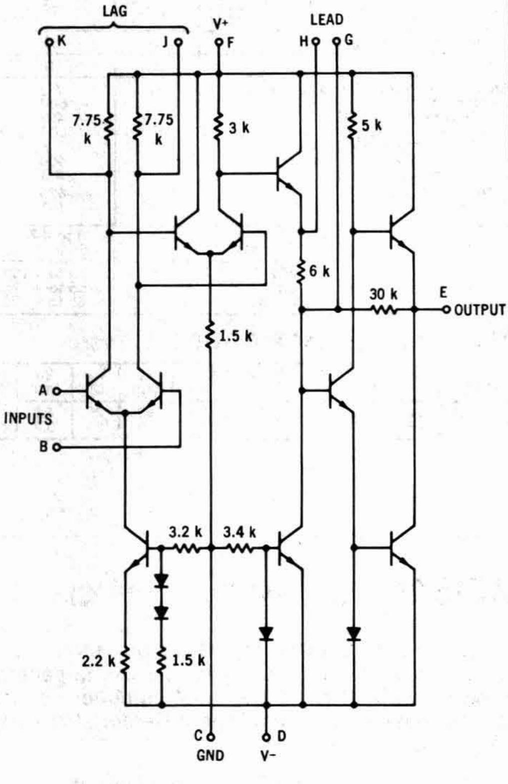
F SUFFIX
CASE 606
(Formerly Case 72)
TO-91

G SUFFIX
CASE 602B
(Formerly Case 71)



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116



PIN CONNECTIONS										
Schematic	A	B	C	D	E	F	G	H	J	K
"G" Package	1	2	3	4	5	6	7	8	9	10
"F" Package	1	2	3	4	5	6	7	8	9	10
"L" and "P" Packages	4	6	8	7	11	12	13	14	1	2

MAXIMUM RATINGS (T_A = 25°C UNLESS OTHERWISE NOTED)

RATING		SYMBOL	VALUE	UNIT
Power Supply Voltage	MC1430 MC1530	V+	+8 +9	Vdc
Power Supply Voltage	MC1430 MC1530	V−	−8 −9	Vdc
Differential Input Signal		V_{in}	±5	Vdc
Load Current		I_L	10	mA
Power Dissipation (Package Limitation)		P_D		
Metal Can			680	mW
Derate above 25°C			4.6	mW/°C
TO-91 Flat Package			500	mW
Derate above 25°C			3.3	mW/°C
Plastic Package			400	mW
Derate above 25°C			3.3	mW/°C
Ceramic Package			625	mW
Derate above 25°C			5.0	mW/°C
Operating Temperature Range	MC1430 MC1530	T_A	0 to +75 −55 to +125	°C
Storage Temperature Range	MC1430G,F,L MC1430P MC1530	T_{stg}	−55 to +150 −55 to +125 −65 to +175	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C)

TYPE	V+ and V− (Vdc)	V_{out} @ (V_{pk})	R_L (kΩ)	A_{VOL} (V/V)	Z_{in} (kΩ)	Z_{out} (Ω)	V_{io} (mV)	CMV_{in} (V_{pk})	CM_{rej} (dB)
MC1430	+6 and −6	±5.0	1.0	5000	15	25	2.0	±2.5	−75
MC1530	+6 and −6	±5.2	1.0	5000	20	25	1.0	±2.7	−75

MC1431F,G,L,P (0 to +75°C)
MC1531F,G (−55 to +125°C)

. . . similar to the MC1430 and MC1530, except with Darlington input configuration which greatly increases the input impedance.

F SUFFIX
CASE 606
(Formerly Case 72)
TO-91

G SUFFIX
CASE 602B
(Formerly Case 71)

L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

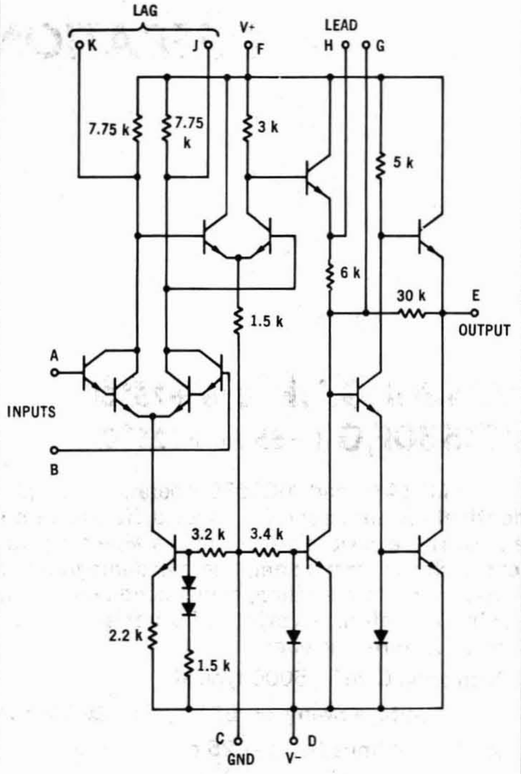
P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116

MAXIMUM RATINGS (T_A = 25°C UNLESS OTHERWISE NOTED)

RATING		SYMBOL	VALUE	UNIT
Power Supply Voltage	MC1431 MC1531	V+	+8 +9	Vdc
Power Supply Voltage	MC1431 MC1531	V-	−8 −9	Vdc
Differential Input Signal		V_{in}	±5	Vdc
Load Current		I_L	10	mA
Power Dissipation (Package Limitation) Metal Can Derate above 25°C TO-91 Flat Package Derate above 25°C Plastic Package Derate above 25°C Ceramic Package Derate above 25°C		P_D	 680 4.6 500 3.3 400 3.3 625 5.0	 mW mW/°C mW mW/°C mW mW/°C mW mW/°C
Operating Temperature Range	MC1431 MC1531	T_A	0 to +75 −55 to +125	°C
Storage Temperature Range	MC1431G,F,L MC1431P MC1531	T_{stg}	−55 to +150 −55 to +125 −65 to +175	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C)

TYPE	V+ and V− (Vdc)	V_{out} (Vpk) @	R_L (kΩ)	A_{VOL} (V/V)	Z_{in} (kΩ)	Z_{out} (Ω)	V_{io} (mV)	CMV_{in} (Vpk)	CM_{rej} (dB)
MC1431	+6 and −6	±5.0	1.0	3500	600	25	5.0	±2.2	−75
MC1531	+6 and −6	±5.2	1.0	3500	2000	25	3.0	±2.4	−65



PIN CONNECTIONS

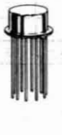
Schematic	A	B	C	D	E	F	G	H	J	K
"G" Package	1	2	3	4	5	6	7	8	9	10
"F" Package	1	2	3	4	5	6	7	8	9	10
"L" and "P" Packages	4	6	8	7	11	12	13	14	1	2

MC1520F,G (−55° to +125°C)

. . . the MC1520 differential output monolithic operational-amplifier is designed for use in general-purpose or wide band differential amplifier applications, especially those requiring differential outputs. Primary features include:

- Differential Input and Differential Output
- Wide Closed-Loop Bandwidth; 10 MHz
- Differential Gain; 70 dB
- High Input Impedance; 2.0 megohms:
- Low Output Impedance; 50 ohms

CASE 606
(FORMERLY CASE 72)
(SUFFIX F)



CASE 602A
(FORMERLY CASE 71A)
(SUFFIX G)

MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V+ V-	+8.0 −8.0	Vdc
Differential Input Signal	V_{in}	±8.0	Vdc
Load Current	I_{L1}, I_{L2}	15	mA
Power Dissipation (Package Limitation) Metal Can Derate above 25°C Flat Package Derate above 25°C	P_D	 680 4.6 500 3.3	 mW mW/°C mW mW/°C
Operating Temperature Range	T_A	−55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C)

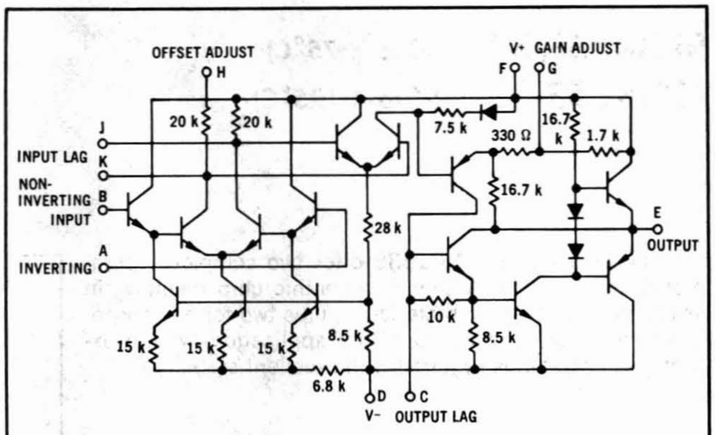
TYPE	V+ and V- (Vdc)	V_{out} (Vpk) @	R_L (kΩ)	A_{VOL} (V/V)	Z_{in} (MΩ)	Z_{out} (Ω)	V_{io} (mV)	CMV_{in} (Vpk)	CM_{rej} (dB)
MC1520	+6 and −6	±4.0	7.0	1500	2.0	50	5.0	±3.0	−90

MC1433F,G,L,P (0 to +75°C)
MC1533F,G,L (−55 to +125°C)

. . . the MC1433 and MC1533 operational amplifiers are identical circuits specified over different temperature ranges. These devices feature:

- Open Loop Gain = 60,000 typical
- Output Voltage Swing = ±13 V typical @ ±15 V Supplies
- Temperature Drift = ±5 μV/°C typical
- Input Offset Voltage = 1.0 mV typical

Voltage-gain and input offset voltage are adjustable while operating characteristics are dependent on external feedback components.


OFFSET ADJUST
H
V+
F
GAIN ADJUST
G
J
INPUT LAG
K
NON-INVERTING INPUT
B
INVERTING
A
20 k
20 k
7.5 k
330 Ω
16.7 k
1.7 k
16.7 k
28 k
E
OUTPUT
10 k
8.5 k
8.5 k
15 k
15 k
15 k
6.8 k
D
C
V−
OUTPUT LAG

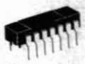
PIN CONNECTIONS										
Schematic	A	B	C	D	E	F	G	H	J	K
"G" Package	1	2	3	4	5	6	7	8	9	10
"F" Package	10	1	2	3	4	5	6	7	8	9
"L" and "P" Packages	4	5	6	7	11	12	13	14	2	3

MAXIMUM RATINGS (T_A = 25°C UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage MC1433	V+ V−	+18 −18	Vdc Vdc
MC1533	V+ V−	+20 −20	Vdc Vdc
Differential Input Signal	V_{in}	±10	Volts
Common Mode Input Swing	CMV_{in}	±V+	Volts
Load Current	I_L	10	mA
Output Short Circuit Duration	t_s	1.0	s
Power Dissipation (Package Limitation)	P_D		
Metal Can		680	mW
Derate above 25°C		4.6	mW/°C
TO-91 Flat Package		500	mW
Derate above 25°C		3.3	mW/°C
Plastic Package		400	mW
Derate above 25°C		3.3	mW/°C
Ceramic Package		625	mW
Derate above 25°C		5.0	mW/°C
Operating Temperature Range MC1433 MC1533	T_A	0 to +75 −55 to +125	°C
Storage Temperature Range G,F, & L Pkgs P Pkg	T_{stg}	−65 to +150 −65 to +125	°C

F SUFFIX
CASE 606
(Formerly Case 72)
TO-91

G SUFFIX
CASE 602B
(Formerly Case 71)



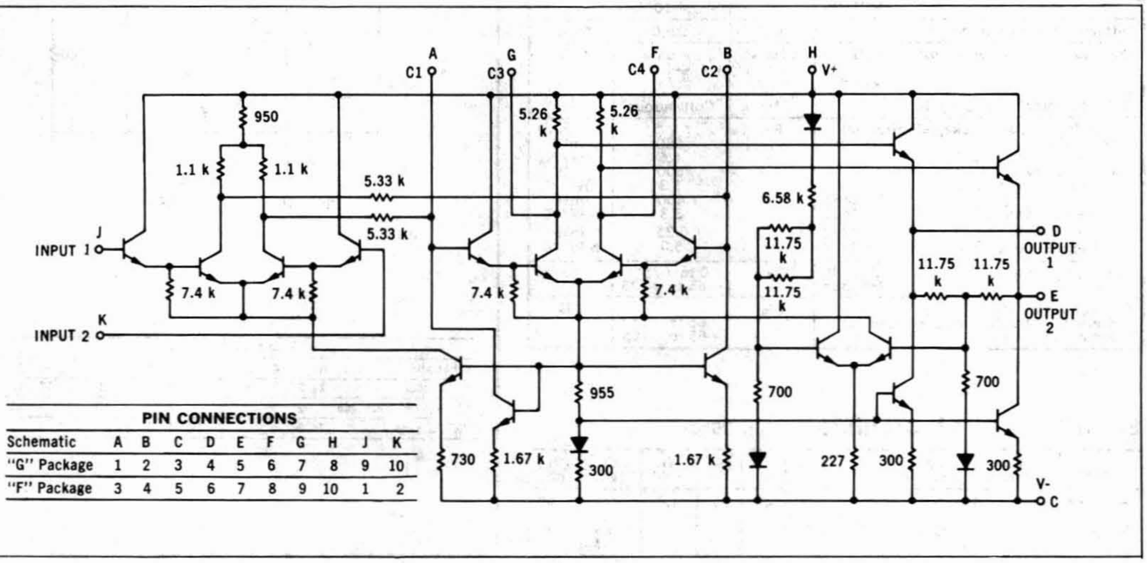
L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116

ELECTRICAL CHARACTERISTICS (T_A = 25°C)

TYPE	V+ and V− (Vdc)	V_{out} (V_{pk}) @	R_L (kΩ)	A_{VOL} (V/V)	Z_{in} (kΩ)	Z_{out} (Ω)	V_{io} (mV)	CMV_{in} (V_{pk})	CM_{rej} (dB)
MC1433	+15 and −15	±12	2.0	60,000*	600	100	1.0*	±9.0	−100
MC1533	+15 and −15	±12	2.0	60,000*	1000	100	1.0*	+10 −9.0	−100

*Adjustable


A
C1
G
C3
F
C4
B
C2
H
V+
950
1.1 k
1.1 k
5.33 k
5.33 k
5.26 k
5.26 k
6.58 k
11.75 k
11.75 k
J
INPUT 1
7.4 k
7.4 k
7.4 k
7.4 k
D
OUTPUT 1
11.75 k
11.75 k
E
OUTPUT 2
K
INPUT 2
955
700
700
730
1.67 k
300
1.67 k
227
300
300
V−
C

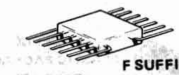
PIN CONNECTIONS										
Schematic	A	B	C	D	E	F	G	H	J	K
"G" Package	1	2	3	4	5	6	7	8	9	10
"F" Package	3	4	5	6	7	8	9	10	1	2

MC1435F,G,L,P (0 to +75°C)
MC1535F,G (−55° to +125°C)

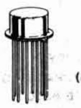
. . . the MC1435 and MC1535 offer two complete operational amplifiers on a single monolithic chip resulting in excellent matching characteristics, plus two-for-one spacewise. Ideal for chopper stabilized applications where extremely high gain is required with excellent stability.

Typical Amplifier Features:

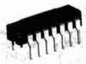
- High Open Loop Gain Characteristics — $A_{VOL} = 7{,}000$
- Low Temperature Drift — ±10 μV/°C
- Large Output Voltage Swing — ±3.6 V typ @ ±6.0 V supply
- Low Input Offset Voltage — 1.0 mV
- Low Input Noise Voltage — 0.5 μV



F SUFFIX
CASE 607
(Formerly Case 83)
TO-86

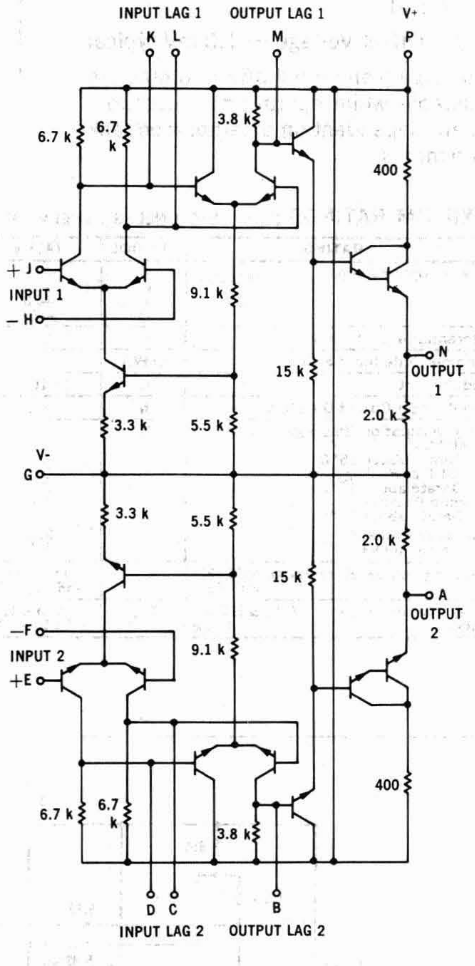


G SUFFIX
CASE 602B
(Formerly Case 71)



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116



MAXIMUM RATINGS ($T_A = 25°C$ unless otherwise noted)

RATING		SYMBOL	VALUE	UNIT
Power Supply Voltage	MC1435 MC1535	V+	+9.0 +10	Vdc
Power Supply Voltage	MC1435 MC1535	V-	−9.0 −10	Vdc
Differential Input Signal		V_{in}	±5.0	Volts
Common Mode Input Swing	MC1435 MC1435 MC1535	CMV_{in}	+5.0 −4.0 ±V +	Volts
Output Short Circuit Duration		t_S	Continuous	
Power dissipation (package limitation)		P_D		
Metal Can			680	mW
Derate above 25°C			4.6	mW/°C
Flat Package			500	mW
Derate above 25°C			3.3	mW/°C
Plastic Package	MC1435		400	mW
Derate above 25°C	MC1435		3.3	mW/°C
Ceramic Package	MC1435		6.25	mW
Derate above 25°C	MC1435		5.0	mW/°C
Operating Temperature Range	MC1435 MC1535	T_A	0 to +75° −55 to +125	°C
Storage Temperature Range		T_{stg}		°C
Metal Can and Ceramic Package			−65 to +150	
Plastic Package			−65 to +125	

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V+ and V- (Vdc)	V_{out} (V_{pk})	@	R_L (kΩ)	A_{VOL} (V/V)	Z_{in} (kΩ)	Z_{out} (Ω)	V_{io} (mV)	CMV_{in} (V_{pk})	CM_{rej} (dB)
MC1435	+6 and −6	±3.6		10	7,000	45	1.7	1.0	+3.9 −2.7	−90
MC1535	+6 and −6	±3.6		10	7,000	45	1.7	1.0	+3.9 −2.7	−90

PIN CONNECTIONS

Schematic	A	B	C	D	E	F	G	H	J	K	L	M	N	P
"F" Package	1	2	3	4	5	6	7	8	9	10	11	12	13	14
"L" and "P" Packages	1	2	3	4	5	6	7	8	9	10	11	12	13	14
"G" Package	7	8	—	—	9	10	1	2	3	—	—	4	5	6

MC1437L,P (0 to +75°C)
MC1537L (−55 to +125°C)

. . . the MC1437 and MC1537 are designed for use as summing amplifiers, integrators, or amplifiers with operating characteristics as a function of the external feedback components. Ideal for chopper stabilized applications where extremely high gain is required with excellent stability.

Typical Amplifier Features:

- High-Performance Open Loop Gain Characteristics $A_{VOL} = 45{,}000$
- Low Temperature Drift — ±3 μV/°C
- Large Output Voltage Swing — ±14 V typical @ 15 V Supply
- Low Output Impedance — $Z_{out} = 30$ ohms

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

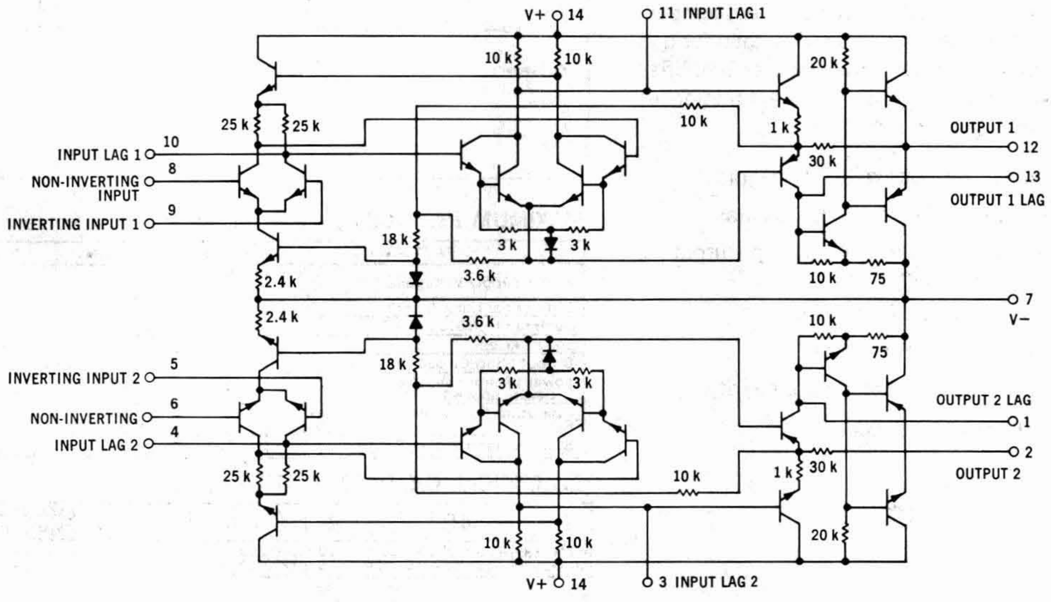
RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V+ V−	+18 −18	Vdc Vdc
Differential Input Signal	V_{in}	±5.0	Volts
Common Mode Input Swing	CMV_{in}	±V+	Volts
Output Short Circuit Duration	t_s	5.0	s
Power Dissipation (Package Limitation) MC1437L,P Derate above 25°C MC1537L Derate above 25°C	P_D	 625 5.0 750 6.0	 mW mW/°C mW mW/°C
Operating Temperature Range MC1437L,P MC1537L	T_A	 0 to +75 −55 to +125	°C
Storage Temperature Range MC1437P MC1437L, MC1537L	T_{stg}	 −65 to +125 −65 to +150	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V+ and V− (Vdc)	V_{out} @ (V_{pk})	R_L (kΩ)	A_{VOL} (V/V)	Z_{in} (kΩ)	Z_{out} (Ω)	V_{io} (mV)	CMV_{in} (V_{pk})	CM_{rej} (dB)
MC1437	+15 and −15	±14	10	45,000	150	30	1.0	±10	−110
MC1537	+15 and −15	±14	10	45,000	400	30	1.0	±10	−110

L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116


V+ 14
11 INPUT LAG 1
10 k
10 k
20 k
25 k
25 k
10 k
1 k
INPUT LAG 1 10
NON-INVERTING INPUT 8
INVERTING INPUT 1 9
30 k
OUTPUT 1
12
13
OUTPUT 1 LAG
18 k
3 k
3 k
2.4 k
3.6 k
10 k
75
7
V−
2.4 k
3.6 k
10 k
18 k
75
INVERTING INPUT 2 5
3 k
3 k
NON-INVERTING 6
INPUT LAG 2 4
OUTPUT 2 LAG
1
2
OUTPUT 2
25 k
25 k
10 k
1 k
30 k
10 k
10 k
20 k
V+ 14
3 INPUT LAG 2

MC1439G (0 to +75°C)
MC1539G (−55 to +125°C)

. . . the MC1439 and MC1539 operational amplifiers are identical circuits specified over different temperature ranges. These devices are designed for use as a summing amplifier, integrator, or amplifier with operating characteristics as a function of the external feedback components.

- Low Input Offset Voltage — 3.0 mV max
- Low Input Offset Current — 60 nA max
- Large Power-Bandwidth — 20 Vp-p Output Swing at 20 kHz min
- Output Short-Circuit Protection
- Input Over-Voltage Protection
- Class AB Output for Excellent Linearity
- Slew Rate —34 V/μs typ

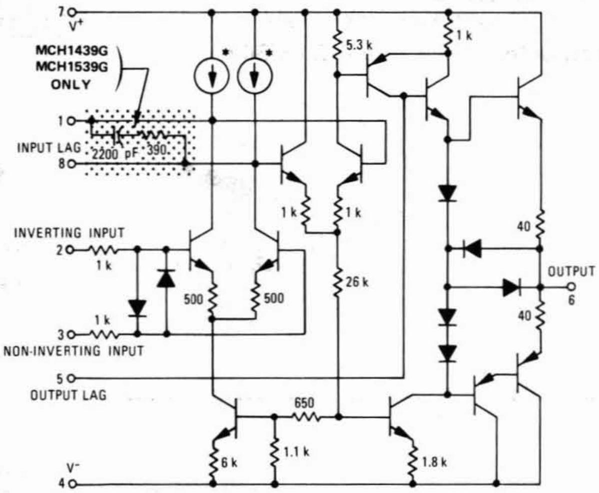
G SUFFIX
CASE 601
(Formerly Case 96)
TO-99

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

CHARACTERISTIC	SYMBOL	RATING	UNIT
Power Supply Voltage	V+ V−	+18 −18	Vdc Vdc
Differential Input Signal	V_{in}	±V+	Volts
Common Mode Input Swing	CMV_{in}	±V+	Volts
Load Current	I_L	15	mA
Output Short Circuit Duration	ts	Continuous	
Power Dissipation (Package Limitation) Derate above $T_A = 25°C$	P_D	680 4.6	mW mW/°C
Operating Temperature Range MC1439 MC1539	T_A	0 to +75 −55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V+ and V− (Vdc)	V_{out} @ (V_{pk})	R_L (kΩ)	A_{VOL} (V/V)	Z_{in} (kΩ)	Z_{out} (kΩ)	$\|V_{io}\|$ (mV)	CMV_{in} (V_{pk})	CM_{rej} (dB)
MC1439	+15 and −15	±14	10	100,000	300	4.0	2.0	±12	−110
MC1539	+15 and −15	±14	10	120,000	300	4.0	1.0	±12	−110



*Patent pending.

MCH1439G (0 to +75°C)
MCH1539G (−55 to +125°C)

. . . the MCH1439 and MCH1539 internally compensated hybrid operational amplifiers are identical circuits specified over different temperature ranges. These devices are designed for use as a summing amplifier, integrator, or amplifier with operating characteristics as a function of the external feedback components.

- Low Input Offset Voltage — 3.0 mV max
- Low Input Offset Current — 60 nA max
- Large Power-Bandwidth — 20 Vp-p Output Swing at 20 kHz min
- Output Short-Circuit Protection
- Input Over-Voltage Protection
- Class AB Output for Excellent Linearity
- Slew Rate — 4.2 V/μs typ

G SUFFIX
CASE 619

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

CHARACTERISTIC	SYMBOL	RATING	UNIT
Power Supply Voltage	V+ V−	+18 −18	Vdc Vdc
Differential Input Signal	V_{in}	±V+	Volts
Common Mode Input Swing	CMV_{in}	±V+	Volts
Load Current	I_L	15	mA
Output Short Circuit Duration	ts	Continuous	
Power Dissipation (Package Limitation) Derate above $T_A = 25°C$	P_D	680 4.6	mW mW/°C
Operating Temperature Range MCH1439 MCH1539	T_A	0 to +75 −55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V+ and V− (Vdc)	V_{out} @ (V_{pk})	R_L (kΩ)	A_{VOL} (V/V)	Z_{in} (kΩ)	Z_{out} (kΩ)	V_{io} (mV)	CMV_{in} (V_{pk})	CM_{rej} (dB)
MCH1439	+15 and −15	±14	10	100,000	300	4.0	2.0	±12	−110
MCH1539	+15 and −15	±14	10	120,000	300	4.0	1.0	±12	−110

MC1709CF,G,L,P (0 to +75°C)
MC1709F,G,L (−55 to +125°C)

. . . the MC1709C and MC1709 operational amplifiers are identical circuits specified over different temperature ranges. These amplifiers feature:

- Open Loop Gain = 45,000 typical
- Output Voltage Swing = ±14 V typical @ ±15 V Supplies
- Temperature Drift = ±3.0 μV/°C typical
- Input Offset Voltage < 2.0 mV typical

F SUFFIX
CASE 606
(Formerly Case 72)
TO-91

G SUFFIX
CASE 601
(Formerly Case 96)
TO-99

L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

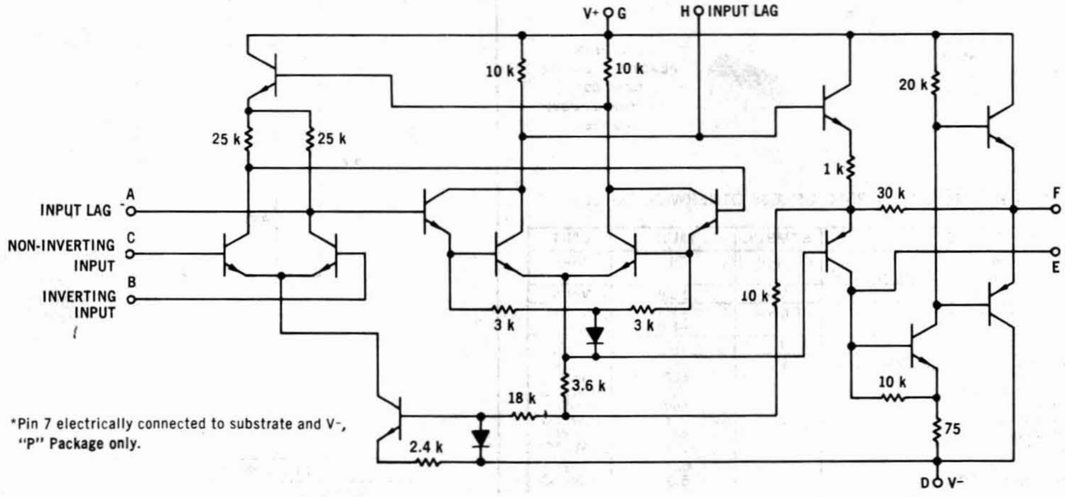
P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V^+ V^-	+18 −18	Vdc Vdc
Differential Input Signal	V_{in}	±5.0	Volts
Common Mode Input Swing	CMV_{in}	$\pm V^+$	Volts
Load Current	I_L	10	mA
Output Short Circuit Duration	t_s	5.0	s
Power Dissipation (Package Limitation) Metal Can Derate above 25°C TO-91 Flat Package Derate above 25°C Plastic Package Derate above 25°C Ceramic Package Derate above 25°C	P_D	 680 4.6 500 3.3 400 3.3 625 5.0	 mW mW/°C mW mW/°C mW mW/°C mW mW/°C
Operating Temperature Range MC1709C MC1709	T_A	0 to +75 −55 to +125	°C
Storage Temperature Range G,F & L Pkg P Pkg	T_{stg}	−65 to +150 −65 to +125	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V^+ and V^- (Vdc)	V_{out} (V_{pk}) @	R_L (kΩ)	A_{VOL} (V/V)	Z_{in} (kΩ)	Z_{out} (Ω)	V_{io} (mV)	CMV_{in} (V_{pk})	CM_{rej} (dB)
MC1709C	+15 and −15	±13	2.0	45,000	250	150	2.0	±10	−90
MC1709	+15 and −15	±13	2.0	45,000	400	150	1.0	±10	−90



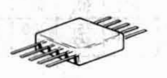
*Pin 7 electrically connected to substrate and V−, "P" Package only.

PIN CONNECTIONS								
Schematic	A	B	C	D	E	F	G	H
"G" Package	1	2	3	4	5	6	7	8
"F" Package	2	3	4	5	6	7	8	9
"L" and "P" Packages	3	4	5	6*	9	10	11	12

MC1712CF,G,L,P (0 to +75°C)
MC1712F,G,L (−55 to +125°C)

. . . the MC1712 and MC1712C are identical circuits specified over different temperature ranges. These devices are designed for use as wideband dc operational amplifiers. Operating characteristics are a function of the external feedback components. Primary features include:

- Open Loop Gain = 3600 typical
- Temperature Drift = ±2.5 μV/°C
- Output Voltage Swing = ±5.3 V typical @ +12 V and −6 V Supplies
- Input Offset Voltage = 1.1 mV typical

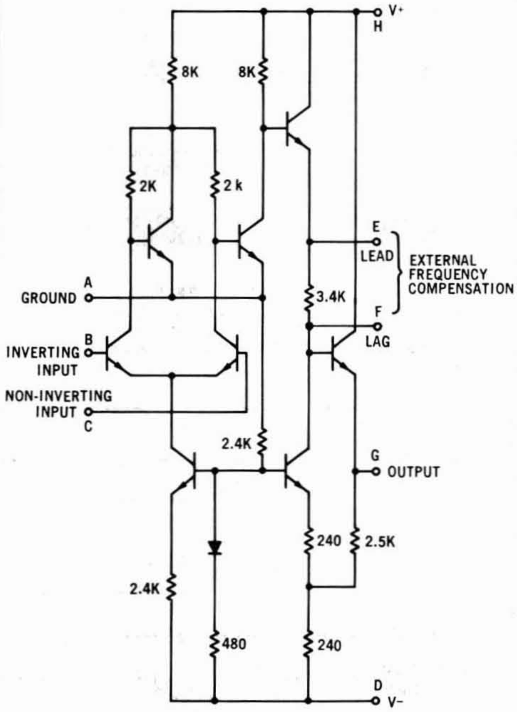


F SUFFIX
CASE 606
(Formerly Case 72)
TO-91

G SUFFIX
CASE 601
(Formerly Case 96)
TO-99

L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116



MAXIMUM RATINGS (T_A = 25°C UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage (Total between V+ and V− terminals)	$\vert V+\vert+\vert V-\vert$	21	Vdc
Differential Input Signal	V_{in}	±5.0	Volts
Common Mode Input Swing	CMV_{in}	+1.5 −6.0	Volts
Peak Load Current	I_L	50	mA
Power Dissipation (Package Limitation)	P_D		
Metal Can		680	mW
Derate above 25°C		4.6	mW/°C
Flat Package		500	mW
Derate above 25°C		3.3	mW/°C
Plastic Package		400	mW
Derate above 25°C		3.3	mW/°C
Ceramic Package		625	mW
Derate above 25°C		5.0	mW/°C
Operating Temperature Range MC1712C MC1712	T_A	0 to 75 −55 to +125	°C
Storage Temperature Range G,F & L Pkg. P Pkg.	T_{stg}	−65 to +150 −65 to +125	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C)

TYPE	V+ and V− (Vdc)	V_{out} (V_{pk})	@ R_L (kΩ)	A_{VOL} (V/V)	Z_{in} (kΩ)	Z_{out} (Ω)	V_{io} (mV)	CMV_{in} (V_{pk})	CM_{rej} (dB)
MC1712C	+12 and −6	±5.3	100	3400	35	200	1.5	+0.5 −4.0	−95
MC1712	+12 and −6	±5.3	100	3600	40	200	1.1	+0.5 −4.0	−100

PIN CONNECTIONS

Schematic	A	B	C	D	E	F	G	H
"G" Package	1	2	3	4	5	6	7	8
"F" Package	2	3	4	5	6	7	8	10
"L" and "P" Packages	3	4	5	6*	9	10	12	13

*Pin 7 is electrically connected to substrate and to V—, "P" Package only.

HIGH-FREQUENCY AMPLIFIERS

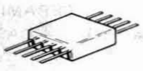
MC1510F, G (−55 to +125°C)
MC1509F (−55 to +125°C)

. . . a monolithic wideband video amplifier designed for use as a high-frequency amplifier with operating characteristics that provide a flat frequency response from dc to 40 MHz. Features:

- High Gain Characteristics
  $A_v = 93$
- Wide Bandwidth — dc to 40 MHz
- Large Output Voltage Swing
  4.5 V p-p typical @ ±6.0 V Supply
- Low Output Distortion
  THD ≦ 1.5%

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V^+ V^-	+8.0 −8.0	Vdc Vdc
Differential Input Signal	V_{in}	±5.0	Volts
Common Mode Input Swing	CMV_{in}	±6.0	Volts
Load Current	I_L	10	mA
Output Short Circuit Duration	ts	5.0	s
Power Dissipation (Package Limitation) Metal Can Derate above $T_A = 25°C$ Flat Package Derate above $T_A = 25°C$	P_D	 680 4.6 500 3.3	 mW mW/°C mW mW/°C
Operating Temperature Range	T_A	−55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C

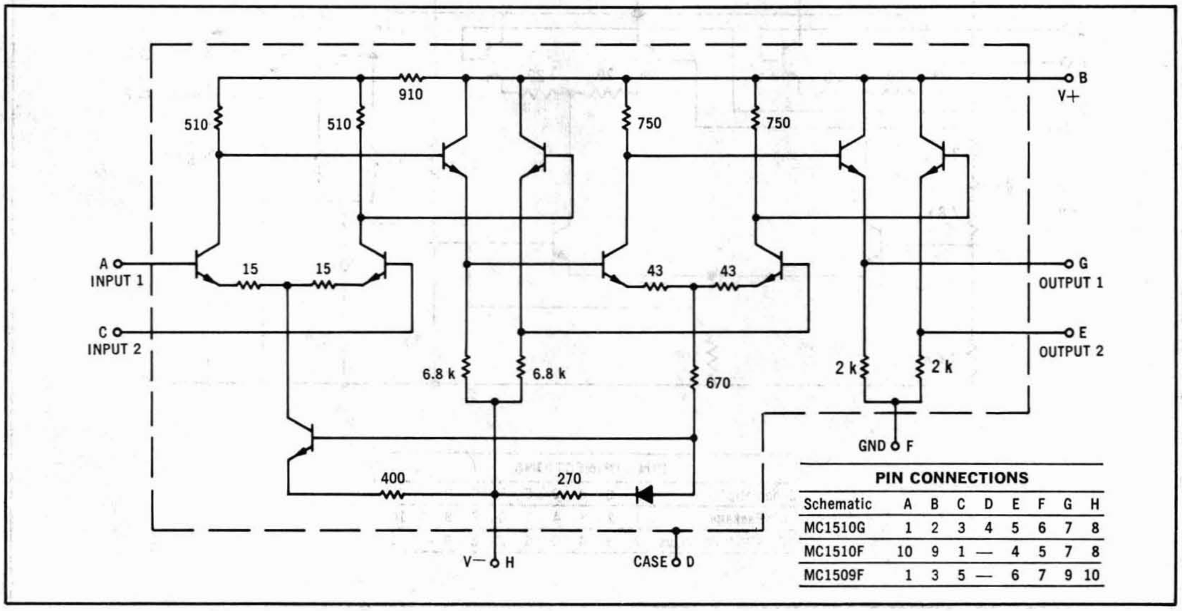


F SUFFIX
CASE 608
(Formerly Case 73)

G SUFFIX
CASE 601
(Formerly Case 96)
TO-99

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	(Vdc) V^+ and V^-	V_{out} (V_{p-p}) @	R_L (k Ω)	Av	BW (MHz)	Z_{in} (k Ω)	Z_{out} (Ω)	V_n (μV)
MC1510	+6 and −6	4.5	5.0	93	40	6.0	35	4.5 @ 10 MHz
MC1509	+6 and −6	4.5	5.0	93	40	6.0	35	



PIN CONNECTIONS

Schematic	A	B	C	D	E	F	G	H
MC1510G	1	2	3	4	5	6	7	8
MC1510F	10	9	1	—	4	5	7	8
MC1509F	1	3	5	—	6	7	9	10

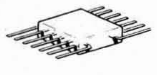
MC1545F, G, L (−55 to +125°C)

. . . the dual-input MC1545 is designed for use as a general-purpose gated wideband-amplifier, video switch, sense amplifier, multiplexer, modulator, FSK circuit, limiter, AGC circuit, or pulse amplifier.

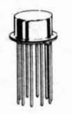
- Large Bandwidth; 75 MHz typical
- Channel-Select Time of 20 ns typical
- Differential Inputs and Differential Output

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

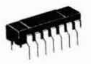
RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V^+ V^-	+12 −12	Vdc
Differential Input Signal	V_{in}	±5.0	Vdc
Load Current	I_L	25	mA
Power Dissipation (Package Limitation) Flat Package Derate above 25°C Ceramic Dual In-Line Derate above 25°C Metal Can Derate above 25°C	P_D	 500 3.3 625 5.0 680 4.6	 mW mW/°C mW mW/°C mW mW/°C
Operating Temperature Range	T_A	−55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C



F SUFFIX
CASE 607
(Formerly Case 83)
TO-86



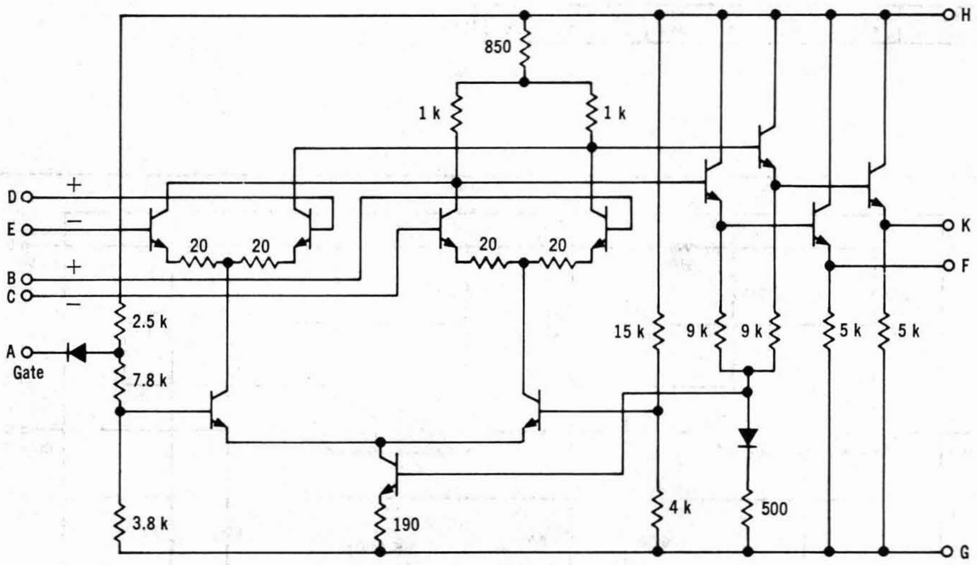
G SUFFIX
CASE 602A
(Formerly Case 71A)



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

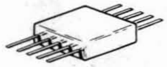
TYPE	V^+ and V^- (Vdc)	V_{out} (V_{p-p})	A_v (dB)	BW (MHz)	Z_{in} (kΩ)	Z_{out} (Ω)	CM_{rej} (dB)	CMV_{in} (V_p)	$V_{n(in)}$ (μVrms)
MC1545	+5.0 and −5.0	2.0	18	75	10	25	85	±2.5	25



PIN CONNECTIONS

Schematic	A	B	C	D	E	F	G	H	J	K
"G" Package	1	2	3	4	5	6	7	8	9	10
"F" & "L" Packages	2	3	4	5	6	7	8	9	—	1

MC1550F,G (–55 to +125°C)



F SUFFIX
CASE 606
(Formerly Case 72)
TO-91

G SUFFIX
CASE 602B
(Formerly Case 71)

. . . a versatile, common-emitter, common-base cascode circuit for use in communications applications. This device features:

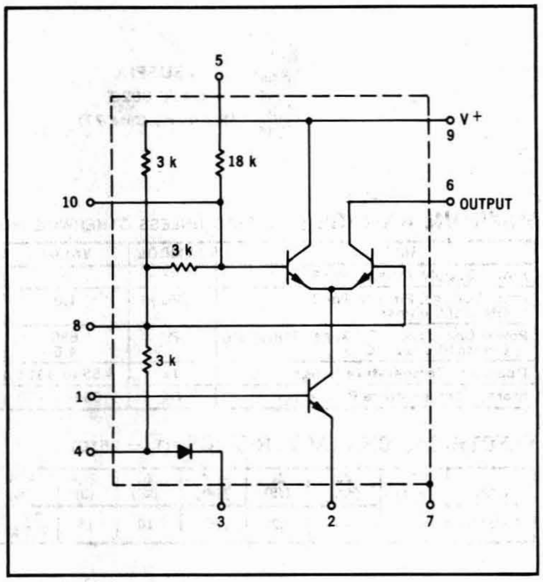
- Constant Input Impedance over Entire AGC Range
- High Power Gain — 30 dB @ 60 MHz, 0.5 MHz BW
- Noise Figure = 5 dB @ 60 MHz
- High Voltage-Gain — Bandwidth Product — 2 GHz

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage, Pin 9	V+	20	Vdc
AGC Supply Voltage	V_{AGC}	20	Vdc
Differential Input Voltage, Pin 1 to Pin 4 ($R_s = 500$ ohms)	V_{in}	±5	V(rms)
Power Dissipation (Package Limitation)	P_D		
Metal Can		680	mW
Derate above $T_A = 25°C$		4.6	mW/°C
Flat Package		500	mW
Derate above $T_A = 25°C$		3.3	mW/°C
Operating Temperature Range	T_A	–55 to +125	°C
Storage Temperature Range	T_{stg}	–65 to +150	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V+ (Vdc)	V_{out} (dc) Vdc	A_P (dB)	A_v (dB)	BW (MHz)	Z_{in} (kΩ)	Z_{out} (kΩ)	NF (dB)
MC1550	6.0	5.9	25 @ 60 MHz	26	60	1.8	100	5.0 @ 60 MHz



MC1552G (–55 to +125°C)

. . . the MC1552 is intended for use as a wide-band linear amplifier or as a fast-rise pulse amplifier. A three-stage, direct-coupled, common-emitter cascade circuit incorporates series-series feedback. Features:

- High Gain — 34 dB ± 1 dB
- Low Distortion — 0.2% @ 200 kHz
- Wide Bandwidth — 40 MHz
- Low Temperature Drift — ±0.002 dB/°C

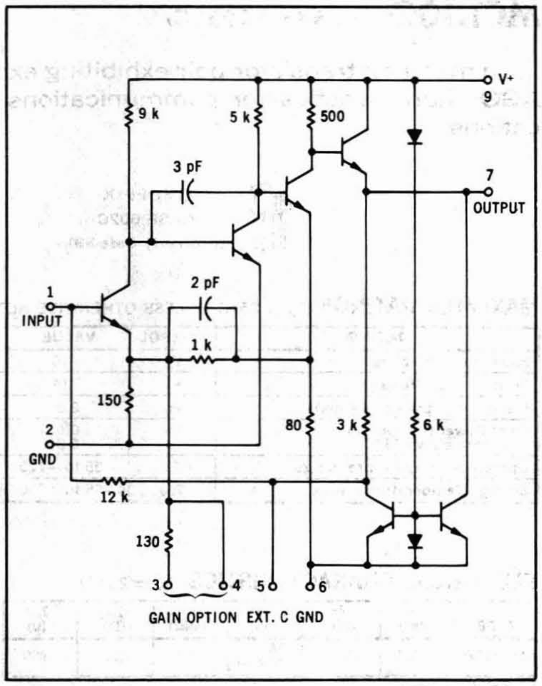
G SUFFIX
CASE 602B
(Formerly Case 71)

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage, Pin 9	V+	9	Vdc
Input Voltage, Pin 1 to Pin 2 ($R_S = 500$ ohms)	V_{in}	1.0	V(rms)
Power Dissipation (Package Limitation) Derate above 25°C	P_D	680 4.6	mW mW/°C
Operating Temperature Range	T_A	–55 to +125	°C
Storage Temperature Range	T_{stg}	–65 to +150	°C

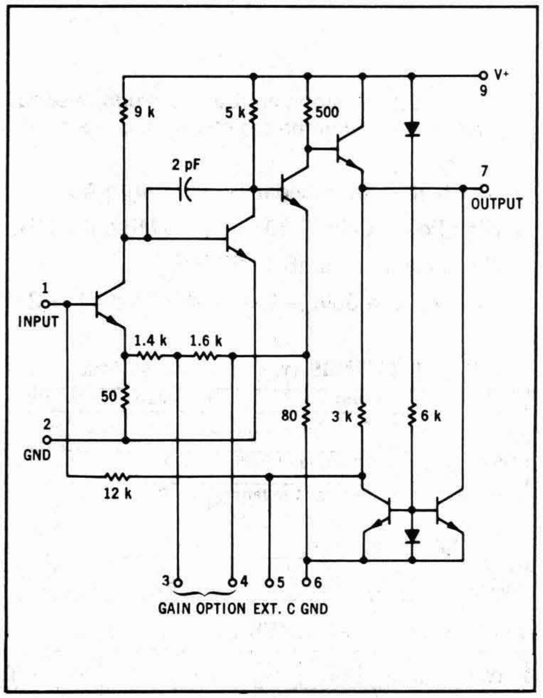
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

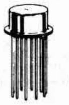
TYPE	V+ (Vdc)	V_{out} (V_{p-p})	A_v (dB)	BW (MHz)	Z_{in} (kΩ)	Z_{out} (Ω)	Dist. (%)	NF (dB)
MC1552	6.0	4.2	34	40	10	16	0.2 @ 200 kHz	5.0 @ 30 MHz



MC1553G (−55 to +125°C)

. . . similar to the MC1552 except higher gain (52 dB ± 1 dB) and narrower bandwidth (35 MHz).





G SUFFIX
CASE 602B
(Formerly Case 71)

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

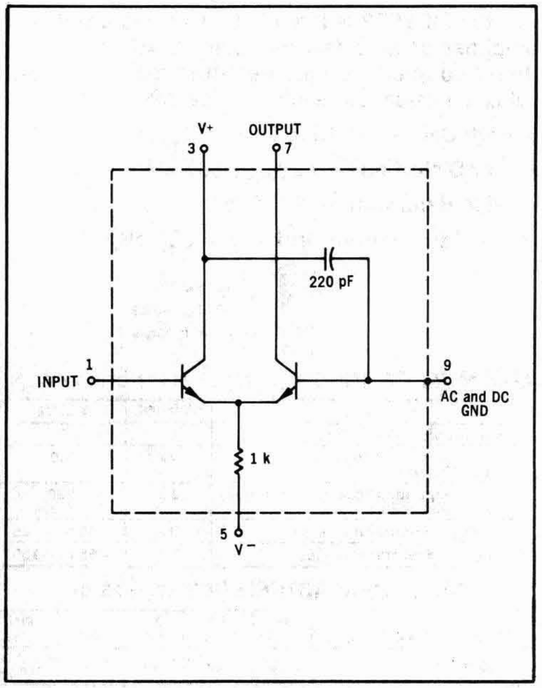
RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage, Pin 9	V^+	9	Vdc
Input Voltage, Pin 1 to Pin 2 ($R_S = 500$ ohms)	V_{in}	1.0	V(rms)
Power Dissipation (Package Limitation) Derate above 25°C	P_D	680 4.6	mW mW/°C
Operating Temperature Range	T_A	−55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V^+ (Vdc)	V_{out} (V_{p-p})	A_V (dB)	BW (MHz)	Z_{in} (kΩ)	Z_{out} (Ω)	THD (%)	NF (dB)
MC1553	6.0	4.2	52	35	10	16	0.2 @ 200 kHz	5.0 @ 30 MHz

MC1110G (−55 to +125°C)

. . . a matched transistor pair exhibiting excellent AGC characteristics for communications applications.



G SUFFIX
CASE 602C
(Formerly Case 89)

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V^+	+10	Vdc
Power Supply Voltage	V^-	−14	Vdc
Maximum Input Level (rms)	V_{in}	2.0	V(rms)
Total Power Dissipation Derate above 25°C	P_D	0.5 5.0	Watt mW/°C
Operating Temperature Range	T_A	−55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +200	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V^+ (Vdc)	V^- (Vdc)	A_P* (dB)	BW (MHz)	Z_{in} (Ω)	Z_{out} (Ω)	NF (dB)
MC1110	+5.0	−4.0	26 @ 100 MHz	300	500	800	4.0 @ 100 MHz

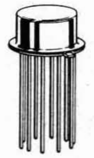
* Transducer gain

POWER AMPLIFIERS

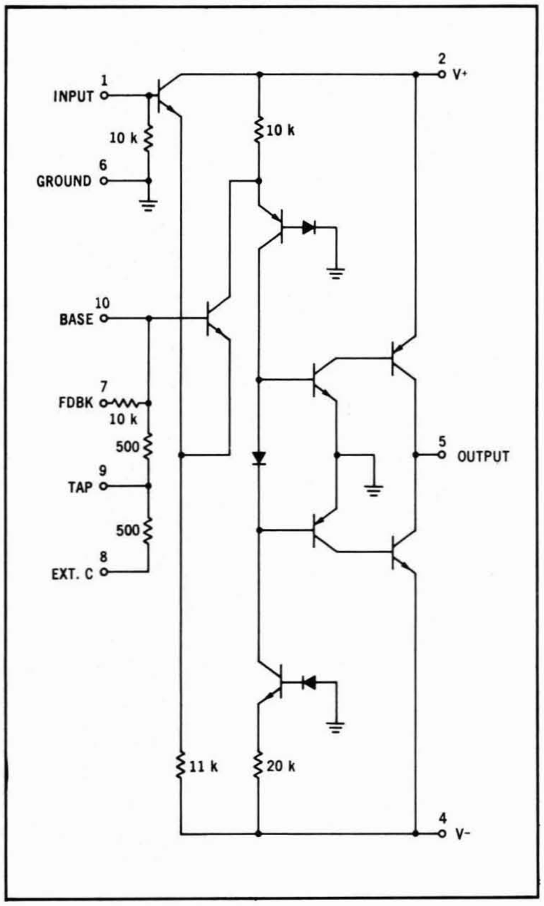
MC1524 (−55 to +125°C)

. . . the MC1524 is a hybrid circuit intended for use as a power amplifier, and utilizes a complementary output capable of delivering 1 watt into a 16-ohm load. Features include:

- Low Standby Current Drain — 1.5 mA
- Low Total Harmonic Distortion — 0.6% typical @ 1 kHz
- Excellent Gain-Temperature Stability



G SUFFIX
CASE 602B
(Formerly Case 71)



MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V^+	12	Vdc
Power Supply Voltage	V^-	12	Vdc
Operating Temperature Range	T_A	−55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +175	°C
Maximum Audio Output Power ($T_A = -55°C$ to $+125°C$)	$P_{out(max)}$	1.0	Watt

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V_+ (Vdc)	V_- (Vdc)	V_{out} (V_{p-p}) @	R_L (Ω)	A_V V/V	BW (kHz)	Z_{in} (kΩ)	Z_{out} (Ω)	P_{out} (W)	THD (%)
MC1524	+6.0	−6.0	10	16	38	350	8.5	0.6	1.0	0.6

MC1554 (−55 to +125°C)

. . . a monolithic circuit designed to amplify signals to 300 kHz with one watt delivered to a direct or capacitively coupled load.

- Low Total Harmonic Distortion — 0.4% typical @ 1 Watt
- Low Output Impedance — 0.2 ohm
- Excellent Gain — Temperature Stability

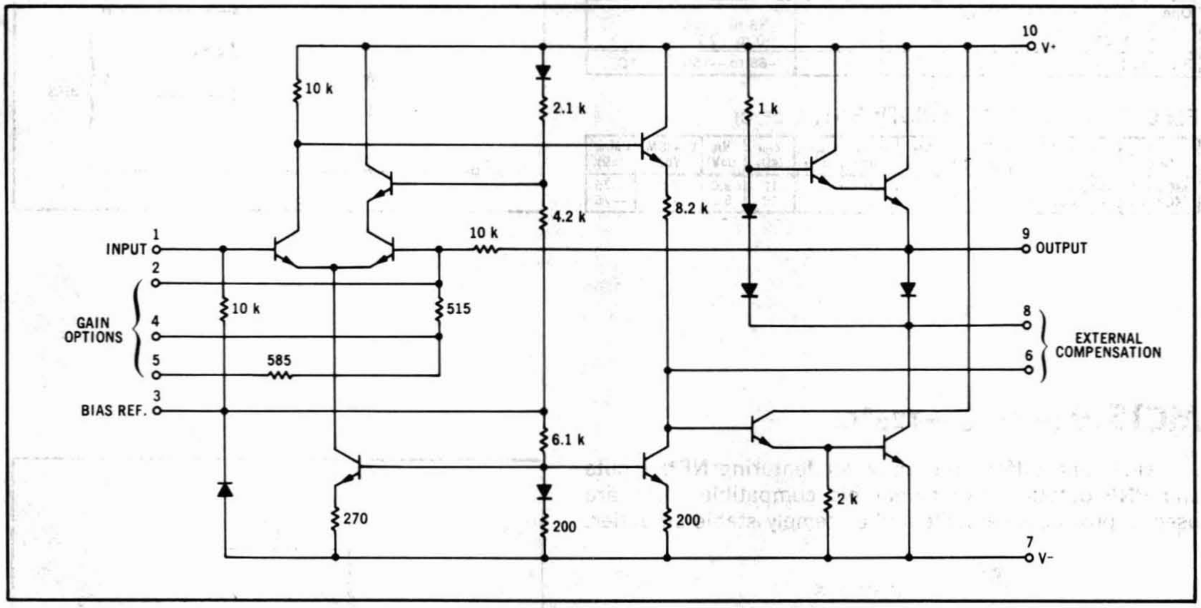
G SUFFIX
CASE 602B
(Formerly Case 71)

MAXIMUM RATINGS (T$_A$ = 25°C UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Total Power Supply Voltage	$\lvert V^+\rvert + \lvert V^-\rvert$	18	Vdc
Peak Load Current	I_{out}	0.5	Amp
Audio Output Power	P_{out}	1.8	Watt
Power Dissipation (Package Limitation) $T_A = 25°C$ Derate above 25°C $T_C = 25°C$ Derate above 25°C	P_D	 600 4.8 1.8 14.4	 mW mW/°C Watt mW/°C
Operating Temperature Range	T_C	−55 to +125	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C)

TYPE	V_+ (Vdc)	V_- (Vdc)	V_{out} (V_{p-p}) @	R_L (Ω)	A_V (V/V)	BW (kHz)	Z_{in} (kΩ)	Z_{out} (Ω)	P_{out} (W)	THD (%)
MC1554	+16 or +8.0	−8.0	12	16	10, 18, 36	250	10	0.2	1.0	0.4

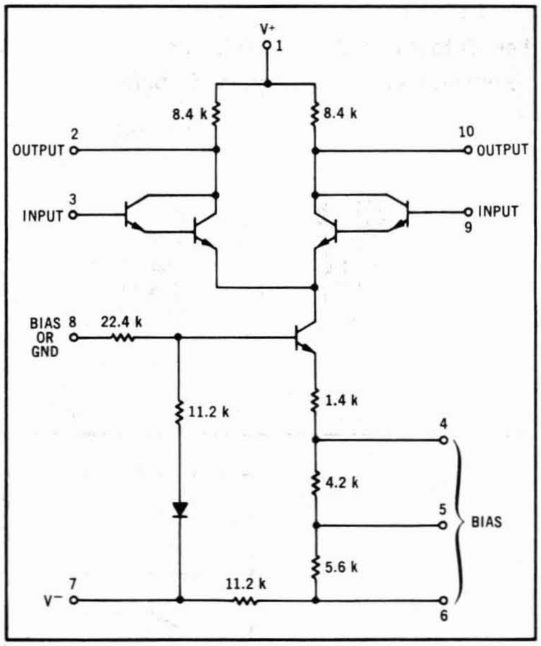

10
V+
10 k
2.1 k
1 k
4.2 k
8.2 k
1
INPUT
10 k
9
OUTPUT
2
GAIN OPTIONS
4
5
10 k
515
585
8
6
EXTERNAL COMPENSATION
3
BIAS REF.
6.1 k
2 k
270
200
200
7
V−

DIFFERENTIAL AMPLIFIERS

MC1429 (0 to +75°C)
MC1529 (−55 to +125°C)

. . . designed for high-gain applications. Features built-in temperature compensated current source for excellent temperature stability.

G SUFFIX
CASE 602B
(Formerly Case 71)



MAXIMUM RATINGS (T_A = 25°C UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V^+	+14	Vdc
Power Supply Voltage	V^-	−14	Vdc
Differential Input Signal	V_{in}	±5.0	Vdc
Power Dissipation (Package Limitation) Derate above 25°C	P_D	680 4.6	mW mW/°C
Operating Temperature Range MC1529 MC1429	T_A	−55 to +125 0 to +75	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C

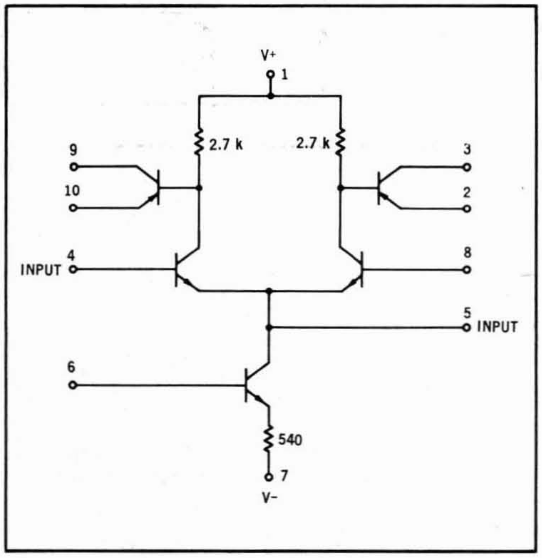
ELECTRICAL CHARACTERISTICS (T_A = 25°C)

TYPE	V^+ and V^- (Vdc)	V_{out} (V_{p-p})	A_{dd} (dB)	$A_{V(se)}$ (dB)	Z_{in} (kΩ)	Z_{out} (kΩ)	V_{io} (mV)	V_{out} (CM) Vdc	CM_{rej} (dB)
MC1429	+12 and −12	6.0	38	31	40	12	9.0	7.0	−75
MC1529	+12 and −12	6.0	38	32	50	10	6.0	7.0	−75

MC1519 (−55 to +125°C)

. . . wide-band differential amplifier featuring **NPN** inputs and **PNP** outputs. Two monolithic compatible chips are used to provide a versatile and extremely stable amplifier.

G SUFFIX
CASE 602B
(Formerly Case 71)



MAXIMUM RATINGS (T_A = 25°C UNLESS OTHERWISE NOTED)

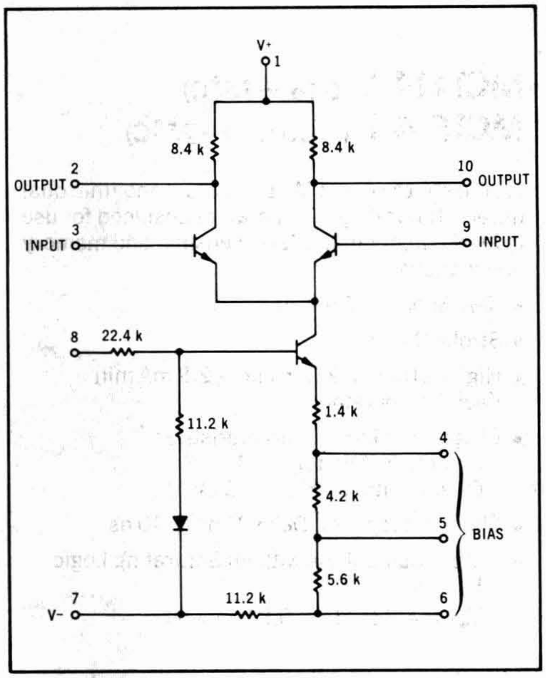
RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V^+	+14	Vdc
Power Supply Voltage	V^-	−14	Vdc
Differential Input Signal	V_{in}	±5.0	Vdc
Total Power Dissipation Derate above 25°C	P_D	300 2.0	mW mW/°C
Operating Temperature Range	T_A	−55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +175	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C)

TYPE	V^+ and V^- (Vdc)	V_{out} (V_{p-p})	A_{dd} (dB)	$A_{V(se)}$ (dB)	Z_{in} (kΩ)	Z_{out} (kΩ)	V_{io} (mV)	CMV_{in} (V_{pk})	CM_{rej} (dB)
MC1519	+12 and −12	14	73	67	2.6	2.7	2.0	+4.4 −6.3	−89

MC1525 (−55 to +125°C)

. . . designed for high-gain applications. Features built-in temperature compensated current source for excellent temperature stability.


V+
1
8.4 k
8.4 k
2
OUTPUT
10
OUTPUT
3
INPUT
9
INPUT
8
22.4 k
11.2 k
1.4 k
4
4.2 k
5
BIAS
5.6 k
7
V−
11.2 k
6

G SUFFIX
CASE 602B
(Formerly Case 71)

MAXIMUM RATINGS (T$_A$ = 25°C UNLESS OTHERWISE NOTED)

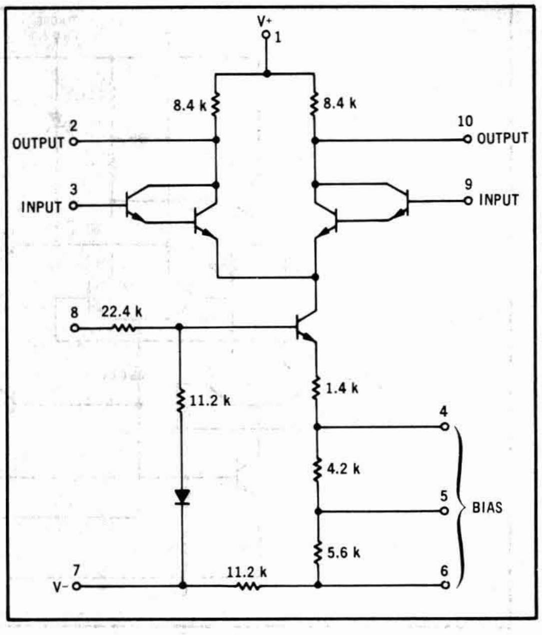
RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V+	+14	Vdc
Power Supply Voltage	V−	−14	Vdc
Differential Input Signal	V_{in}	±5.0	Vdc
Power Dissipation (Package Limitation) Derate above 25°C	P_D	680 4.6	mW mW/°C
Operating Temperature Range	T_A	−55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +175	°C

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C)

TYPE	V+ and V− (Vdc)	V_{out} (V_{p-p})	A_{dd} (dB)	$A_{V(se)}$ (dB)	Z_{in} (kΩ)	Z_{out} (kΩ)	V_{io} (mV)	$V_{out(CM)}$ (V_{pk})	CM_{rej} (dB)
MC1525	+12 and −12	8.0	43	38	3.0	9.0	3.0	±5.5	−85

MC1526 (−55 to +125°C)

. . . similar to MC1525 except with Darlington input configuration, which offers a much higher input impedance.


V+
1
8.4 k
8.4 k
2
OUTPUT
10
OUTPUT
3
INPUT
9
INPUT
8
22.4 k
11.2 k
1.4 k
4
4.2 k
5
BIAS
5.6 k
7
V−
11.2 k
6

G SUFFIX
CASE 602B
(Formerly Case 71)

MAXIMUM RATINGS (T$_A$ = 25°C UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V+	+14	Vdc
Power Supply Voltage	V−	−14	Vdc
Differential Input Signal	V_{in}	±5	Vdc
Power Dissipation (Package Limitation) Derate above 25°C	P_D	680 4.6	mW mW/°C
Operating Temperature Range	T_A	−55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +175	°C

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C)

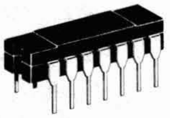
TYPE	V+ and V− (Vdc)	V_{out} (V_{p-p})	$A_{V(diff)}$ (dB)	$A_{V(se)}$ (dB)	Z_{in} (kΩ)	Z_{out} (kΩ)	V_{io} (mV)	$V_{out(CM)}$ (V_{pk})	CM_{rej} (dB)
MC1526	+12 and −12	8.0	36	33	70	9.0	5.0	±5.5	−85

DUAL SENSE AMPLIFIERS

MC1414 L (0 to +75°C)
MC1514 L (−55 to +125°C)

. . . the MC1414 and MC1514 are monolithic dual differential voltage comparators designed for use in level detection, low-level sensing, and memory applications.

- Two Separate Outputs
- Strobe Capability
- High Output Sink Current — 2.8 mA min *Each* Comparator
- Differential Input Characteristics:
  - Input Offset Voltage = 1.0 mV
  - Offset Voltage Drift = 3.0 μV/°C
- Short Propagation Delay Time — 40 ns
- Output Compatible with All Saturating Logic Forms
  - $V_{out} = +3.2$ V to -0.5 V typical



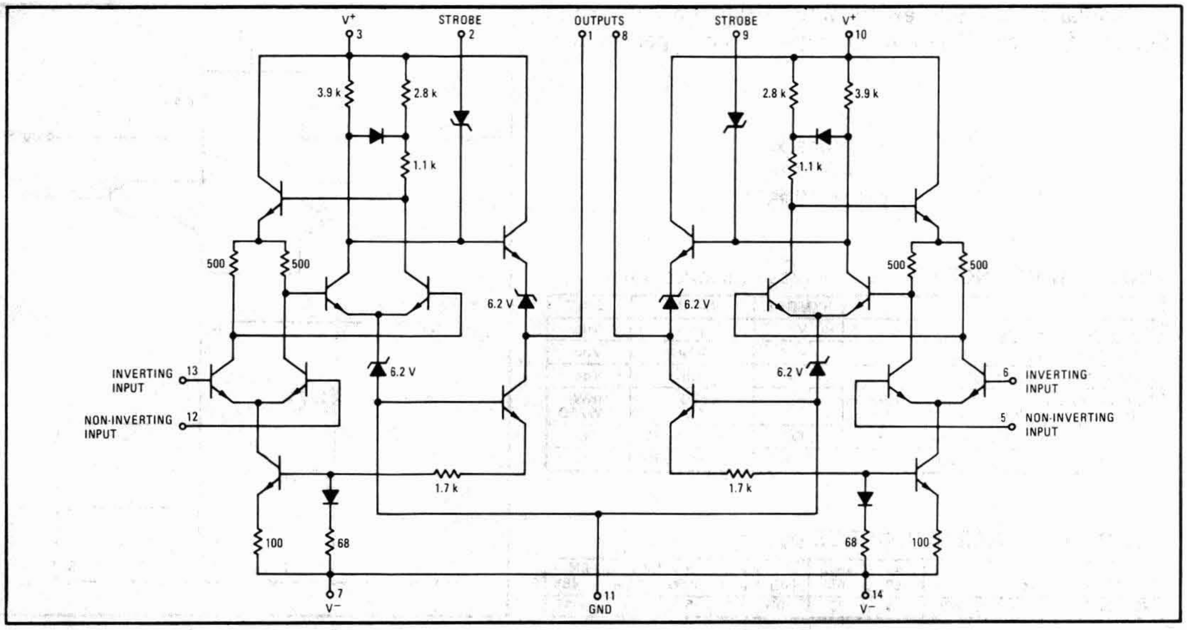
L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V^+ V^-	+14 −7.0	Vdc Vdc
Differential Input Signal	V_{in}	±5.0	Volts
Common Mode Input Swing	CMV_{in}	±7.0	Volts
Peak Load Current	I_L	10	mA
Power Dissipation (package limitation) Ceramic Dual In-Line Package Derate above $T_A = 50°C$	P_D	750 6.0	mW mW/°C
Operating Temperature Range MC1414 MC1514	T_A	0 to +75 −55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V+ (Vdc)	V− (Vdc)	V_{io} (mV)	A_{VOL} (V/V)	V_{OH} (Vdc)	V_{OL} (Vdc)	t_{pd} (ns)	CMV_{in} (Vdc)	TCV_{io} (μV/°C)
MC1414	+12	−6.0	1.5	1500	3.2	−0.5	40	±5.0	5.0
MC1514	+12	−6.0	1.0	1700	3.2	−0.5	40	±5.0	3.0


V+ 3
STROBE 2
OUTPUTS 1 8
STROBE 9
V+ 10
3.9 k
2.8 k
1.1 k
500
500
6.2 V
6.2 V
INVERTING INPUT 13
NON-INVERTING INPUT 12
1.7 k
100
68
7 V−
11 GND
14 V−
2.8 k
3.9 k
1.1 k
500
500
6.2 V
6.2 V
6 INVERTING INPUT
5 NON-INVERTING INPUT
1.7 k
68
100

MC1440F,G,L,P (0 to +75°C)
MC1540F,G,L (−55 to +125°C)

. . . consisting of a wideband differential amplifier, a dc restoration circuit which also incorporates facilities to externally adjust the threshold, and an output gate which is strobed from saturated logic. It is designed to detect bipolar differential signals derived by a core memory with cycle times as low as 0.5 µs. MC1440 and MC1540 are identical circuits specified over different temperature ranges.

- Differential Threshold Characteristics:
  - Adjustable Threshold — 10-25 mV
  - Nominal Threshold — 17 mV @ $V_6 = -6$ V
  - Input Offset Voltage — 1 mV
  - Threshold Drift — +10 V/°C
- Fast Response Time — 20 ns
- Short Recovery Time
  - 50 ns @ $e_{in} = 1.8$ V Common Mode
  - 50 ns @ $e_{in} = 400$ mV Differential Mode

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V^+ V^-	+10 −10	Vdc Vdc
Differential Input Signal	V_{in}	±5.0	Volts
Common Mode Input Swing	CMV_{in}	±5.0	Volts
Peak Load Current	I_L	25	mA
Power Dissipation (Package Limitation)	P_D		
Metal Can		680	mW
Derate above 25°C		4.6	mW/°C
Flat Package		500	mW
Derate above 25°C		3.3	mW/°C
Ceramic Dual In-Line Pkg.		625	mW
Derate above 25°C		5.0	mW/°C
Plastic Package		415	mW
Derate above 25°C		3.3	mW/°C
Operating Temperature Range MC1440G, F, P, L MC1540F MC1540G, L	T_A	0 to +75 −55 to +100 −55 to +125	°C
Storage Temperature Range	T_{stg}	−65 to +150	°C

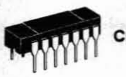
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V^+ (Vdc)	V^- (Vdc)	V_{th}* (mV)	A_V (V/V)	V_{OH} (Vdc)	V_{OL} (Vdc)	t_{pd} (ns)	t_R (ns)	CMV_{in} (Vpk)	TCV_{th} (µV/°C)
MC1540	+6.0	−6.0	17	85	5.9	0.35	10	20	±5.0	10
MC1440	+6.0	−6.0	17	85	5.8	0.4	10	20	±5.0	10

*Input Offset Voltage = 1.0 mV; V_{th} is adjustable.

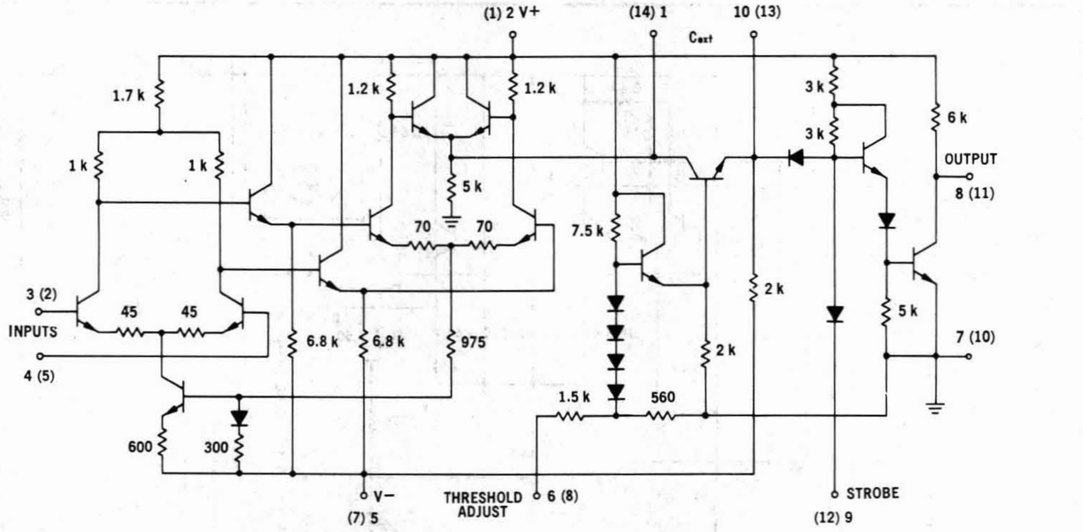
F SUFFIX
CASE 606
(Formerly Case 72)
TO-91

G SUFFIX
CASE 602B
(Formerly Case 71)



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116

P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116



Number at terminal end represents pin number for devices in flat package and metal can. Number in parenthesis represents pin number for dual in-line ceramic and plastic packages.

MC1441F,L,P (0 to +75°C)
MC1541F,L (−55 to +125°C)

. . . consisting of a dual-channel gated sense amplifier with separate wideband differential input amplifiers. Either can be gated on from saturated logic levels. The sense amplifier features adjustable threshold, saturated logic output levels, and a strobe input that accommodates saturated logic levels. Designed to detect bipolar signals from either of two sense lines. Operates with core memory cycle times less than 0.5 μs.

- Nominal Threshold — 17 mV
- Input Offset Voltage — 1.0 mV typical
- Propagation Delay
    - Input to Gate-Output — 20 ns
    - Input to Amplifier-Output — 10 ns
    - Gate Response Time — 15 ns
    - Strobe Response Time — 15 ns
- Common Mode Input Range — 1.5 Volts
- Differential Mode Input Range
    - With Gate On — 600 mV
    - With Gate Off — 1.5 Volts
- Power Dissipation — 140 mW typical

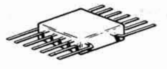
MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V^+ V^-	+10 −10	Vdc Vdc
Differential Input Signal	V_{in}	±5	Vdc
Common Mode Input Voltage	CMV_{in}	±5	Vdc
Load Current	I_L	25	mA
Power Dissipation (Package Limitation)	P_D		
Flat Package		500	mW
Derate above 25°C		3.3	mW/°C
Ceramic Dual In-Line Package		600	mW
Derate above 25°C		4.8	mW/°C
Plastic Package		415	mW
Derate above 25°C		3.3	mW/°C
Operating Temperature Range	T_A		°C
MC1541F, MC1541L		−55 to +125	
MC1441F, MC1441L, MC1441P		0 to +75	
Storage Temperature Range	T_{stg}		°C
Ceramic Packages		−65 to +150	
Plastic Package		−55 to +125	

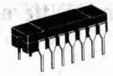
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V+ (Vdc)	V− (Vdc)	V_{th}* (mV)	A_V (V/V)	V_{OH} (Vdc)	V_{OL} (mVdc)	t_{pd} (ns)	t_R (ns)	CMV_{in} (Vpk)
MC1541	+5.0	−5.0	17	75	4.9	350	20	30	±5.0
MC1441	+5.0	−5.0	17	75	4.9	350	20	30	±5.0

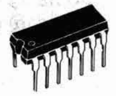
*Input Offset Voltage = 1.0 mV; V_{th} is adjustable



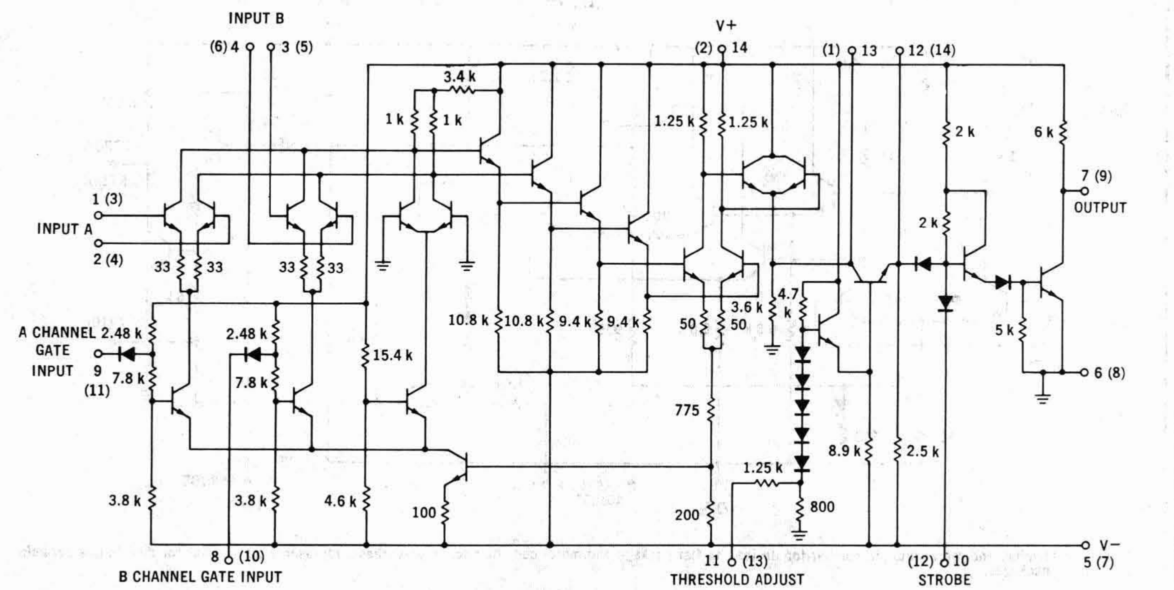
F SUFFIX
CASE 607
(Formerly Case 83)
TO-86



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116

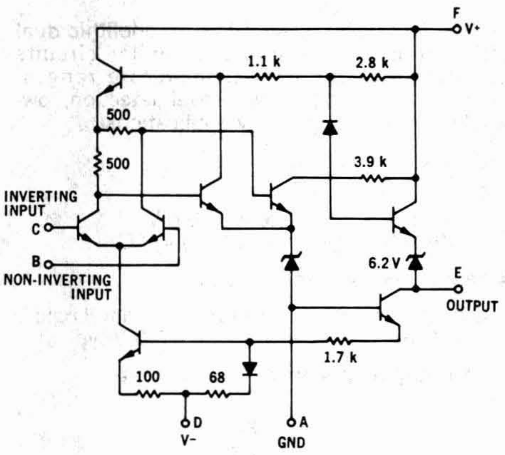

INPUT B
(6) 4
3 (5)
V+
(2) 14
(1) 13
12 (14)
3.4 k
1 k
1 k
1.25 k
1.25 k
2 k
6 k
7 (9)
OUTPUT
1 (3)
INPUT A
2 (4)
33
33
33
33
2 k
10.8 k
10.8 k
9.4 k
9.4 k
50
50
3.6 k
4.7 k
5 k
A CHANNEL GATE INPUT 9 (11)
2.48 k
7.8 k
2.48 k
7.8 k
15.4 k
6 (8)
775
8.9 k
2.5 k
1.25 k
3.8 k
3.8 k
4.6 k
100
800
200
V−
5 (7)
8 (10)
B CHANNEL GATE INPUT
11 (13)
THRESHOLD ADJUST
(12) 10
STROBE

Number at terminal end represents pin number for flat package. Number in parenthesis represents pin number for dual in-line ceramic and plastic packages.

MC1710CF,G,L,P (0 to +75°C)
MC1710F,G,L (−55 to +125°C)

. . . the MC1710 and MC1710C are identical circuits specified over different temperature ranges. These devices are differential voltage comparators for use in level detection, low-level sensing, and memory applications. Features:

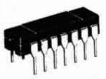
- Differential Input Characteristics:
  Input Offset Voltage = 1 mV
  Offset Voltage Drift = 3 μV/°C
- Fast Response Time — 40 ns
- Low Output Impedance — 200 ohms
- Output Compatible with All Saturating Logic Forms — +3.2 V to −0.5 V typical



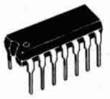
PIN CONNECTIONS						
Schematic	A	B	C	D	E	F
"G" Package	1	2	3	4	7	8
"F" Package	1	2	3	5	6	8
"L" & "P" Pkgs	2	3	4	6	9	11

F SUFFIX
CASE 606
(Formerly Case 72)
TO-91

G SUFFIX
CASE 601
(Formerly Case 96)
TO-99



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V+ V−	+14 −7.0	Vdc Vdc
Differential Input Signal	V_{in}	±5.0	Volts
Common Mode Input Swing	CMV_{in}	±7.0	Volts
Peak Load Current	I_L	10	mA
Power Dissipation (Package Limitation) Metal Can Derate above 25°C Flat Package Derate above 25°C Ceramic Dual In-Line Package Derate above 25°C Plastic Package Derate above 25°C	P_D	 680 4.6 500 3.3 600 4.8 400 3.3	 mW mW/°C mW mW/°C mW mW/°C mW mW/°C
Operating Temperature Range MC1710C MC1710	T_A	0 to +75 −55 to +125	°C
Storage Temperature Range G, F, & L Pkgs. P Pkg.	T_{stg}	−65 to +150 −65 to +125	°C

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

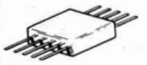
TYPE	V^+ (Vdc)	V^- (Vdc)	V_{io} (mV)	A_{VOL} (V/V)	V_{OH} (Vdc)	V_{OL} (Vdc)	t_R (ns)	CMV_{in} (Vdc)	TCV_{io} (μV/°C)
MC1710	+12	−6.0	1.0	1700	3.2	−0.5	40	±5.0	3.0
MC1710C	+12	−6.0	1.5	1500	3.2	−0.5	40	±5.0	5.0

MC1711CF,G,L,P (0 to +75°C)
MC1711F,G,L (−55 to +125°C)

. . . the MC1711 and MC1711C monolithic dual differential comparators are similar circuits specified over different temperature ranges. They are designed for use in level detection, low-level sensing, and memory applications.

Typical Characteristics:

- Differential Input
  Input Offset Voltage = 1.0 mV
  Offset Voltage Drift = 5.0 μV/°C
- Fast Response Time — 40 ns
- Output Compatible with All Saturating Logic Forms — V_{out} = +4.5 V to −0.5 V typical
- Low Output Impedance — 200 ohms



F SUFFIX
CASE 606
(Formerly Case 72)
TO-91

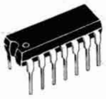
MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V+ V−	+14 −7.0	Vdc Vdc
Differential Input Signal	V_{in}	±5.0	Volts
Common Mode Input Swing	CMV_{in}	±7.0	Volts
Peak Load Current	I_L	50	mA
Power Dissipation (Package Limitation)	P_D		
Metal Can Derate above 25°C		680 4.6	mW mW/°C
Flat Package Derate above 25°C		500 3.3	mW mW/°C
Ceramic Dual In-Line Package Derate above 25°C		650 5.0	mW mW/°C
Plastic Package Derate above 25°C		400 3.3	mW mW/°C
Operating Temperature Range MC1711C MC1711	T_A	0 to +75 −55 to +125	°C
Storage Temperature Range G,F,&L Pkgs. P Pkg.	T_{stg}	−65 to +150 −65 to +125	°C

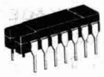
ELECTRICAL CHARACTERISTICS (T_A = 25°C)

TYPE	V+ (Vdc)	V− (Vdc)	V_{io} (mV)	A_{VOL} (V/V)	V_{OH} (Vdc)	V_{OL} (Vdc)	t_R (ns)	CMV_{in} (V_{pk})	TCV_{io} (μV/°C)
MC1711	+12	−6.0	1.0	1500	3.2	−0.5	40	±5.0	5.0
MC1711C	+12	−6.0	1.0	1500	3.2	−0.5	40	±5.0	5.0

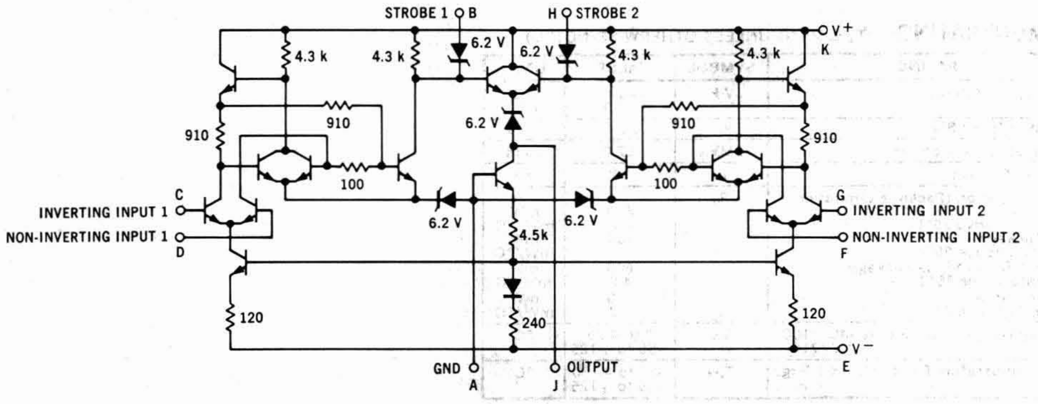
G SUFFIX
CASE 602A
(Formerly Case 71A)



P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



STROBE 1 B
H STROBE 2
V+
K
4.3 k
4.3 k
6.2 V
6.2 V
4.3 k
4.3 k
910
910
910
910
6.2 V
100
100
C
INVERTING INPUT 1
NON-INVERTING INPUT 1
D
6.2 V
6.2 V
4.5k
G
INVERTING INPUT 2
NON-INVERTING INPUT 2
F
120
240
120
V−
E
GND
A
OUTPUT
J

PIN CONNECTIONS

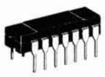
Schematic	A	B	C	D	E	F	G	H	J	K
"G" Package	1	2	3	4	5	6	7	8	9	10
"F" Package	9	10	1	2	3	4	5	6	7	8
"L"&"P"Pkgs	12	13	2	3	4	5	6	9	10	11

DUAL STEREO PREAMPLIFIERS

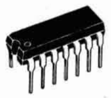
MC1303L,P (0 to +75°C)

. . . monolithic dual preamplifier designed for amplifying low-level signals in audio applications. Each preamplifier provides:

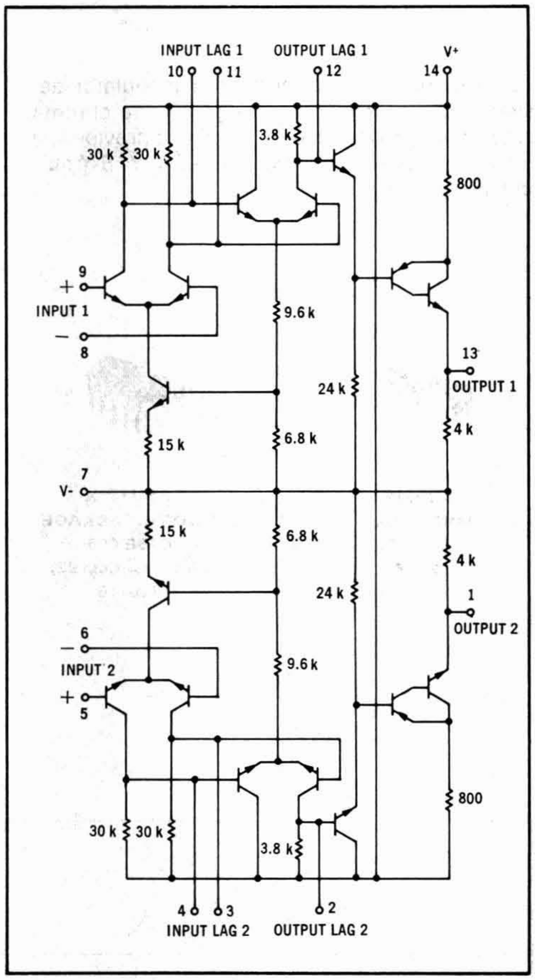
- Low Input Noise Voltage — 0.5 μV typical
- Large Output Voltage Swing — 4.5 Vrms min
- High Open-Loop Voltage Gain = 8,000 min
- Channel Separation = 60 dB min at 10 kHz
- Short-Circuit-Proof Design



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116



INPUT LAG 1
OUTPUT LAG 1
V+
10
11
12
14
3.8 k
30 k
30 k
800
9
+
INPUT 1
−
8
9.6 k
13
OUTPUT 1
24 k
4 k
15 k
6.8 k
7
V-
15 k
6.8 k
4 k
24 k
1
OUTPUT 2
6
−
INPUT 2
9.6 k
+
5
800
30 k
30 k
3.8 k
4
3
2
INPUT LAG 2
OUTPUT LAG 2

MAXIMUM RATINGS ($T_A = 25°C$ UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V+ V−	+15 −15	Vdc Vdc
Power Dissipation (Package Limitation) Derate above 25°C	P_D	625 5.0	mW mW/°C
Operating Temperature Range	T_A	0 to +75	°C

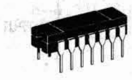
ELECTRICAL CHARACTERISTICS ($T_A = 25°C$)

TYPE	V+ and V− (Vdc)	A_{VOL} V/V	V_{out} V_{rms}	V_{io} (mV)	e_{out} 1 / e_{out} 2 dB
MC1303	+13 and −13	10,000	5.5	1.5	70

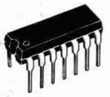
DUAL CHROMA DEMODULATORS

MC1325L,P (0 to +70°C)

. . . a monolithic dual chroma demodulator designed for color TV, requiring only the chroma signal and two phases of reference to provide low impedance signals to drive the R-Y, G-Y, B-Y output stages directly.



L SUFFIX
CERAMIC PACKAGE
CASE 605C
TO-116



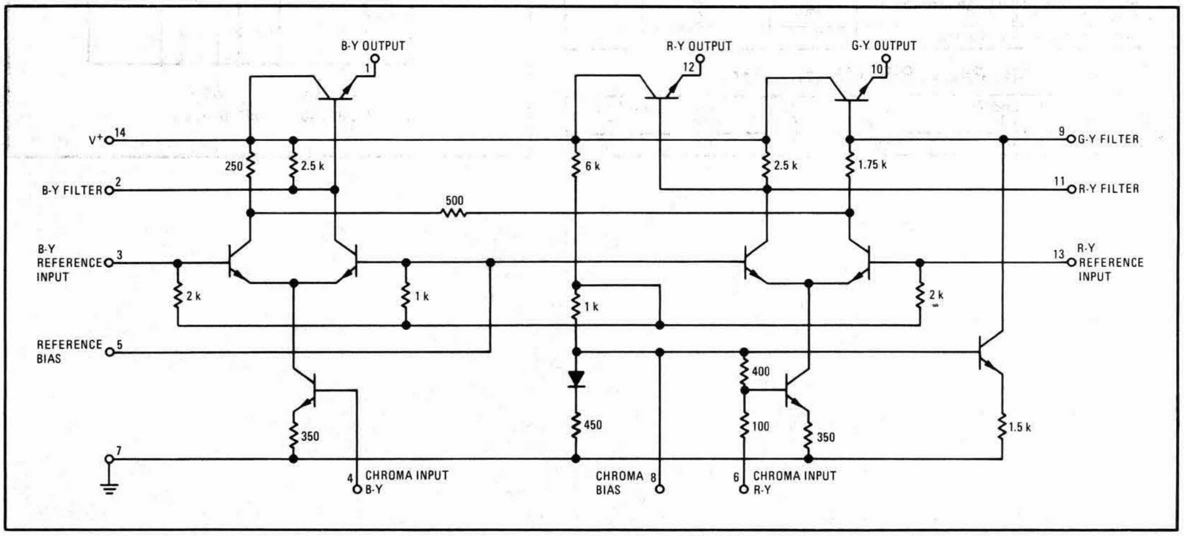
P SUFFIX
PLASTIC PACKAGE
CASE 605
(Formerly Case 93)
TO-116

MAXIMUM RATINGS (T$_A$ = 25°C UNLESS OTHERWISE NOTED)

RATING	SYMBOL	VALUE	UNIT
Power Supply Voltage	V^+	+24	Vdc
Reference Signal Input	e_r, e'_r	12	V_{p-p}
Output Current	I_{out}	30	mA
Chroma Signal Input	e_c	8.0	V_{p-p}
Power Dissipation (Package Limitation) Derate above T$_A$ = 25°C	P_D	625 5.0	mW mW/°C
Operating Temperature Range	T_A	0 to +70	°C

ELECTRICAL CHARACTERISTICS (T$_A$ = 25°C)

TYPE	V^+ (Vdc)	Z_O	Z_{in} (KΩ)	e_r, e'_r (V_{p-p})	V_{out} (undistorted) (V_{p-p})	Chroma Sig. (V_{p-p})
MC1325	+20	100	2.3	2.0 — 10	4.0	3.5


B-Y OUTPUT
1
R-Y OUTPUT
12
G-Y OUTPUT
10
V+ 14
250
2.5 k
6 k
2.5 k
1.75 k
9 G-Y FILTER
B-Y FILTER 2
11 R-Y FILTER
500
B-Y REFERENCE INPUT 3
13 R-Y REFERENCE INPUT
2 k
1 k
1 k
2 k
REFERENCE BIAS 5
400
100
350
350
450
1.5 k
7
4 CHROMA INPUT B-Y
CHROMA BIAS 8
6 CHROMA INPUT R-Y

VOLTAGE REGULATORS

MC1460G,R (0 to +75°C)
MC1560G,R (−55 to +125°C)

. . . positive-power-supply monolithic voltage regulators designed to deliver load current up to 600 mA without use of an external power transistor.

- Electronic "Shut-Down" Control and Short-Circuit Protection
- Excellent Load Regulation (Low Output Impedance = 20 milliohms typ from dc to 100 kHz)
- High Power Capability: up to 10 Watts
- Excellent Transient Response and Temperature Stability
- High Ripple Rejection = 0.002%/V typ
- Single External Transistor Can Boost Load Current to Greater Than 10 Amperes

MAXIMUM RATINGS ($T_C = 25°C$ UNLESS OTHERWISE NOTED)

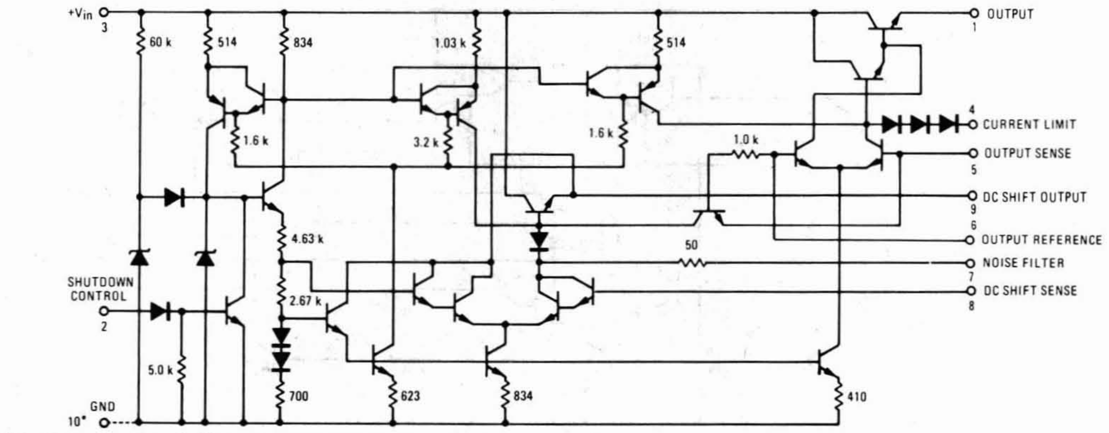
RATING	SYMBOL	VALUE		UNIT
Input Voltage	V_{in}	20		Vdc
		G Package	R Package	
Load Current	I_L	250	600	mA
Power Dissipation (Derate to $T_J = 150°C$) $T_A = 25°C$ Derate above $T_A = 25°C$ $T_C = 25°C$ Derate above $T_C = 25°C$ $T_C = 65°C$ Derate above $T_C = 65°C$	P_D	0.68 5.4 1.8 14.4 — —	2.0 16 — — 10 120	Watts mW/°C Watts mW/°C Watts mW/°C
Operating Temperature Range MC1460 MC1560	T_A	0 to +75 −55 to +125		°C
Storage Temperature Range	T_{stg}	−65 to +150		°C

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$)

TYPE	V_{in} max (Vdc)	V_O max (Vdc)	V_n (mVrms)	TC_{VO} (%/°C)	Z_{out} (mΩ)
MC1460	20	17	0.150	±0.002	25
MC1560	20	17	0.150	±0.002	15

G SUFFIX
CASE 602A
(Formerly Case 71A)

R SUFFIX
CASE 614


+Vin 3
60 k
514
834
1.03 k
514
1.6 k
3.2 k
1.6 k
1.0 k
OUTPUT 1
4 CURRENT LIMIT
OUTPUT SENSE 5
DC SHIFT OUTPUT 9
6 OUTPUT REFERENCE
50
NOISE FILTER 7
DC SHIFT SENSE 8
4.63 k
2.67 k
SHUTDOWN CONTROL 2
5.0 k
700
623
834
410
GND 10*

*Pin 10 is ground on "G" package, only case is ground on "R" package.

MC1461G,R (0 to +75°C)
MC1561G,R (−55 to +125°C)

. . . positive-power-supply monolithic voltage regulators designed to deliver load current up to 600 mA without use of an external power transistor.

- Electronic "Shut-Down" Control and Short-Circuit Protection
- Excellent Load Regulation (Low Output Impedance = 20 milliohms typ from dc to 100 kHz)
- High Power Capability: up to 17.5 Watts
- Excellent Transient Response and Temperature Stability
- High Ripple Rejection = 0.002%/V typ
- Single External Transistor Can Boost Load Current to Greater Than 10 Amperes

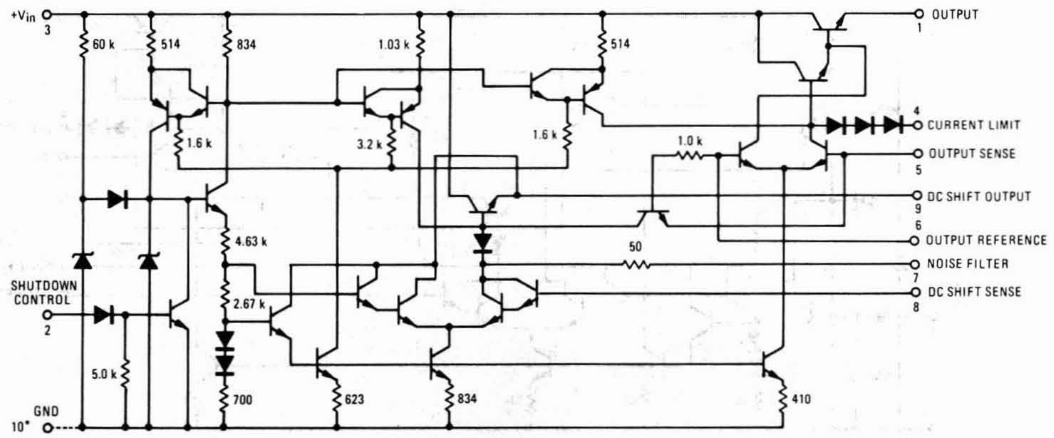
RATING	SYMBOL	VALUE		UNIT
Input Voltage	V_{in}	35		Vdc
		G Package	R Package	
Load Current	I_L	250	600	mA
Current, Pin 2	$I_{pin\ 2}$	10	10	mA
Power Dissipation (Derate to $T_J = 150°C$)	P_D			
$T_A = 25°C$		0.68	2.0	Watts
Derate above $T_A = 25°C$		5.4	16	mW/°C
$T_C = 25°C$		1.8	17.5	Watts
Derate above $T_C = 25°C$		14.4	120	mW/°C
Operating Temperature Range MC1461 MC1561	T_A	0 to +75 −55 to +125		°C
Storage Temperature Range	T_{stg}	−65 to +150		°C

ELECTRICAL CHARACTERISTICS ($T_C = 25°C$)

TYPE	V_{in} max (Vdc)	V_O max (Vdc)	V_{in} (mVrms)	TC_{VO} (%/°C)	Z_{out} (mΩ)
MC1461	35	32	0.150	±0.002	35
MC1561	40	37	0.150	±0.002	20

G SUFFIX
CASE 602A
(Formerly Case 71A)

R SUFFIX
CASE 614


+Vin 3
60 k
514
834
1.03 k
514
OUTPUT 1
1.6 k
3.2 k
1.6 k
1.0 k
4 CURRENT LIMIT
OUTPUT SENSE 5
DC SHIFT OUTPUT 9
6 OUTPUT REFERENCE
4.63 k
50
NOISE FILTER 7
SHUTDOWN CONTROL 2
2.67 k
DC SHIFT SENSE 8
5.0 k
700
623
834
410
GND 10*

*Pin 10 is ground on "G" package, only case is ground on "R" package.

OUTLINE DIMENSIONS

MOTOROLA CASE NUMBER CROSS REFERENCE

Case 1	TO-3
Case 3	TO-3*
Case 3A	TO-3*
Case 4	TO-41
Case 4-04	TO-41
Case 5	TO-36
Case 6	–
Case 7	TO-68
Case 8	–
Case 9	TO-61
Case 11	TO-3
Case 11A	TO-3*
Case 12	TO-3*
Case 16	TO-41*
Case 17	–
Case 19	–
Case 20	TO-72
Case 21	TO-17
Case 22	TO-18
Case 22A	TO-18*
Case 23	TO-107
Case 24	TO-102
Case 25	–
Case 26	TO-46
Case 27	TO-52
Case 28	–
Case 29	TO-92
Case 29A	–
Case 29B	See Case 182
Case 31	TO-5
Case 31A	Now Case 31 (2)
Case 32	–
Case 32A	–
Case 32B	TO-77
Case 32C	–
Case 33	TO-89
Case 33A	–
Case 34	–
Case 34A	TO-12
Case 35	TO-71
Case 36	TO-60
Case 39	TO-37
Case 41	–
Case 42	DO-5
Case 43	DO-21
Case 44	DO-4
Case 45	–
Case 45A	–
Case 46	–
Case 47	–
Case 47A	–
Case 47B	–
Case 48	–

Case 49	–
Case 51	DO-7
Case 52	DO-13
Case 53	–
Case 54	TO-3*
Case 55	–
Case 56	DO-4
Case 56A	DO-4
Case 56B	–
Case 57	–
Case 58	–
Case 59	DO-41
Case 60	–
Case 61	TO-41
Case 62	–
Case 63	–
Case 64	TO-48
Case 68	–
Case 70	–
Case 71	See Case 602B
Case 71A	See Case 602A
Case 72	See Case 606
Case 73	See Case 608
Case 77	–
Case 79	TO-39
Case 79A	–
Case 80	TO-66
Case 81	DO-31
Case 81A-01	–
Case 81A-02	–
Case 82	–
Case 83	TO-86
Case 85	–
Case 85L	–
Case 86	–
Case 86L	–
Case 87	–
Case 87L	–
Case 88	–
Case 88L	–
Case 90	–
Case 91	–
Case 92	–
Case 93	See Case 605
Case 94	–
Case 96	See Case 601
Case 96A	See Case 603
Case 98	See Case 604
Case 100	–
Case 101	See Cases 125-128
Case 102	See Cases 129-132

Case 103	See Cases 133-136
Case 104	See Cases 137-139
Case 105	–
Case 106	–
Case 107	–
Case 108	–
Case 109	–
Case 110	–
Case 111	–
Case 112	–
Case 113	–
Case 114	–
Case 115	–
Case 116	–
Case 117	–
Case 118	–
Case 119	–
Case 120	–
Case 121	–
Case 122	–
Case 123	–
Case 124	–
Case 125	Formerly Case 101
Case 126	Formerly Case 101
Case 127	Formerly Case 101
Case 128	Formerly Case 101
Case 129	Formerly Case 102
Case 130	Formerly Case 102
Case 131	Formerly Case 102
Case 132	Formerly Case 102
Case 133	Formerly Case 103
Case 134	Formerly Case 103
Case 135	Formerly Case 103
Case 136	Formerly Case 103
Case 137	Formerly Case 104
Case 138	Formerly Case 104
Case 139	Formerly Case 104
Case 142	–
Case 143	TO-9
Case 144	–
Case 144A	–
Case 144B	–
Case 145	–
Case 145A	–
Case 145B	–
Case 146	DO-14
Case 149	TO-1
Case 152	–
Case 154	–
Case 154A	–
Case 155	–
Case 155A	–
Case 156	–

*Modified

MOTOROLA CASE NUMBER CROSS REFERENCE (continued)

Case 156A	–
Case 157	–
Case 157A	–
Case 158	–
Case 159	–
Case 160	TO-59
Case 160A	TO-59
Case 161	TO-41
Case 166	Formerly Case 28A
Case 167	–
Case 168	–
Case 169	Formerly Case 59A
Case 171	–
Case 172	–
Case 173	–

Case 179	–
Case 180	–
Case 181	–
Case 182	Formerly Case 29B
Case 189	–
Case 190	–
Case 601	TO-99 Formerly Case 96
Case 602A	Formerly Case 71A
Case 602B	Formerly Case 71
Case 602C	Formerly Case 89
Case 603	TO-100 Formerly Case 96A
Case 604	Formerly Case 98
Case 605	TO-116 Formerly Case 93

Case 605C	TO-116
Case 606	TO-91 Formerly Case 72
Case 607	TO-86 Formerly Case 83
Case 608	TO-90 Formerly Case 73
Case 609	TO-85
Case 612	–
Case 614	–
Case 617	–
Case 618	–
Case 619	–
Case 620	–

REGISTERED CASE NUMBER CROSS REFERENCE

DO-4	Case 44 Case 56 Case 56A
DO-5	Case 42
DO-7	Case 51
DO-13	Case 52
DO-14	Case 146
DO-21	Case 43
DO-31	Case 81
DO-41	Case 59
TO-1	Case 149
TO-3	Case 1 Case 11
TO-3*	Case 3 Case 3A Case 11A Case 12 Case 54
TO-5	Case 31
TO-9	Case 143

TO-12	Case 34A
TO-17	Case 21
TO-18	Case 22
TO-18*	Case 22A
TO-36	Case 5
TO-37	Case 39
TO-39	Case 79
TO-41	Case 4 Case 4-04 Case 16 Case 61 Case 161
TO-46	Case 26
TO-48	Case 64
TO-52	Case 27
TO-59	Case 160 Case 160A
TO-60	Case 36
TO-61	Case 9
TO-66	Case 80
TO-68	Case 7
TO-71	Case 35

TO-72	Case 20
TO-77	Case 32B
TO-85	Case 609
TO-86	Case 83 Case 607
TO-89	Case 33
TO-90	Case 608 (Formerly Case 73)
TO-91	Case 606 (Formerly Case 72)
TO-92	Case 29
TO-99	Case 601 (Formerly Case 96)
TO-100	Case 603 (Formerly Case 96A
TO-102	Case 24
TO-107	Case 23
TO-116	Case 605 (Formerly Case 93) Case 605C

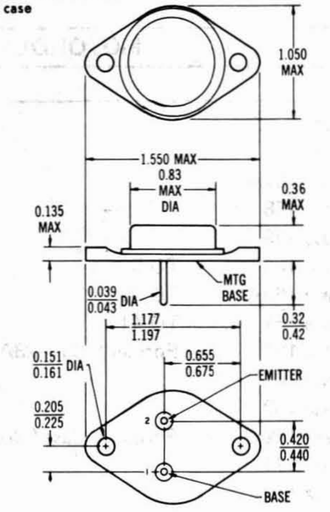
*Modified

CASE DIMENSIONS

All dimensions are in inches

CASE 1 TO-3 PACKAGE

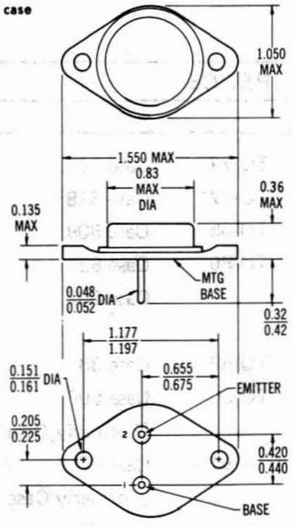
Collector connected
to case



1.050
MAX
1.550 MAX
0.83
MAX
DIA
0.36
MAX
0.135
MAX
0.039
0.043
DIA
MTG
BASE
0.32
0.42
1.177
1.197
0.151
0.161
DIA
0.655
0.675
EMITTER
0.205
0.225
2
0.420
0.440
1
BASE

CASE 3 (TO-3 Except Pin Diameter)

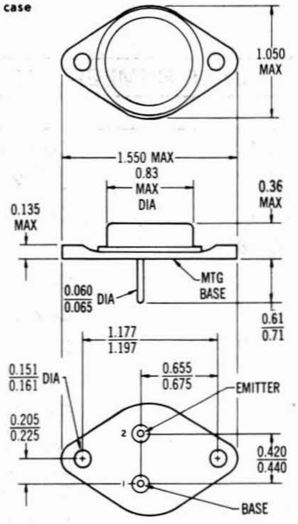
Collector connected
to case



1.050
MAX
1.550 MAX
0.83
MAX
DIA
0.36
MAX
0.135
MAX
0.048
0.052
DIA
MTG
BASE
0.32
0.42
1.177
1.197
0.151
0.161
DIA
0.655
0.675
EMITTER
0.205
0.225
2
0.420
0.440
1
BASE

CASE 3A (TO-3 Except Pin Diameter)

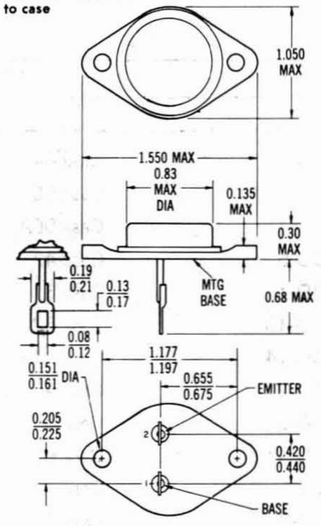
Collector connected
to case



1.050
MAX
1.550 MAX
0.83
MAX
DIA
0.36
MAX
0.135
MAX
0.060
0.065
DIA
MTG
BASE
0.61
0.71
1.177
1.197
0.151
0.161
DIA
0.655
0.675
EMITTER
0.205
0.225
2
0.420
0.440
1
BASE

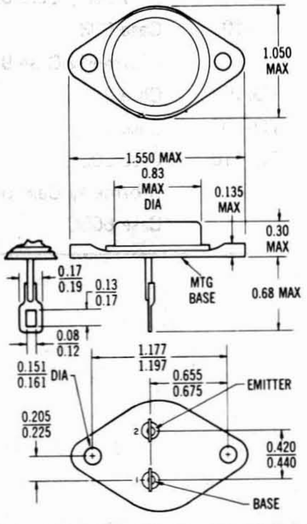
CASE 4 TO-41 PACKAGE

Collector connected
to case



1.050
MAX
1.550 MAX
0.83
MAX
DIA
0.135
MAX
0.30
MAX
0.19
0.21
0.13
0.17
MTG
BASE
0.68 MAX
0.08
0.12
1.177
1.197
0.151
0.161
DIA
0.655
0.675
EMITTER
0.205
0.225
2
0.420
0.440
1
BASE

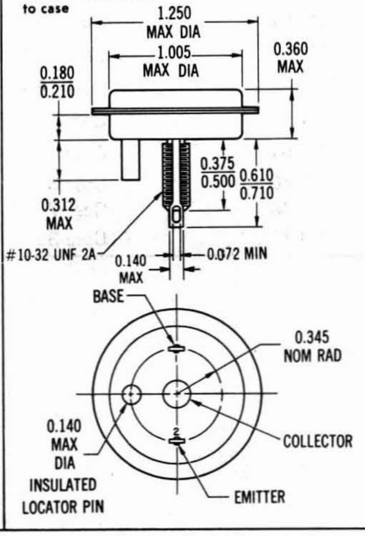
CASE 4-04 TO-41 PACKAGE



1.050
MAX
1.550 MAX
0.83
MAX
DIA
0.135
MAX
0.30
MAX
0.17
0.19
0.13
0.17
MTG
BASE
0.68 MAX
0.08
0.12
1.177
1.197
0.151
0.161
DIA
0.655
0.675
EMITTER
0.205
0.225
2
0.420
0.440
1
BASE

CASE 5 TO-36 PACKAGE

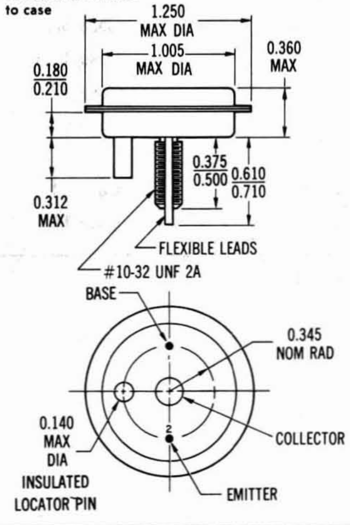
Collector connected
to case



1.250
MAX DIA
1.005
MAX DIA
0.360
MAX
0.180
0.210
0.375
0.500
0.610
0.710
0.312
MAX
#10-32 UNF 2A
0.140
MAX
0.072 MIN
BASE
1
0.345
NOM RAD
0.140
MAX
DIA
INSULATED
LOCATOR PIN
2
COLLECTOR
EMITTER

CASE 6

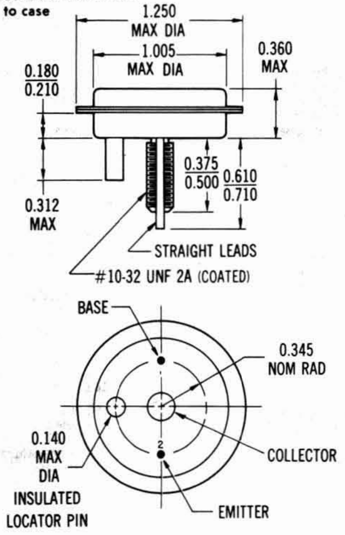
Collector connected
to case



1.250
MAX DIA
1.005
MAX DIA
0.360
MAX
0.180
0.210
0.375
0.500
0.610
0.710
0.312
MAX
FLEXIBLE LEADS
#10-32 UNF 2A
BASE
0.345
NOM RAD
0.140
MAX
DIA
INSULATED
LOCATOR PIN
2
COLLECTOR
EMITTER

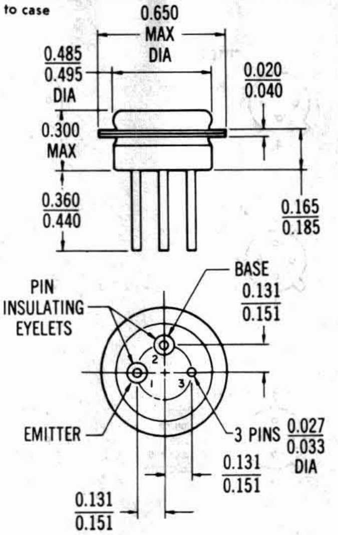
CASE 7 TO-68 PACKAGE

Collector connected to case

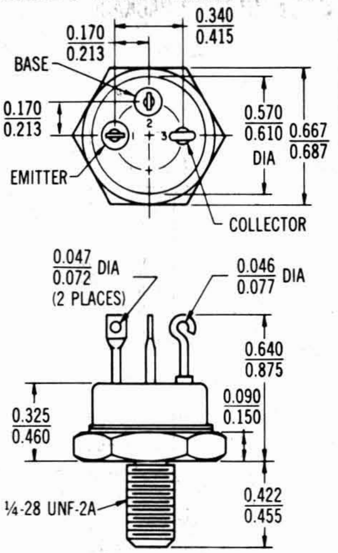

1.250
MAX DIA
1.005
MAX DIA
0.360
MAX
0.180
0.210
0.375
0.500
0.610
0.710
0.312
MAX
STRAIGHT LEADS
#10-32 UNF 2A (COATED)
BASE
0.345
NOM RAD
0.140
MAX
DIA
INSULATED
LOCATOR PIN
COLLECTOR
EMITTER
1
2

CASE 8

Collector connected to case

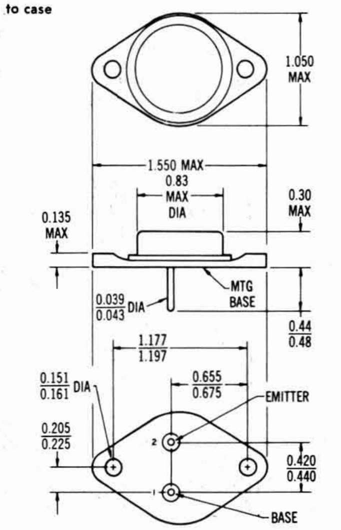

0.650
MAX
DIA
0.485
0.495
DIA
0.020
0.040
0.300
MAX
0.360
0.440
0.165
0.185
PIN
INSULATING
EYELETS
BASE
0.131
0.151
EMITTER
3 PINS
0.027
0.033
DIA
0.131
0.151
0.131
0.151
1
2
3

CASE 9 TO-61 PACKAGE


0.170
0.213
0.340
0.415
BASE
0.170
0.213
0.570
0.610
DIA
0.667
0.687
EMITTER
COLLECTOR
1
2
3
0.047
0.072 DIA
(2 PLACES)
0.046
0.077 DIA
0.640
0.875
0.090
0.150
0.325
0.460
¼-28 UNF-2A
0.422
0.455

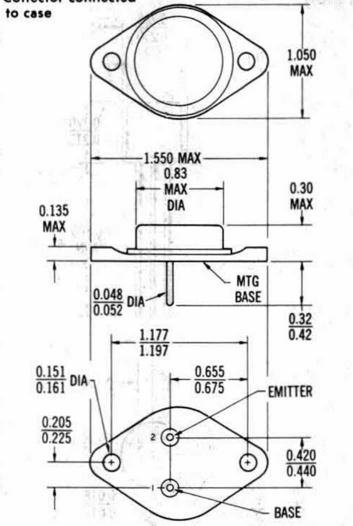
CASE 11 TO-3 PACKAGE

Collector connected to case


1.050
MAX
1.550 MAX
0.83
MAX
DIA
0.30
MAX
0.135
MAX
MTG
BASE
0.039
0.043 DIA
0.44
0.48
1.177
1.197
0.151
0.161 DIA
0.655
0.675
EMITTER
0.205
0.225
2
0.420
0.440
1
BASE

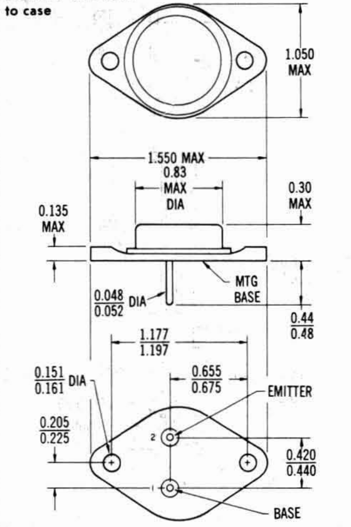
CASE 11A (TO-3 Except Pin Diameter)

Collector connected to case


1.050
MAX
1.550 MAX
0.83
MAX
DIA
0.30
MAX
0.135
MAX
MTG
BASE
0.048
0.052 DIA
0.32
0.42
1.177
1.197
0.151
0.161 DIA
0.655
0.675
EMITTER
0.205
0.225
2
0.420
0.440
1
BASE

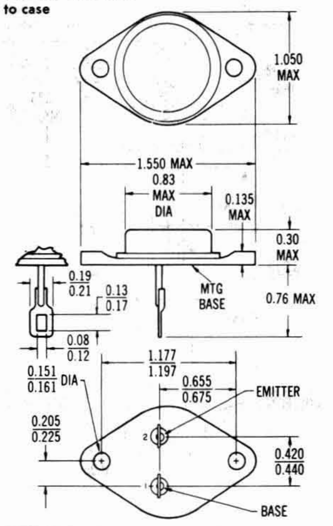
CASE 12 (TO-3 Except Pin Diameter)

Collector connected to case

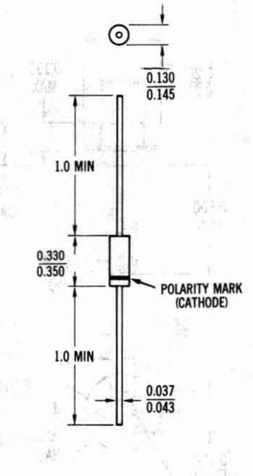

1.050
MAX
1.550 MAX
0.83
MAX
DIA
0.30
MAX
0.135
MAX
MTG
BASE
0.048
0.052 DIA
0.44
0.48
1.177
1.197
0.151
0.161 DIA
0.655
0.675
EMITTER
0.205
0.225
2
0.420
0.440
1
BASE

CASE 16 (TO-41 Except Lug Length)

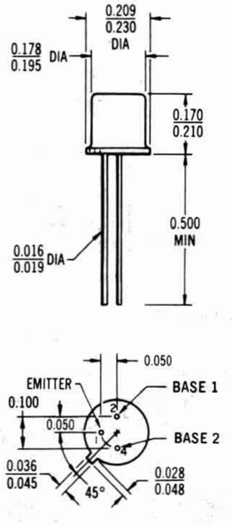
Collector connected to case


1.050
MAX
1.550 MAX
0.83
MAX
DIA
0.135
MAX
0.30
MAX
0.19
0.21
0.13
0.17
MTG
BASE
0.76 MAX
0.08
0.12
1.177
1.197
0.151
0.161 DIA
0.655
0.675
EMITTER
0.205
0.225
2
0.420
0.440
1
BASE

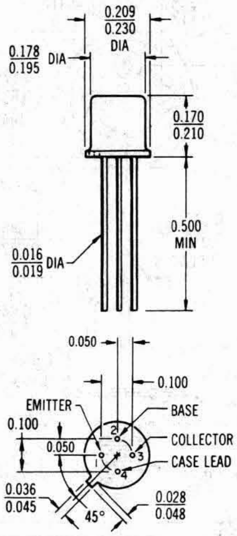
CASE 17


0.130
0.145
1.0 MIN
0.330
0.350
POLARITY MARK
(CATHODE)
1.0 MIN
0.037
0.043

CASE 19

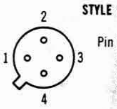

0.209
0.230
DIA
0.178
0.195 DIA
0.170
0.210
0.500
MIN
0.016
0.019 DIA
0.050
EMITTER
BASE 1
0.100
0.050
BASE 2
0.036
0.045
45°
0.028
0.048
1
2
3

CASE 20 TO-72 PACKAGE


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
EMITTER
BASE
0.100
COLLECTOR
0.050
CASE LEAD
1
2
3
4
0.036
0.045
45°
0.028
0.048

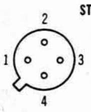
CASE 20 STYLES

STYLE 1



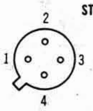
Pin 1. Source
2. Drain
3. Gate
4. Case

STYLE 2



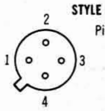
Pin 1. Source
2. Gate
3. Drain
4. Substrate and Case

STYLE 3



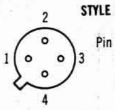
Pin 1. Drain
2. Source
3. Gate
4. Case

STYLE 4



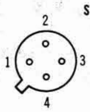
Pin 1. Source
2. Gate 1
3. Drain
4. Gate 2 — Substrate and Case

STYLE 5



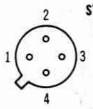
Pin 1. Source
2. Gate
3. Drain
4. Case

STYLE 6



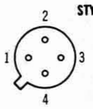
Pin 1. Drain
2. Source and Substrate
3. Gate
4. Source and Substrate

STYLE 7



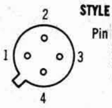
Pin 1. Drain
2. Source
3. Gate
4. Case and Substrate

STYLE 8



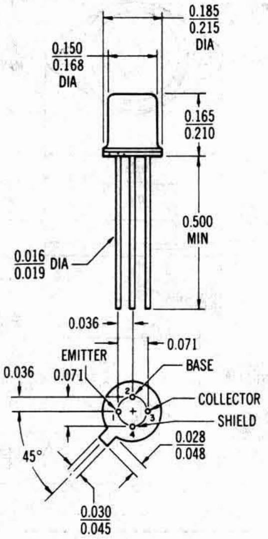
Pin 1. Emitter 2
2. Base 1
3. Collector
4. Emitter 1, Base 2

STYLE 9

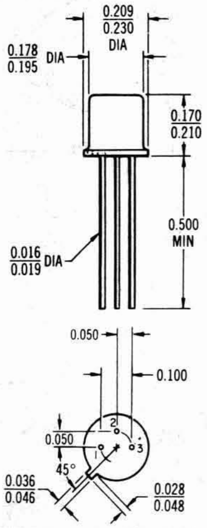


Pin 1. Drain
2. Gate 2
3. Gate 1
4. Source, Substrate and Case

CASE 21 TO-17 PACKAGE

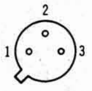

0.185
0.215
DIA
0.150
0.168
DIA
0.165
0.210
0.500
MIN
0.016
0.019
DIA
0.036
0.071
EMITTER
BASE
0.036
0.071
COLLECTOR
SHIELD
1
2
3
4
0.028
0.048
45°
0.030
0.045

CASE 22 TO-18 PACKAGE


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
0.050
45°
1
2
3
0.036
0.046
0.028
0.048

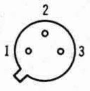
CASE 22 STYLES

STYLE 1



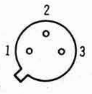
Pin 1. Emitter
2. Base
3. Collector

STYLE 2



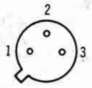
Pin 1. Source Substrate, and Case
2. Gate
3. Drain

STYLE 3



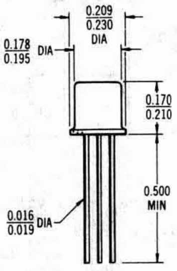
Pin 1. Source
2. Drain
3. Gate

STYLE 4

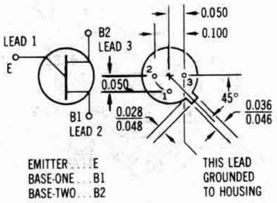


Pin 1. Source
2. Drain
3. Gate and Case

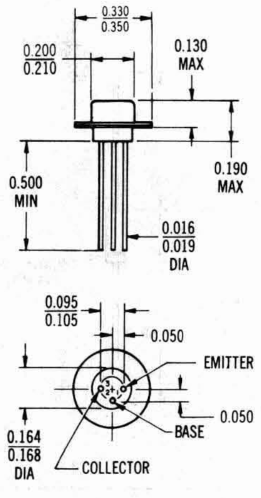
CASE 22A (TO-18 Except Lead Position)


0.209
0.230
DIA
0.178
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA

APPROX. WEIGHT .015 OZ.

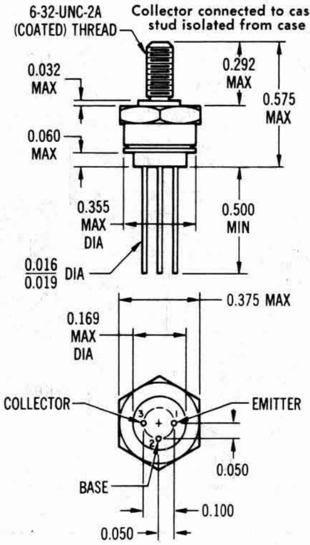

LEAD 1
E
B2
LEAD 3
B1
LEAD 2
0.050
0.100
0.050
2
1
3
45°
0.028
0.048
0.036
0.046
EMITTER . . . . E
BASE-ONE . . . B1
BASE-TWO . . . B2
THIS LEAD GROUNDED TO HOUSING

CASE 23 TO-107 PACKAGE

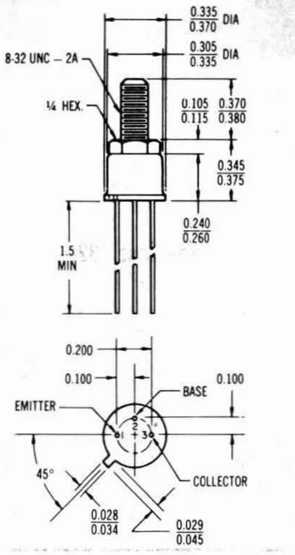

0.330
0.350
0.200
0.210
0.130
MAX
0.500
MIN
0.190
MAX
0.016
0.019
DIA
0.095
0.105
0.050
EMITTER
0.050
BASE
0.164
0.168
DIA
COLLECTOR
1
2
3

CASE 24 TO-102 PACKAGE

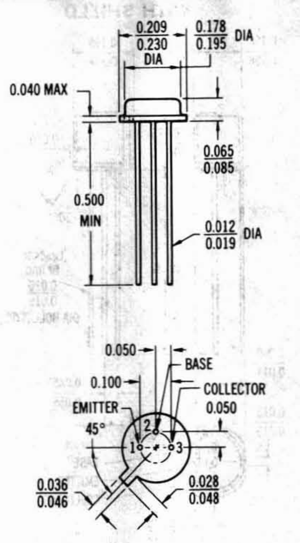
Collector connected to case; stud isolated from case


6-32-UNC-2A
(COATED) THREAD
0.032
MAX
0.292
MAX
0.575
MAX
0.060
MAX
0.355
MAX
DIA
0.500
MIN
0.016
0.019
DIA
0.375 MAX
0.169
MAX
DIA
COLLECTOR
EMITTER
1
2
3
0.050
BASE
0.100
0.050

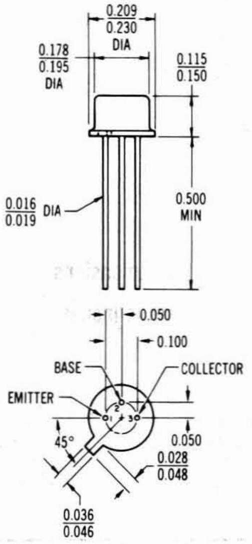
CASE 25


0.335/0.370 DIA
0.305/0.335 DIA
8-32 UNC – 2A
¼ HEX.
0.105/0.115
0.370/0.380
0.345/0.375
0.240/0.260
1.5 MIN
0.200
0.100
0.100
EMITTER
BASE
1
2
3
45°
COLLECTOR
0.028/0.034
0.029/0.045

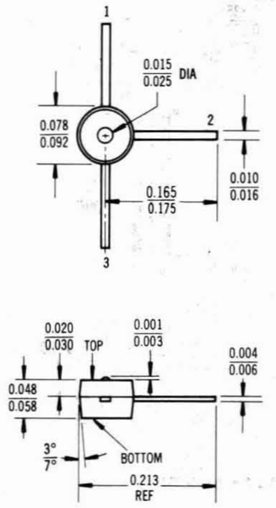
CASE 26 TO-46 PACKAGE


0.209/0.230 DIA
0.178/0.195 DIA
0.040 MAX
0.065/0.085
0.500 MIN
0.012/0.019 DIA
0.050
BASE
0.100
COLLECTOR
EMITTER
0.050
45°
1
2
3
0.036/0.046
0.028/0.048

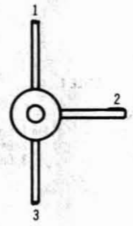
CASE 27 TO-52 PACKAGE


0.209/0.230 DIA
0.178/0.195 DIA
0.115/0.150
0.016/0.019 DIA
0.500 MIN
0.050
0.100
BASE
COLLECTOR
EMITTER
1
2
3
45°
0.050
0.028/0.048
0.036/0.046

CASE 28

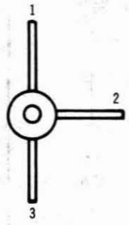

1
0.015/0.025 DIA
0.078/0.092
2
0.010/0.016
0.165/0.175
3
0.020/0.030
TOP
0.001/0.003
0.004/0.006
0.048/0.058
3°/7°
BOTTOM
0.213 REF

CASE 28 STYLES



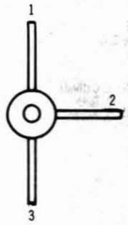
STYLE 1

Pin 1. Base
2. Emitter
3. Collector



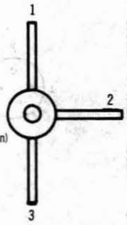
STYLE 2

Pin 1. Anode 2
2. Anode 1
3. Cathode (Common)



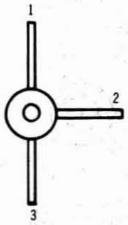
STYLE 3

Pin 1. Cathode 2
2. Cathode 1
3. Anode (Common)



STYLE 4

Pin 1. Cathode 1
2. Anode 2
3. Cathode 2, Anode 1

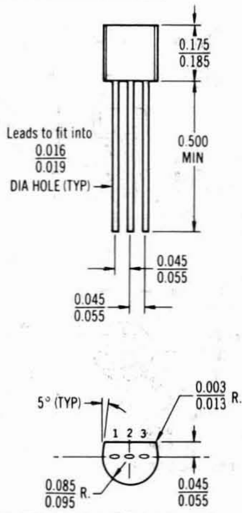


STYLE 5

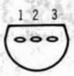
Pin 1. Drain
2. Source
3. Gate

CASE 29 TO-92 PACKAGE

PLASTIC TRANSISTOR

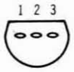

0.175/0.185
Leads to fit into 0.016/0.019 DIA HOLE (TYP)
0.500 MIN
0.045/0.055
0.045/0.055
5° (TYP)
0.003/0.013 R.
1 2 3
0.085/0.095 R.
0.045/0.055

CASE 29 STYLES



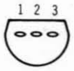
STYLE 1

Pin 1. Emitter
2. Base
3. Collector



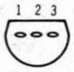
STYLE 2

Pin 1. Base
2. Emitter
3. Collector



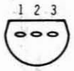
STYLE 3

Pin 1. Anode
2. Anode
3. Cathode



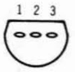
STYLE 4

Pin 1. Cathode
2. Cathode
3. Anode



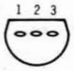
STYLE 5

Pin 1. Drain
2. Source
3. Gate



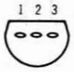
STYLE 6

Pin 1. Gate
2. Source and Substrate
3. Drain



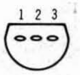
STYLE 7

Pin 1. Source
2. Drain
3. Gate



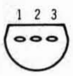
STYLE 8

Pin 1. Drain
2. Gate
3. Source and Substrate



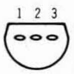
STYLE 9

Pin 1. Base 1
2. Emitter
3. Base 2



STYLE 10

Pin 1. Cathode
2. Gate
3. Anode

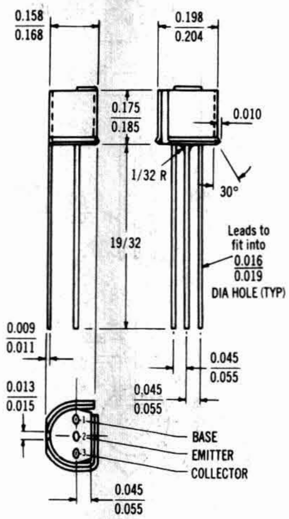


STYLE 11

Pin 1. Anode
2. Cathode and Anode
3. Cathode

All dimensions are in inches

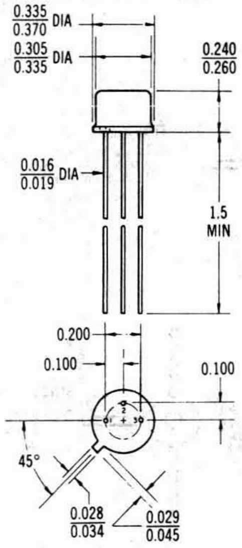
CASE 29A PLASTIC TRANSISTOR WITH SHIELD


0.158/0.168
0.198/0.204
0.175/0.185
0.010
1/32 R
30°
19/32
Leads to fit into 0.016/0.019 DIA HOLE (TYP)
0.009/0.011
0.045/0.055
0.013/0.015
0.045/0.055
1
2
3
BASE
EMITTER
COLLECTOR
0.045/0.055

CASE 29B

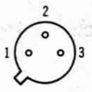
See Case 182

CASE 31 TO-5 PACKAGE


0.335/0.370 DIA
0.305/0.335 DIA
0.240/0.260
0.016/0.019 DIA
1.5 MIN
0.200
0.100
0.100
1
2
3
45°
0.028/0.034
0.029/0.045

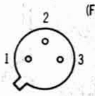
CASE 31 STYLES

STYLE 1



Pin 1. Emitter
2. Base
3. Collector

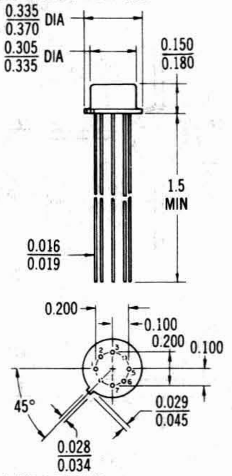
STYLE 2
(Formerly Case 31A)



Pin 1. Cathode
2. Gate
3. Anode

CASE 32

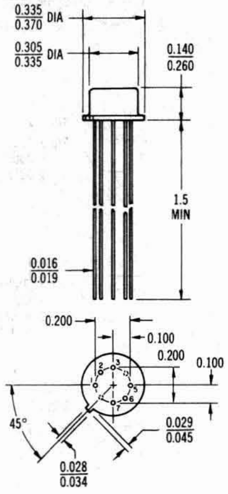
All leads isolated from case


0.335/0.370 DIA
0.305/0.335 DIA
0.150/0.180
1.5 MIN
0.016/0.019
0.200
0.100
0.200
0.100
45°
0.029/0.045
0.028/0.034

PINS 4 AND 8 OMITTED

CASE 32A

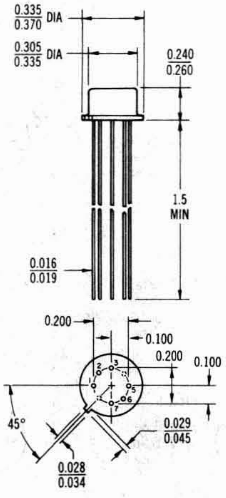
All leads isolated from case


0.335/0.370 DIA
0.305/0.335 DIA
0.140/0.260
1.5 MIN
0.016/0.019
0.200
0.100
0.200
0.100
45°
0.029/0.045
0.028/0.034

PINS 4 AND 8 OMITTED

CASE 32B TO-77 PACKAGE

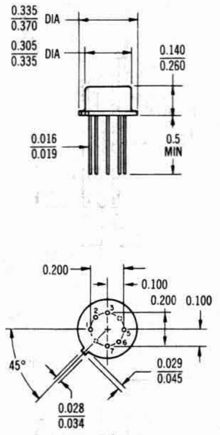
All leads isolated from case


0.335/0.370 DIA
0.305/0.335 DIA
0.240/0.260
1.5 MIN
0.016/0.019
0.200
0.100
0.200
0.100
45°
0.029/0.045
0.028/0.034

PINS 4 AND 8 OMITTED

CASE 32C

All leads isolated from case

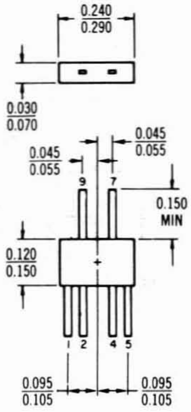

0.335/0.370 DIA
0.305/0.335 DIA
0.140/0.260
0.5 MIN
0.016/0.019
0.200
0.100
0.200
0.100
45°
0.029/0.045
0.028/0.034

PINS 4 AND 8 OMITTED

CASE 33 TO-89 PACKAGE

All leads isolated from case

Lead 1 identified by square impression on underside of case.

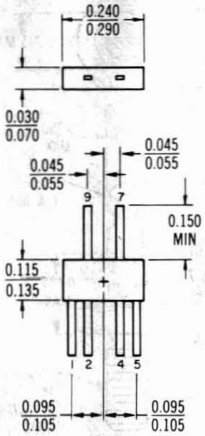


0.240
0.290
0.030
0.070
0.045
0.055
0.045
0.055
9
7
0.150
MIN
0.120
0.150
1
2
4
5
0.095
0.105
0.095
0.105

CASE 33A

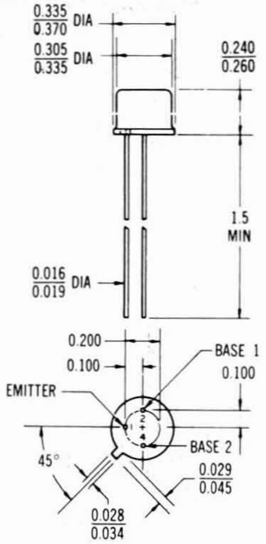
All leads isolated from case

Lead 1 identified by square impression on underside of case.



0.240
0.290
0.030
0.070
0.045
0.055
0.045
0.055
9
7
0.150
MIN
0.115
0.135
1
2
4
5
0.095
0.105
0.095
0.105

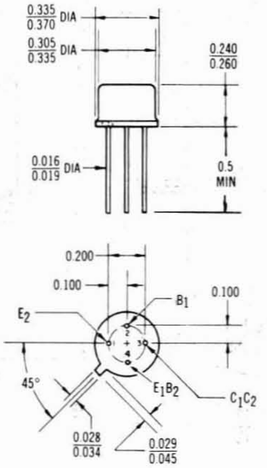
CASE 34



0.335
0.370
DIA
0.305
0.335
DIA
0.240
0.260
1.5
MIN
0.016
0.019
DIA
0.200
0.100
BASE 1
0.100
EMITTER
BASE 2
45°
0.029
0.045
0.028
0.034

CASE 34A TO-12 PACKAGE

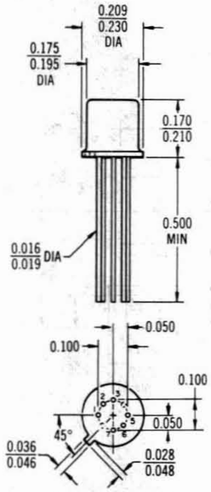
Collectors connected to case



0.335
0.370
DIA
0.305
0.335
DIA
0.240
0.260
0.016
0.019
DIA
0.5
MIN
0.200
0.100
B1
0.100
E2
45°
E1B2
C1C2
0.028
0.034
0.029
0.045

CASE 35 TO-71 PACKAGE

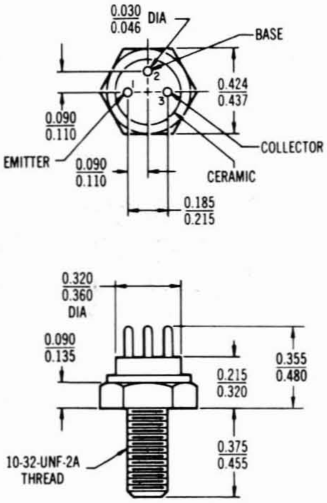
All leads isolated from case



0.209
0.230
DIA
0.175
0.195
DIA
0.170
0.210
0.500
MIN
0.016
0.019
DIA
0.050
0.100
0.100
0.050
45°
0.036
0.046
0.028
0.048

PINS 4 AND 8 OMITTED

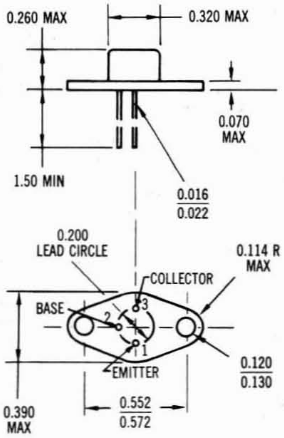
CASE 36 TO-60 PACKAGE



0.030
0.046
DIA
BASE
0.424
0.437
0.090
0.110
EMITTER
0.090
0.110
COLLECTOR
CERAMIC
0.185
0.215
0.320
0.360
DIA
0.090
0.135
0.215
0.320
0.355
0.480
0.375
0.455
10-32-UNF-2A
THREAD

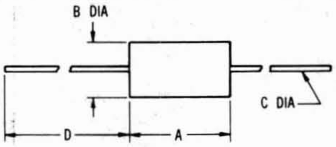
CASE 39 TO-37 PACKAGE

Collector connected to case



0.260 MAX
0.320 MAX
0.070
MAX
1.50 MIN
0.016
0.022
0.200
LEAD CIRCLE
0.114 R
MAX
COLLECTOR
BASE
2
3
1
EMITTER
0.120
0.130
0.390
MAX
0.552
0.572

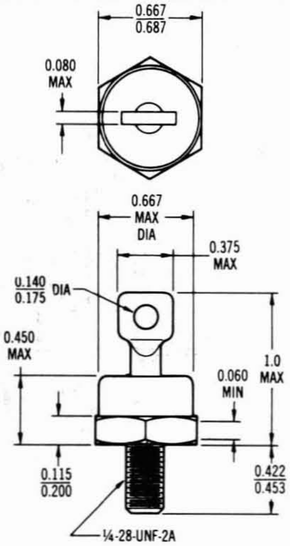
CASE 41



B DIA
C DIA
D
A

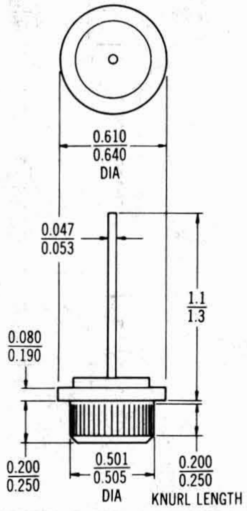
PKG.	OUTLINE DIMENSIONS (INCHES)			
	A MAX	B MAX	C ±0.002	D MIN
41-1	1.00	0.500	0.032	1.25
41-2	0.500	0.375	0.032	1.25
41-3	1.030	0.378	0.032	1.25
41-4	1.220	0.641	0.032	1.75
41-5	0.655	0.641	0.032	1.25
41-6	0.520	0.275	0.020	1.25
41-7	1.000	0.375	0.032	1.25
41-8	0.520	0.260	0.030	1.00
41-9	0.780	0.260	0.030	1.00
41-10	1.155	0.323	0.030	1.00

CASE 42 DO-5 PACKAGE

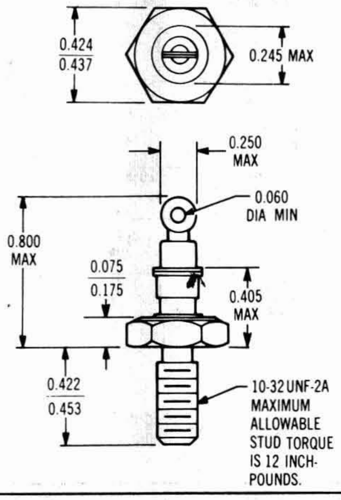


0.667
0.687
0.080
MAX
0.667
MAX
DIA
0.375
MAX
0.140
0.175
DIA
0.450
MAX
1.0
MAX
0.060
MIN
0.115
0.200
0.422
0.453
¼-28-UNF-2A

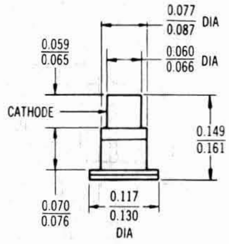
CASE 43 DO-21 PACKAGE


0.610/0.640 DIA
0.047/0.053
1.1/1.3
0.080/0.190
0.200/0.250
0.501/0.505 DIA
0.200/0.250 KNURL LENGTH

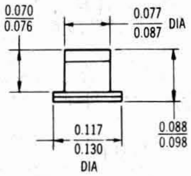
CASE 44 DO-4 PACKAGE


0.424/0.437
0.245 MAX
0.250 MAX
0.060 DIA MIN
0.800 MAX
0.075/0.175
0.405 MAX
0.422/0.453
10-32 UNF-2A MAXIMUM ALLOWABLE STUD TORQUE IS 12 INCH-POUNDS.

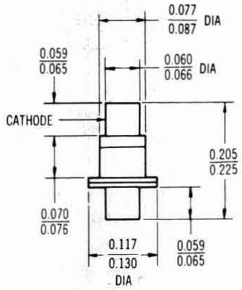
CASE 45


0.077/0.087 DIA
0.059/0.065
0.060/0.066 DIA
CATHODE
0.149/0.161
0.070/0.076
0.117/0.130 DIA

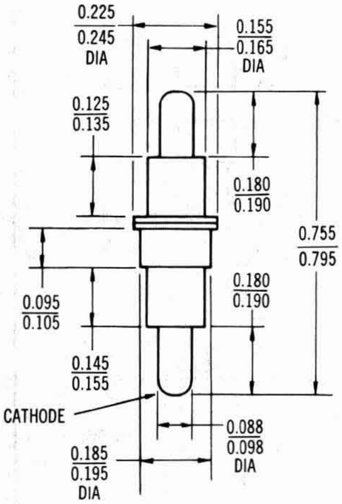
CASE 45A


0.070/0.076
0.077/0.087 DIA
0.117/0.130 DIA
0.088/0.098

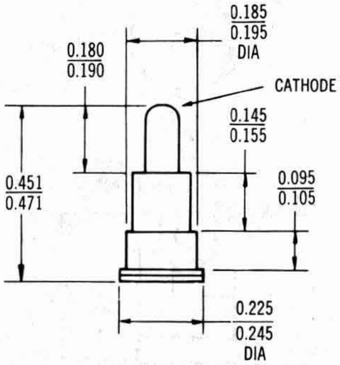
CASE 46


0.077/0.087 DIA
0.059/0.065
0.060/0.066 DIA
CATHODE
0.205/0.225
0.070/0.076
0.117/0.130 DIA
0.059/0.065

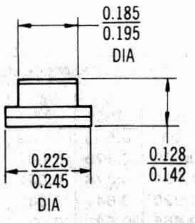
CASE 47


0.225/0.245 DIA
0.155/0.165 DIA
0.125/0.135
0.180/0.190
0.755/0.795
0.095/0.105
0.180/0.190
0.145/0.155
CATHODE
0.088/0.098 DIA
0.185/0.195 DIA

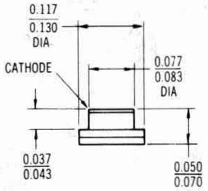
CASE 47A


0.185/0.195 DIA
0.180/0.190
CATHODE
0.145/0.155
0.451/0.471
0.095/0.105
0.225/0.245 DIA

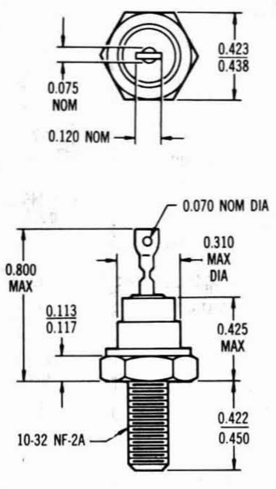
CASE 47B


0.185/0.195 DIA
0.128/0.142
0.225/0.245 DIA

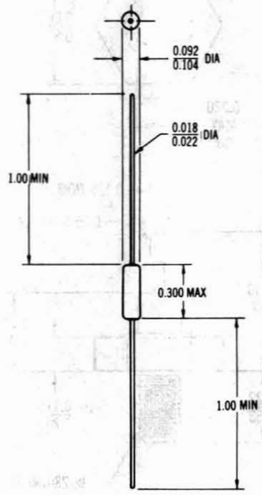
CASE 48


0.117/0.130 DIA
CATHODE
0.077/0.083 DIA
0.037/0.043
0.050/0.070

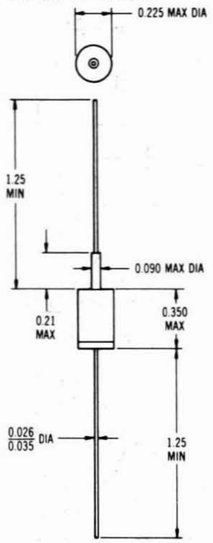
CASE 49


0.423
0.438
0.075
NOM
0.120 NOM
0.070 NOM DIA
0.310
MAX
DIA
0.800
MAX
0.113
0.117
0.425
MAX
0.422
0.450
10-32 NF-2A

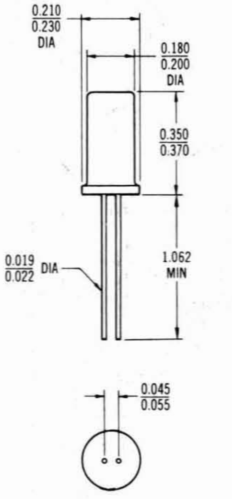
CASE 51 DO-7 PACKAGE


0.092
0.104
DIA
0.018
0.022
DIA
1.00 MIN
0.300 MAX
1.00 MIN

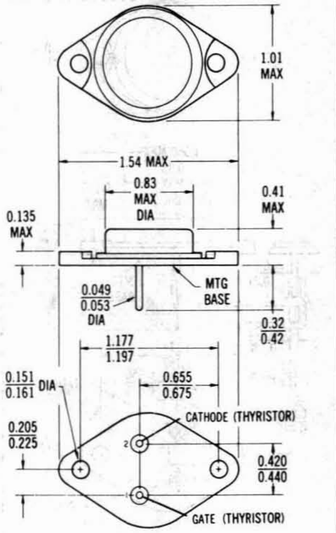
CASE 52 DO-13 PACKAGE


0.225 MAX DIA
1.25
MIN
0.090 MAX DIA
0.21
MAX
0.350
MAX
0.026
0.035
DIA
1.25
MIN

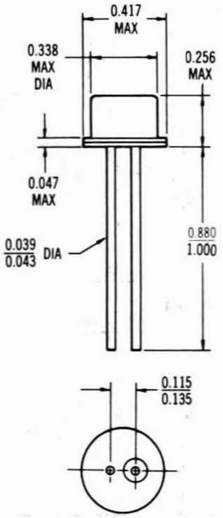
CASE 53


0.210
0.230
DIA
0.180
0.200
DIA
0.350
0.370
0.019
0.022
DIA
1.062
MIN
0.045
0.055

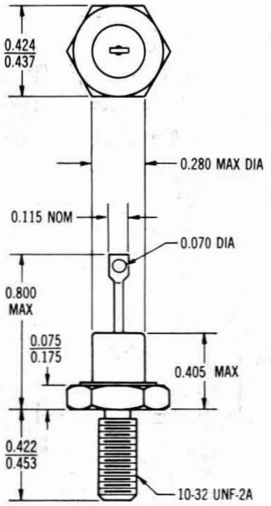
CASE 54 TO-3 Except Pin Diameter


1.01
MAX
1.54 MAX
0.83
MAX
DIA
0.41
MAX
0.135
MAX
MTG
BASE
0.049
0.053
DIA
0.32
0.42
1.177
1.197
0.151
0.161
DIA
0.655
0.675
CATHODE (THYRISTOR)
0.205
0.225
2
0.420
0.440
1
GATE (THYRISTOR)

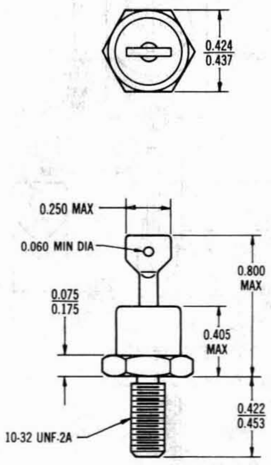
CASE 55


0.417
MAX
0.338
MAX
DIA
0.256
MAX
0.047
MAX
0.039
0.043
DIA
0.880
1.000
0.115
0.135

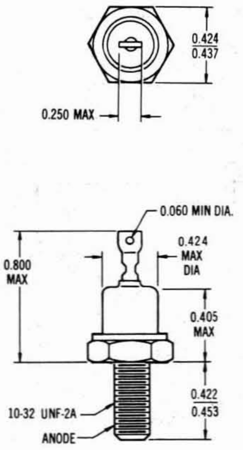
CASE 56 DO-4 PACKAGE


0.424
0.437
0.280 MAX DIA
0.115 NOM
0.070 DIA
0.800
MAX
0.075
0.175
0.405 MAX
0.422
0.453
10-32 UNF-2A

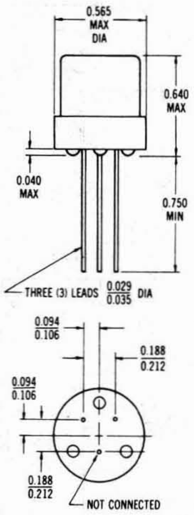
CASE 56A DO-4 PACKAGE


0.424
0.437
0.250 MAX
0.060 MIN DIA
0.800
MAX
0.075
0.175
0.405
MAX
0.422
0.453
10-32 UNF-2A

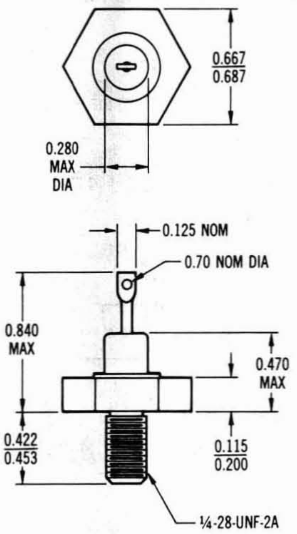
CASE 56B


0.424
0.437
0.250 MAX
0.060 MIN DIA.
0.424
MAX
DIA
0.800
MAX
0.405
MAX
0.422
0.453
10-32 UNF-2A
ANODE

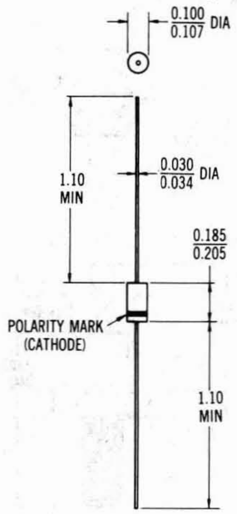
CASE 57


0.565 MAX DIA
0.640 MAX
0.040 MAX
0.750 MIN
THREE (3) LEADS 0.029/0.035 DIA
0.094/0.106
0.188/0.212
0.094/0.106
0.188/0.212
NOT CONNECTED

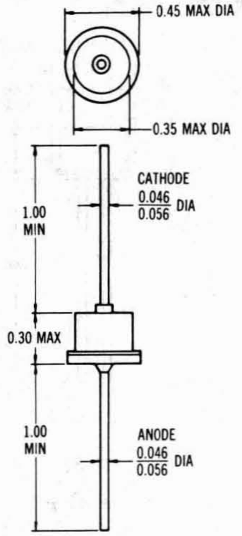
CASE 58


0.667/0.687
0.280 MAX DIA
0.125 NOM
0.70 NOM DIA
0.840 MAX
0.470 MAX
0.422/0.453
0.115/0.200
¼-28-UNF-2A

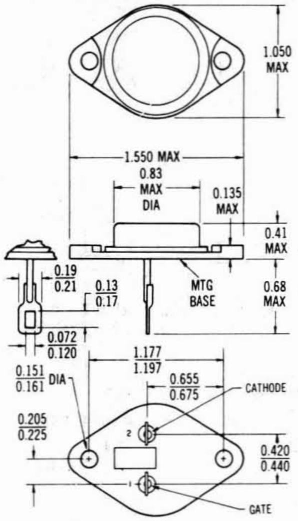
CASE 59 DO-41 PACKAGE


0.100/0.107 DIA
1.10 MIN
0.030/0.034 DIA
0.185/0.205
POLARITY MARK (CATHODE)
1.10 MIN

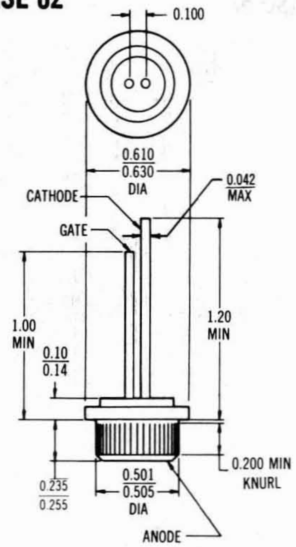
CASE 60


0.45 MAX DIA
0.35 MAX DIA
CATHODE
0.046/0.056 DIA
1.00 MIN
0.30 MAX
1.00 MIN
ANODE
0.046/0.056 DIA

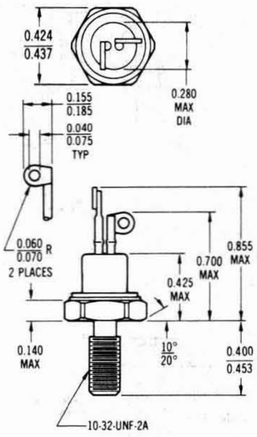
CASE 61 TO-41 PACKAGE


1.050 MAX
1.550 MAX
0.83 MAX DIA
0.135 MAX
0.41 MAX
0.19/0.21
0.13/0.17
MTG BASE
0.68 MAX
0.072/0.120
1.177/1.197
0.151/0.161 DIA
0.655/0.675
CATHODE
0.205/0.225
2
0.420/0.440
1
GATE

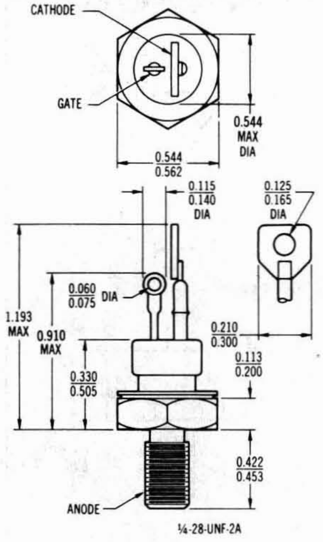
CASE 62


0.100
0.610/0.630 DIA
0.042/MAX
CATHODE
GATE
1.00 MIN
1.20 MIN
0.10/0.14
0.200 MIN KNURL
0.235/0.255
0.501/0.505 DIA
ANODE

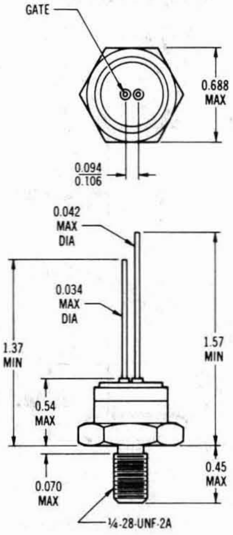
CASE 63


0.424/0.437
0.280 MAX DIA
0.155/0.185
0.040/0.075 TYP
0.060/0.070 R 2 PLACES
0.855 MAX
0.700 MAX
0.425 MAX
0.140 MAX
10°/20°
0.400/0.453
10-32-UNF-2A

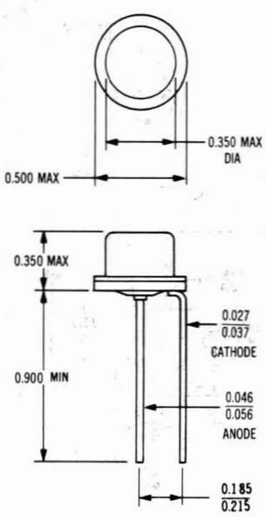
CASE 64 TO-48 PACKAGE


CATHODE
GATE
0.544 MAX DIA
0.544/0.562
0.115/0.140 DIA
0.125/0.165 DIA
0.060/0.075 DIA
1.193 MAX
0.910 MAX
0.210/0.300
0.113/0.200
0.330/0.505
0.422/0.453
ANODE
¼-28-UNF-2A

CASE 68


GATE
0.688 MAX
0.094/0.106
0.042 MAX DIA
0.034 MAX DIA
1.37 MIN
1.57 MIN
0.54 MAX
0.45 MAX
0.070 MAX
¼-28-UNF-2A

CASE 70


0.350 MAX DIA
0.500 MAX
0.350 MAX
0.027/0.037
CATHODE
0.900 MIN
0.046/0.056
ANODE
0.185/0.215

CASE 71 — See Case 602B

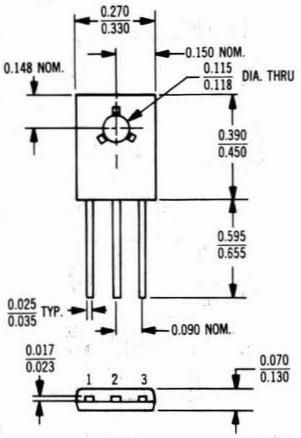
CASE 71A — See Case 602A

CASE 72 — See Case 606

CASE 73 — See Case 608

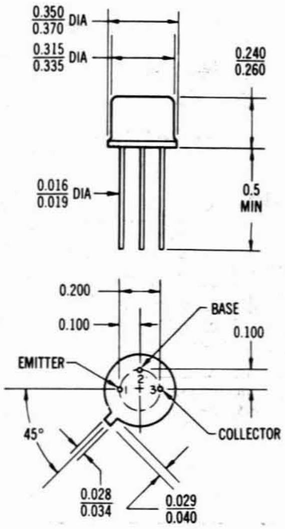
CASE 77

PLASTIC TRANSISTOR

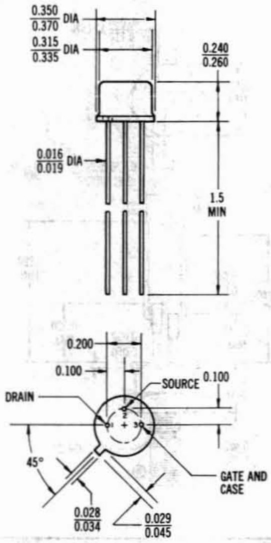

0.270/0.330
0.148 NOM.
0.150 NOM.
0.115/0.118 DIA. THRU
0.390/0.450
0.595/0.655
0.025/0.035 TYP.
0.090 NOM.
0.017/0.023
1 2 3
0.070/0.130

STYLE 1
Pin 1. Emitter
2. Collector
3. Base

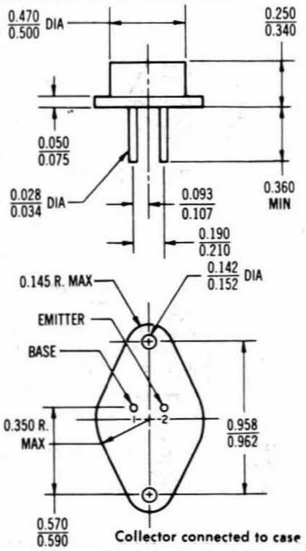
CASE 79 TO-39 PACKAGE


0.350/0.370 DIA
0.315/0.335 DIA
0.240/0.260
0.016/0.019 DIA
0.5 MIN
0.200
0.100
BASE
0.100
EMITTER
1
2
3
COLLECTOR
45°
0.028/0.034
0.029/0.040

CASE 79A

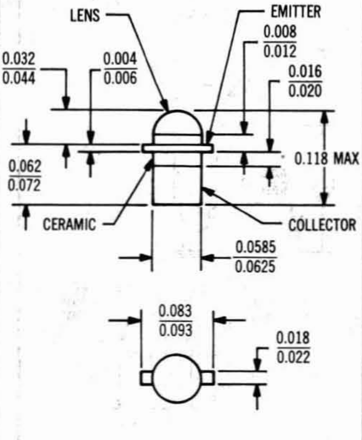

0.350/0.370 DIA
0.315/0.335 DIA
0.240/0.260
0.016/0.019 DIA
1.5 MIN
0.200
0.100
SOURCE
0.100
DRAIN
45°
GATE AND CASE
0.028/0.034
0.029/0.045

CASE 80 TO-66 PACKAGE

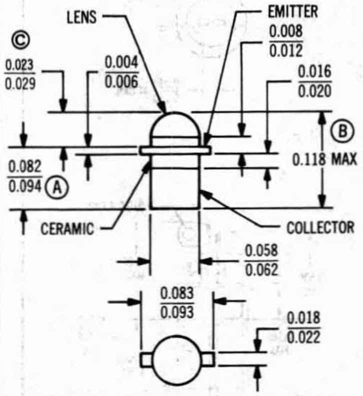

0.470/0.500 DIA
0.250/0.340
0.050/0.075
0.028/0.034 DIA
0.093/0.107
0.360 MIN
0.190/0.210
0.145 R. MAX
0.142/0.152 DIA
EMITTER
BASE
1
2
0.350 R. MAX
0.958/0.962
0.570/0.590

Collector connected to case

CASE 81 DO-31 PACKAGE


LENS
EMITTER
0.008/0.012
0.032/0.044
0.004/0.006
0.016/0.020
0.118 MAX
0.062/0.072
CERAMIC
COLLECTOR
0.0585/0.0625
0.083/0.093
0.018/0.022

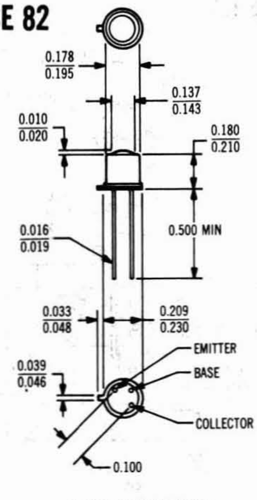
CASE 81A-01


LENS
EMITTER
0.008/0.012
Ⓒ
0.023/0.029
0.004/0.006
0.016/0.020
Ⓑ
0.118 MAX
0.082/0.094 Ⓐ
CERAMIC
COLLECTOR
0.058/0.062
0.083/0.093
0.018/0.022

CASE 81A-02

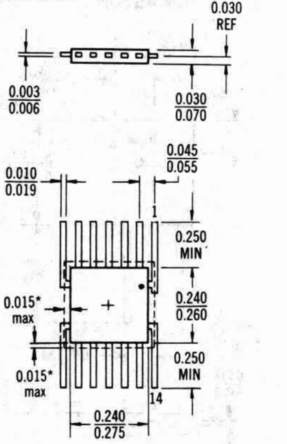
Ⓐ = 0.062/0.072
Ⓑ = 0.105 MAX
Ⓒ = 0.029 MAX

CASE 82


0.178/0.195
0.137/0.143
0.010/0.020
0.180/0.210
0.016/0.019
0.500 MIN
0.033/0.048
0.209/0.230
0.039/0.046
EMITTER
BASE
COLLECTOR
0.100

Leads are gold-plated kovar
Collector internally connected to case.
Package weight ≈ 0.45 grams

CASE 83 TO-86 PACKAGE
(Also Case 607)

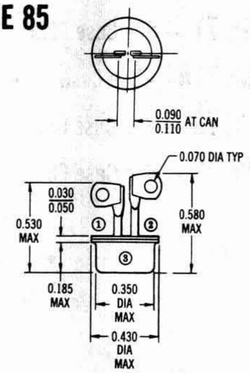

0.030
REF
0.003
0.006
0.030
0.070
0.045
0.055
0.010
0.019
1
0.250
MIN
0.240
0.260
0.015*
max
0.250
MIN
0.015*
max
14
0.240
0.275

Lead 1 identified by color dot or by elbow on lead.
All leads electrically isolated from package.
*Tolerance for lid skewing, glass meniscus, and glass overrun.

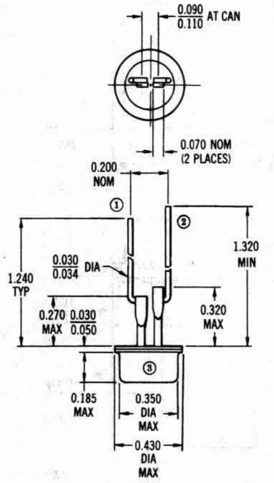
CASE 85, L thru 88, L STYLES

LEAD	STYLE 1 (Thyristors)	STYLE 2 (Triacs)
①	Gate	Gate
②	Cathode	Anode 1
③	Anode	Anode 2

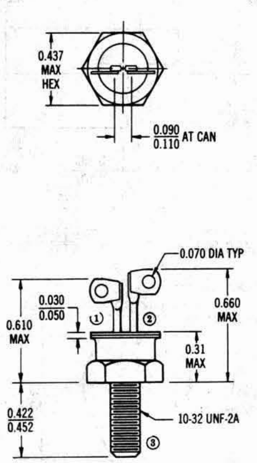
CASE 85


0.090
0.110 AT CAN
0.070 DIA TYP
0.030
0.050
0.530
MAX
①
②
0.580
MAX
③
0.185
MAX
0.350
DIA
MAX
0.430
DIA
MAX

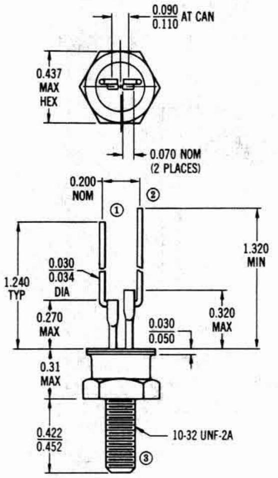
CASE 85L


0.090
0.110 AT CAN
0.070 NOM
(2 PLACES)
0.200
NOM
①
②
1.320
MIN
0.030
0.034 DIA
1.240
TYP
0.320
MAX
0.270 MAX
0.030
0.050
③
0.185
MAX
0.350
DIA
MAX
0.430
DIA
MAX

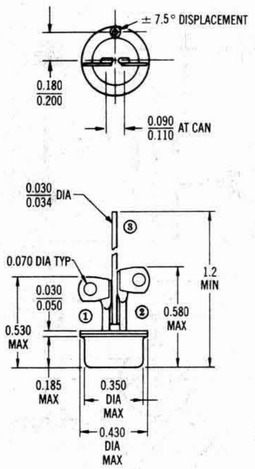
CASE 86


0.437
MAX
HEX
0.090
0.110 AT CAN
0.070 DIA TYP
0.030
0.050
①
②
0.660
MAX
0.610
MAX
0.31
MAX
0.422
0.452
10-32 UNF-2A
③

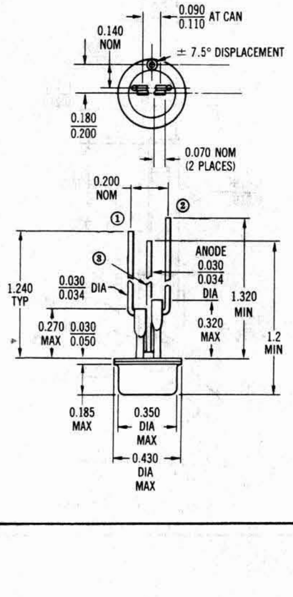
CASE 86L


0.090
0.110 AT CAN
0.437
MAX
HEX
0.070 NOM
(2 PLACES)
0.200
NOM
①
②
1.320
MIN
0.030
0.034
DIA
1.240
TYP
0.270
MAX
0.030
0.050
0.320
MAX
0.31
MAX
0.422
0.452
10-32 UNF-2A
③

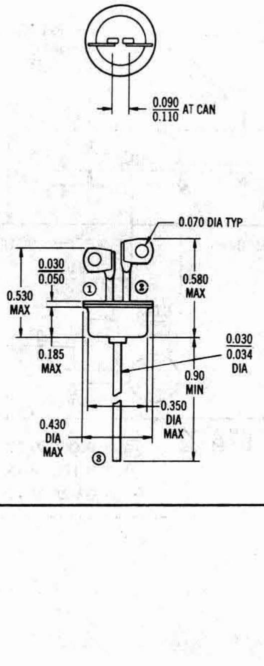
CASE 87


± 7.5° DISPLACEMENT
0.180
0.200
0.090
0.110 AT CAN
0.030
0.034 DIA
③
0.070 DIA TYP
1.2
MIN
0.030
0.050
①
②
0.580
MAX
0.530
MAX
0.185
MAX
0.350
DIA
MAX
0.430
DIA
MAX

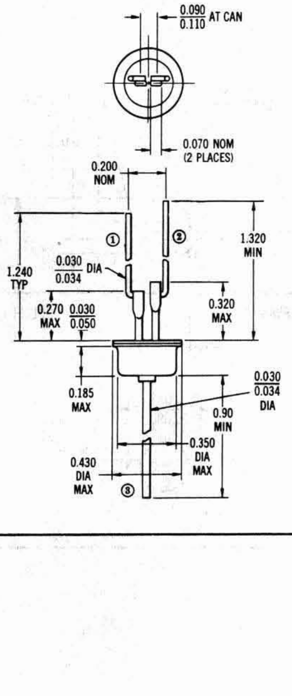
CASE 87L


0.090
0.110 AT CAN
0.140
NOM
± 7.5° DISPLACEMENT
0.180
0.200
0.070 NOM
(2 PLACES)
0.200
NOM
②
①
③
ANODE
0.030
0.034
DIA
1.240
TYP
0.030
0.034 DIA
1.320
MIN
0.320
MAX
0.270
MAX
0.030
0.050
1.2
MIN
0.185
MAX
0.350
DIA
MAX
0.430
DIA
MAX

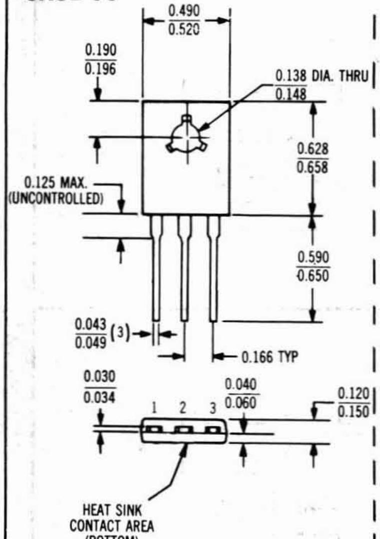
CASE 88


0.090
0.110 AT CAN
0.070 DIA TYP
0.030
0.050
0.530
MAX
①
②
0.580
MAX
0.030
0.034
DIA
0.185
MAX
0.90
MIN
0.350
DIA
MAX
0.430
DIA
MAX
③

CASE 88L

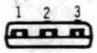

0.090
0.110 AT CAN
0.070 NOM
(2 PLACES)
0.200
NOM
①
②
1.320
MIN
0.030
0.034 DIA
1.240
TYP
0.320
MAX
0.270
MAX
0.030
0.050
0.030
0.034
DIA
0.185
MAX
0.90
MIN
0.350
DIA
MAX
0.430
DIA
MAX
③

CASE 90


0.490
0.520
0.190
0.196
0.138 DIA. THRU
0.148
0.628
0.658
0.125 MAX.
(UNCONTROLLED)
0.590
0.650
0.043
0.049
(3)
0.166 TYP
0.030
0.034
0.040
0.060
0.120
0.150
1 2 3
HEAT SINK
CONTACT AREA
(BOTTOM)

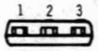
CASE 90 STYLES

STYLE 1



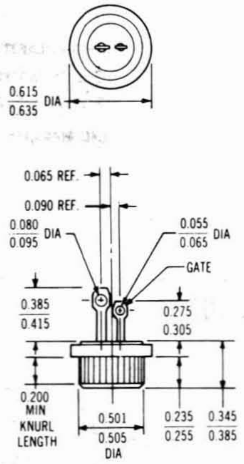
Pin 1. Cathode
2. Anode
3. Gate

STYLE 2

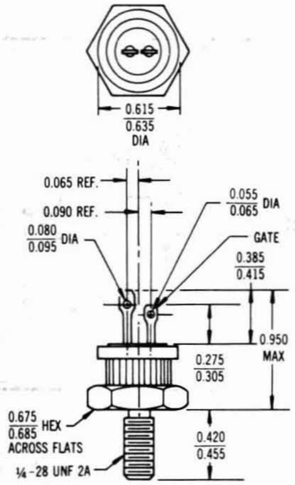


Pin 1. Emitter
2. Collector
3. Base

CASE 91

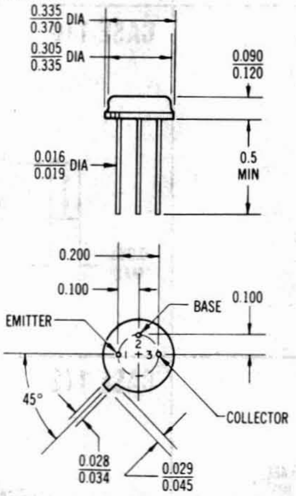

0.615
0.635
DIA
0.065 REF.
0.090 REF.
0.080
0.095
DIA
0.055
0.065
DIA
GATE
0.385
0.415
0.275
0.305
0.200
MIN
KNURL
LENGTH
0.501
0.505
DIA
0.235
0.255
0.345
0.385

CASE 92


0.615
0.635
DIA
0.065 REF.
0.090 REF.
0.055
0.065
DIA
0.080
0.095
DIA
GATE
0.385
0.415
0.950
MAX
0.275
0.305
0.675
0.685
HEX
ACROSS FLATS
0.420
0.455
¼-28 UNF 2A

CASE 93 — See Case 605

CASE 94


0.335
0.370
DIA
0.305
0.335
DIA
0.090
0.120
0.016
0.019
DIA
0.5
MIN
0.200
0.100
0.100
BASE
EMITTER
1
2
3
45°
COLLECTOR
0.028
0.034
0.029
0.045

CASE 96 — See Case 601

CASE 96A — See Case 603

CASE 98 — See Case 604

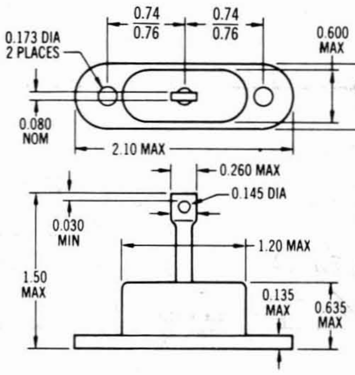
CASE 101 — See Cases 125 thru 128

CASE 102 — See Cases 129 thru 132

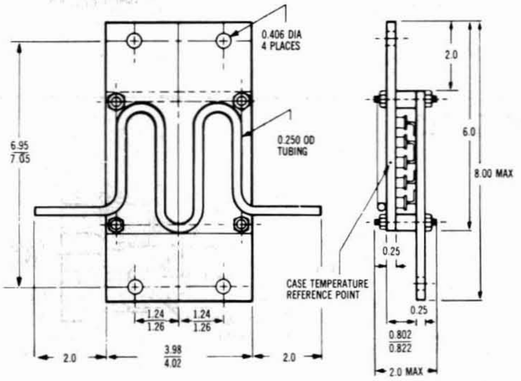
CASE 103 — See Cases 133 thru 136

CASE 104 — See Cases 137 thru 139

CASE 100


0.74
0.76
0.74
0.76
0.600
MAX
0.173 DIA
2 PLACES
0.630
MAX
0.080
NOM
2.10 MAX
0.260 MAX
0.145 DIA
0.030
MIN
1.20 MAX
1.50
MAX
0.135
MAX
0.635
MAX

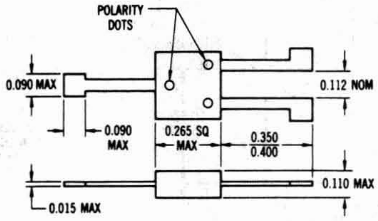
CASE 105


0.406 DIA
4 PLACES
0.250 OD
TUBING
6.95
7.05
2.0
6.0
8.00 MAX
0.25
CASE TEMPERATURE
REFERENCE POINT
0.25
1.24
1.26
1.24
1.26
0.802
0.822
2.0
3.98
4.02
2.0
2.0 MAX

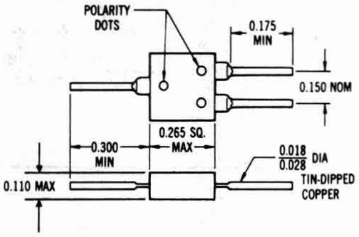
COLOR-CODED POLARITY DOTS:

Y = AC INPUT
R = +DC OUTPUT
(NO MARK) = −DC OUTPUT

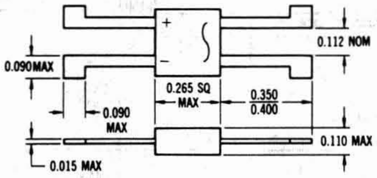
CASE 106


POLARITY DOTS
0.090 MAX
0.112 NOM
0.090 MAX
0.265 SQ MAX
0.350 / 0.400
0.110 MAX
0.015 MAX

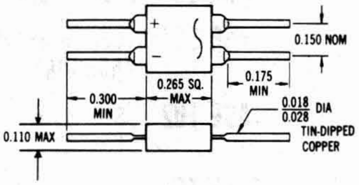
CASE 107


POLARITY DOTS
0.175 MIN
0.150 NOM
0.300 MIN
0.265 SQ. MAX
0.018 / 0.028 DIA
TIN-DIPPED COPPER
0.110 MAX

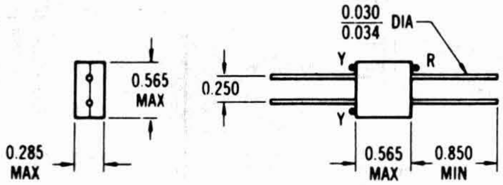
CASE 108


+
−
0.112 NOM
0.090 MAX
0.090 MAX
0.265 SQ MAX
0.350 / 0.400
0.110 MAX
0.015 MAX

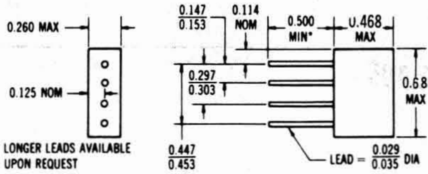
CASE 109


+
−
0.150 NOM
0.175 MIN
0.300 MIN
0.265 SQ. MAX
0.018 / 0.028 DIA
TIN-DIPPED COPPER
0.110 MAX

CASE 110

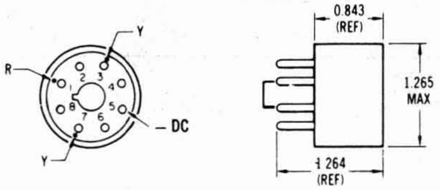

0.030 / 0.034 DIA
Y
R
Y
0.565 MAX
0.250
0.285 MAX
0.565 MAX
0.850 MIN

CASE 111

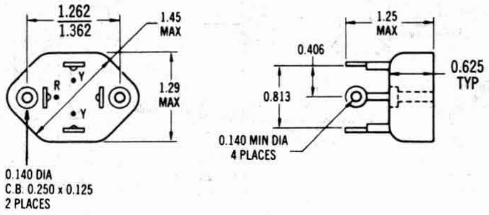

0.260 MAX
0.125 NOM
0.147 / 0.153
0.114 NOM
0.500 MIN*
0.468 MAX
0.297 / 0.303
0.6817 MAX
0.447 / 0.453
LEAD = 0.029 / 0.035 DIA

* LONGER LEADS AVAILABLE UPON REQUEST

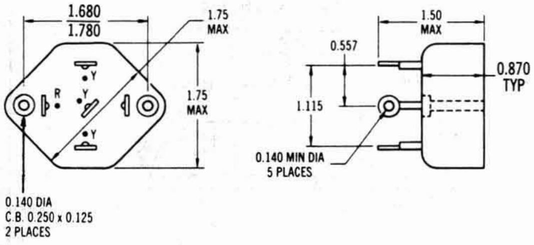
CASE 112


Y
R
1
2
3
4
5
6
7
8
− DC
Y
0.843 (REF)
1.265 MAX
1.264 (REF)

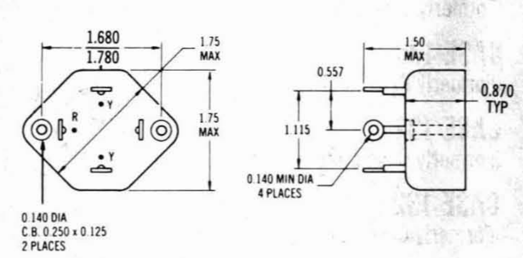
CASE 113


1.262 / 1.362
1.45 MAX
R
Y
Y
1.29 MAX
0.140 DIA
C.B. 0.250 x 0.125
2 PLACES
1.25 MAX
0.406
0.625 TYP
0.813
0.140 MIN DIA
4 PLACES

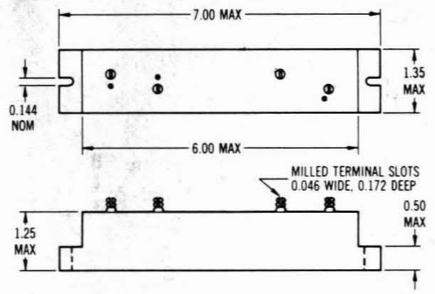
CASE 114


1.680 / 1.780
1.75 MAX
R
Y
Y
Y
1.75 MAX
0.140 DIA
C.B. 0.250 x 0.125
2 PLACES
1.50 MAX
0.557
0.870 TYP
1.115
0.140 MIN DIA
5 PLACES

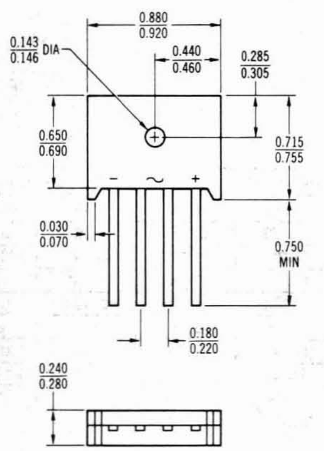
CASE 115


1.680/1.780
1.75 MAX
R
Y
Y
1.75 MAX
0.140 DIA
C.B. 0.250 x 0.125
2 PLACES
1.50 MAX
0.557
0.870 TYP
1.115
0.140 MIN DIA
4 PLACES

CASE 116

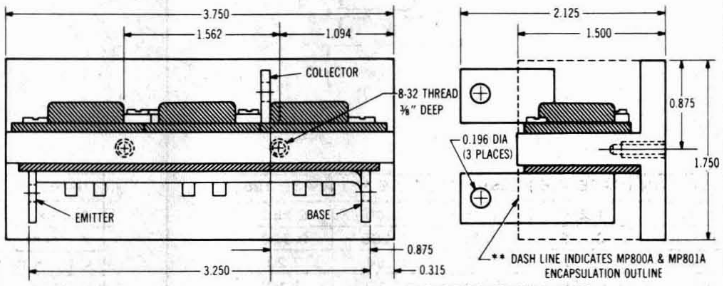

7.00 MAX
1.35 MAX
0.144 NOM
6.00 MAX
MILLED TERMINAL SLOTS
0.046 WIDE, 0.172 DEEP
0.50 MAX
1.25 MAX

CASE 117


0.880/0.920
0.143/0.146 DIA
0.440/0.460
0.285/0.305
0.650/0.690
0.715/0.755
−
~
+
0.030/0.070
0.750 MIN
0.180/0.220
0.240/0.280

LEAD PATTERN CENTERED
LEADS MUST FIT INTO
0.055 MIN. DIA. HOLE

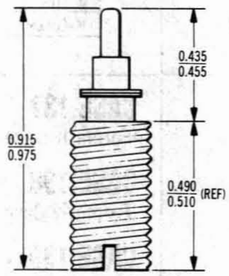
CASE 118


3.750
1.562
1.094
COLLECTOR
8-32 THREAD
3/8" DEEP
EMITTER
BASE
0.875
3.250
0.315
2.125
1.500
0.875
0.196 DIA
(3 PLACES)
1.750
** DASH LINE INDICATES MP800A & MP801A
ENCAPSULATION OUTLINE

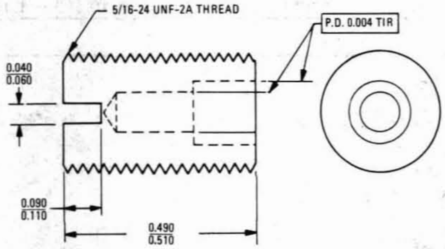
ALL DIMENSIONS ARE NOMINAL VALUES

COLLECTOR IS ELECTRICALLY ISOLATED FROM HEAT SINK CHASSIS

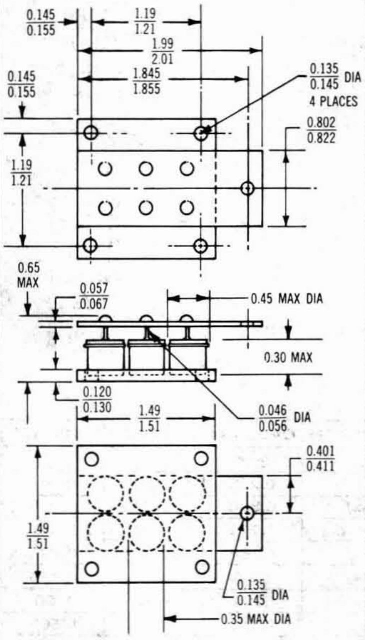
CASE 120


0.435/0.455
0.915/0.975
0.490/0.510 (REF)

CASE 120, 121 ADAPTER DETAIL


5/16-24 UNF-2A THREAD
P.D. 0.004 TIR
0.040/0.060
0.090/0.110
0.490/0.510

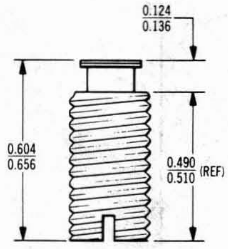
CASE 119


0.145/0.155
1.19/1.21
1.99/2.01
0.145/0.155
1.845/1.855
0.135/0.145 DIA
4 PLACES
0.802/0.822
1.19/1.21
0.65 MAX
0.057/0.067
0.45 MAX DIA
0.30 MAX
0.120/0.130
1.49/1.51
0.046/0.056 DIA
0.401/0.411
1.49/1.51
0.135/0.145 DIA
0.35 MAX DIA

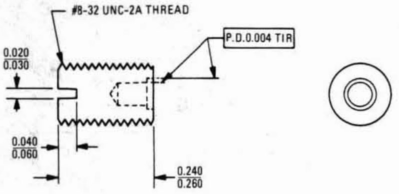
HEAT SINK MAT'L: AL ALLOY 3003
WITH NICKEL PLATING

WEIGHT 30 GRAMS (APPROX)

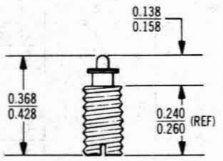
CASE 121


0.124/0.136
0.604/0.656
0.490/0.510 (REF)

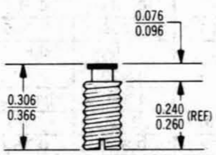
CASE 122, 123, 124 ADAPTER DETAIL


#8-32 UNC-2A THREAD
P.D. 0.004 TIR
0.020/0.030
0.040/0.060
0.240/0.260

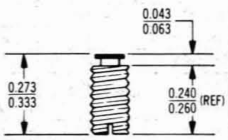
CASE 122


0.138/0.158
0.368/0.428
0.240/0.260 (REF)

CASE 123


0.076/0.096
0.306/0.366
0.240/0.260 (REF)

CASE 124

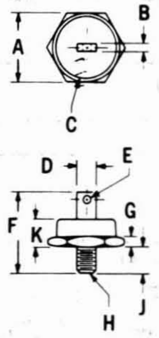

0.043/0.063
0.273/0.333
0.240/0.260 (REF)

CASE 125
(Formerly Case 101)

CASE 126
(Formerly Case 101)

CASE 127
(Formerly Case 101)

CASE 128
(Formerly Case 101)



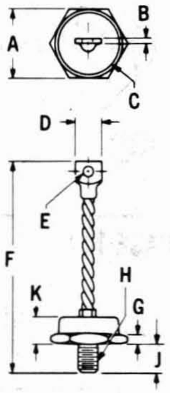
DIMENSION	CASE 125	CASE 126	CASE 127	CASE 128
A (hex)	1.250	1.75	2.00	2.250
B (max)	0.135	0.260	0.260	0.320
C (max dia)	1.20	1.72	1.94	2.20
D (max)	0.525	0.760	1.10	1.10
E (dia)	0.250	0.375	0.562	0.562
F (max)	2.25	3.0	3.50	3.72
G (typ)	0.125	0.375	0.375	0.375
H (thread)	10-32	¾-16 UNF	¾-16 UNF	¾-16 UNF
J (max)	0.500	1.00	1.00	1.00
K (max)	0.570	1.10	1.10	1.10

CASE 129
(Formerly Case 102)

CASE 130
(Formerly Case 102)

CASE 131
(Formerly Case 102)

CASE 132
(Formerly Case 102)



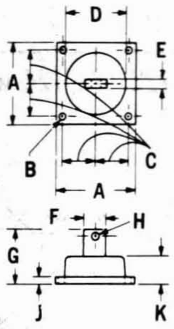
DIMENSION	CASE 129	CASE 130	CASE 131	CASE 132
A (hex)	1.250	1.75	2.00	2.250
B (max)	0.113	0.155	0.200	0.260
C (max dia)	1.20	1.72	1.94	2.20
D (max)	0.590	0.64	1.00	1.155
E (dia)	0.281	0.343	0.531	0.562
F (max)	6.25	8.10	8.10	8.10
G (typ)	0.125	0.375	0.375	0.375
H (thread)	10-32	¾-16 UNF	¾-16 UNF	¾-16 UNF
J (max)	0.500	1.00	1.00	1.00
K (max)	0.570	1.10	1.10	1.10

CASE 133
(Formerly Case 103)

CASE 134
(Formerly Case 103)

CASE 135
(Formerly Case 103)

CASE 136
(Formerly Case 103)

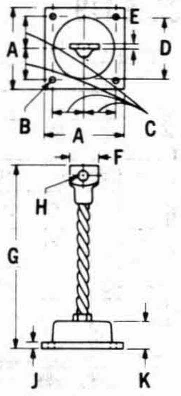


DIMENSION	CASE 133	CASE 134	CASE 135	CASE 136
A (typ)	2.25	3.00	3.00	3.25
B (dia)	0.203	0.281	0.281	0.281
C (max)	0.880	1.255	1.255	1.380
D (max dia)	1.720	2.100	2.200	2.885
E (max)	0.260	0.260	0.320	0.500
F (max)	0.760	1.100	1.100	1.30
G (max)	1.9	2.50	2.70	2.50
H (dia)	0.375	0.562	0.562	0.562
J (max)	0.260	0.260	0.260	0.260
K (max)	1.00	1.00	1.00	1.00

CASE 137
(Formerly Case 104)

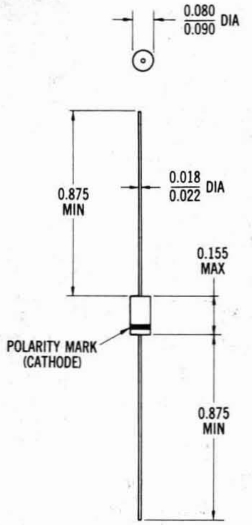
CASE 138
(Formerly Case 104)

CASE 139
(Formerly Case 104)

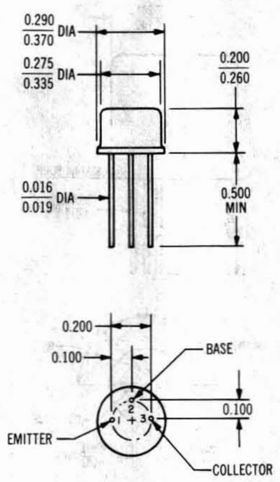


DIMENSION	CASE 137	CASE 138	CASE 139
A (typ)	2.25	3.00	3.00
B (dia)	0.203	0.281	0.281
C (max)	0.880	1.255	1.255
D (max dia)	1.720	2.100	2.20
E (max)	0.155	0.200	0.260
F (max)	0.64	1.00	1.155
G (max)	7.10	6.90	6.90
H (dia)	0.343	0.531	0.562
J (max)	0.260	0.260	0.260
K (max)	1.00	1.00	1.00

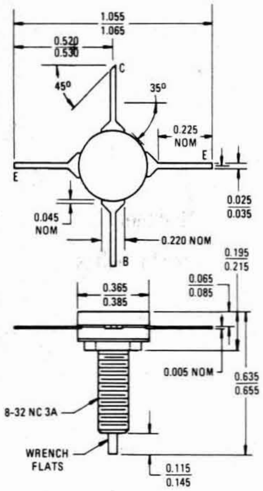
CASE 142


0.080 / 0.090 DIA
0.875 MIN
0.018 / 0.022 DIA
0.155 MAX
POLARITY MARK (CATHODE)
0.875 MIN

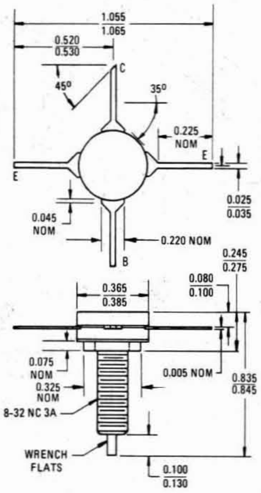
CASE 143 TO-9 PACKAGE


0.290 / 0.370 DIA
0.275 / 0.335 DIA
0.200 / 0.260
0.016 / 0.019 DIA
0.500 MIN
0.200
0.100
BASE
0.100
EMITTER
COLLECTOR
1
2
3

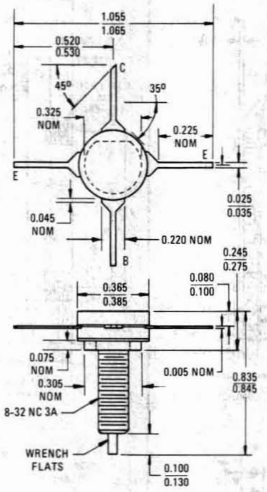
CASE 144


1.055 / 1.065
0.520 / 0.530
C
45°
35°
0.225 NOM
E
E
0.025 / 0.035
0.045 NOM
0.220 NOM
B
0.195 / 0.215
0.065 / 0.085
0.365 / 0.385
0.005 NOM
0.635 / 0.655
8-32 NC 3A
WRENCH FLATS
0.115 / 0.145

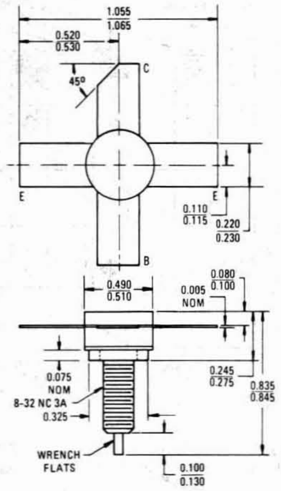
CASE 144A


1.055 / 1.065
0.520 / 0.530
C
45°
35°
0.225 NOM
E
E
0.025 / 0.035
0.045 NOM
0.220 NOM
B
0.245 / 0.275
0.080 / 0.100
0.365 / 0.385
0.075 NOM
0.325 NOM
0.005 NOM
8-32 NC 3A
0.835 / 0.845
WRENCH FLATS
0.100 / 0.130

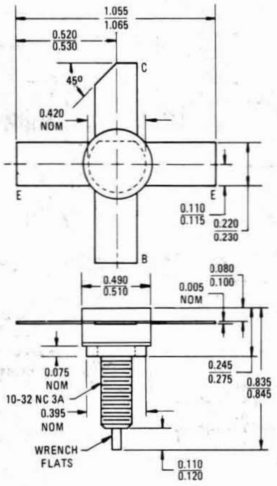
CASE 144B


1.055 / 1.065
0.520 / 0.530
C
45°
35°
0.325 NOM
0.225 NOM
E
E
0.025 / 0.035
0.045 NOM
0.220 NOM
B
0.245 / 0.275
0.080 / 0.100
0.365 / 0.385
0.075 NOM
0.305 NOM
0.005 NOM
8-32 NC 3A
0.835 / 0.845
WRENCH FLATS
0.100 / 0.130

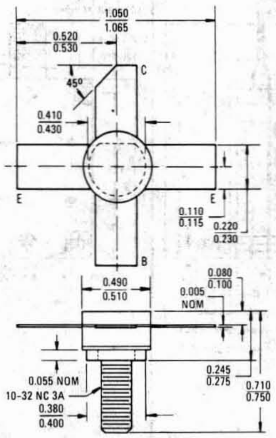
CASE 145


1.055 / 1.065
0.520 / 0.530
C
45°
E
E
0.110 / 0.115
0.220 / 0.230
B
0.490 / 0.510
0.080 / 0.100
0.005 NOM
0.245 / 0.275
0.075 NOM
8-32 NC 3A
0.325
0.835 / 0.845
WRENCH FLATS
0.100 / 0.130

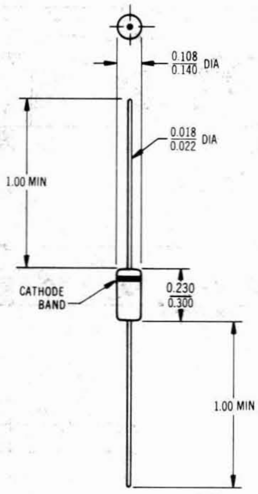
CASE 145A


1.055 / 1.065
0.520 / 0.530
C
45°
0.420 NOM
E
E
0.110 / 0.115
0.220 / 0.230
B
0.490 / 0.510
0.080 / 0.100
0.005 NOM
0.245 / 0.275
0.075 NOM
10-32 NC 3A
0.395 NOM
0.835 / 0.845
WRENCH FLATS
0.110 / 0.120

CASE 145B

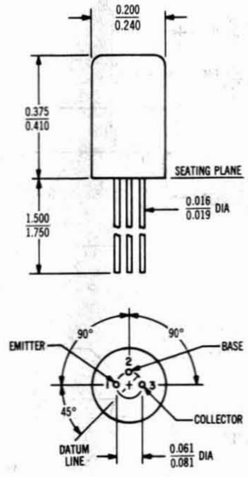

1.050 / 1.065
0.520 / 0.530
C
45°
0.410 / 0.430
E
E
0.110 / 0.115
0.220 / 0.230
B
0.490 / 0.510
0.080 / 0.100
0.005 NOM
0.055 NOM
10-32 NC 3A
0.380 / 0.400
0.245 / 0.275
0.710 / 0.750

CASE 146 DO-14 PACKAGE

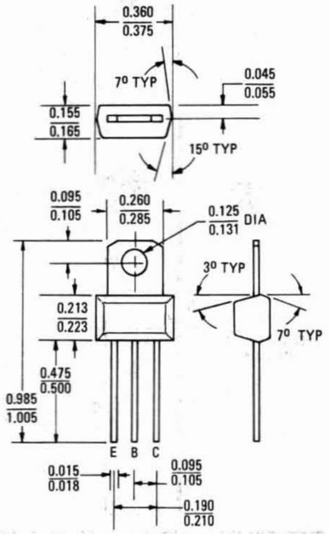

0.108 / 0.140 DIA
0.018 / 0.022 DIA
1.00 MIN
CATHODE BAND
0.230 / 0.300
1.00 MIN

All dimensions are in inches

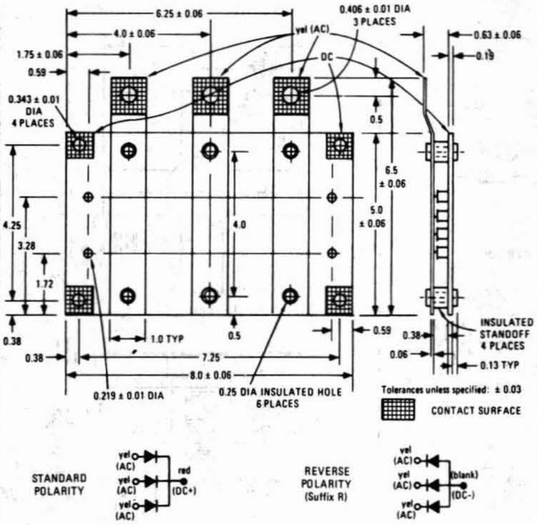
CASE 149 TO-1 PACKAGE


0.200
0.240
0.375
0.410
SEATING PLANE
0.016
0.019 DIA
1.500
1.750
EMITTER
90°
90°
BASE
2
1
3
45°
COLLECTOR
DATUM LINE
0.061
0.081 DIA

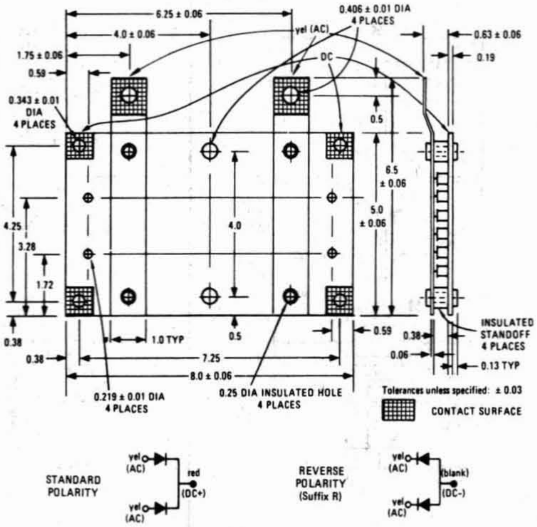
CASE 152 Collector connected to tab


0.360
0.375
7° TYP
0.045
0.055
0.155
0.165
15° TYP
0.095
0.105
0.260
0.285
0.125
0.131 DIA
3° TYP
0.213
0.223
7° TYP
0.475
0.500
0.985
1.005
E B C
0.015
0.018
0.095
0.105
0.190
0.210

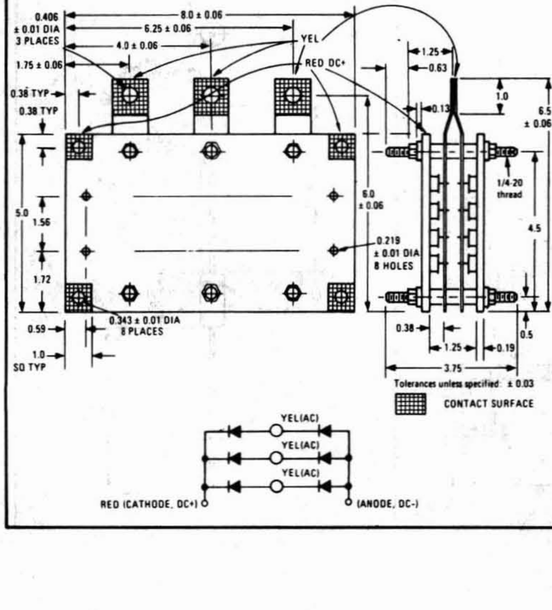
CASE 154


6.25 ± 0.06
0.406 ± 0.01 DIA
3 PLACES
4.0 ± 0.06
yel (AC)
0.63 ± 0.06
1.75 ± 0.06
DC
0.19
0.59
0.343 ± 0.01
DIA
4 PLACES
0.5
6.5
± 0.06
5.0
± 0.06
4.0
4.25
3.28
1.72
0.38
1.0 TYP
0.5
0.59
0.38
INSULATED
STANDOFF
4 PLACES
0.38
7.25
0.06
0.13 TYP
8.0 ± 0.06
0.219 ± 0.01 DIA
0.25 DIA INSULATED HOLE
6 PLACES
Tolerances unless specified: ± 0.03
CONTACT SURFACE
STANDARD
POLARITY
yel
(AC)
yel
(AC)
yel
(AC)
red
(DC+)
REVERSE
POLARITY
(Suffix R)
yel
(AC)
yel
(AC)
yel
(AC)
(blank)
(DC-)

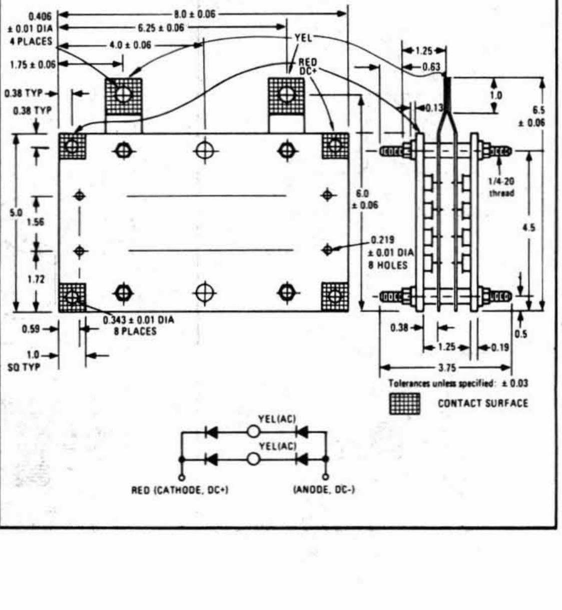
CASE 154A


6.25 ± 0.06
0.406 ± 0.01 DIA
4 PLACES
4.0 ± 0.06
yel (AC)
0.63 ± 0.06
1.75 ± 0.06
DC
0.19
0.59
0.343 ± 0.01
DIA
4 PLACES
0.5
6.5
± 0.06
5.0
± 0.06
4.0
4.25
3.28
1.72
0.38
1.0 TYP
0.5
0.59
0.38
INSULATED
STANDOFF
4 PLACES
0.38
7.25
0.06
0.13 TYP
8.0 ± 0.06
0.219 ± 0.01 DIA
4 PLACES
0.25 DIA INSULATED HOLE
4 PLACES
Tolerances unless specified: ± 0.03
CONTACT SURFACE
STANDARD
POLARITY
yel
(AC)
yel
(AC)
red
(DC+)
REVERSE
POLARITY
(Suffix R)
yel
(AC)
yel
(AC)
(blank)
(DC-)

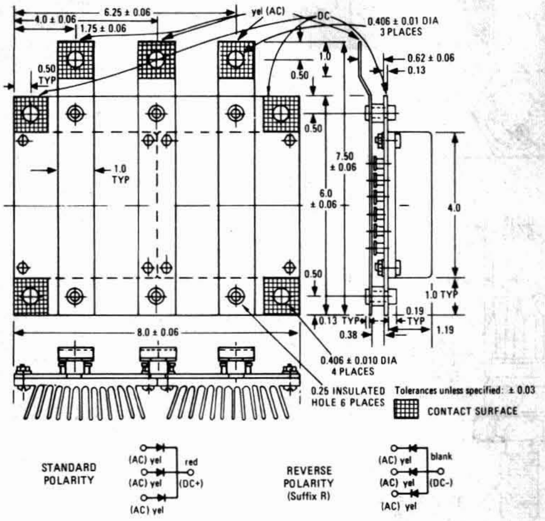
CASE 155


0.406
± 0.01 DIA
3 PLACES
8.0 ± 0.06
6.25 ± 0.06
4.0 ± 0.06
YEL
1.75 ± 0.06
RED DC+
1.25
0.63
0.38 TYP
0.38 TYP
0.13
1.0
6.5
± 0.06
1/4-20
thread
5.0
1.56
6.0
± 0.06
4.5
0.219
± 0.01 DIA
8 HOLES
1.72
0.343 ± 0.01 DIA
8 PLACES
0.59
0.38
0.5
1.25
0.19
1.0
SQ TYP
3.75
Tolerances unless specified: ± 0.03
CONTACT SURFACE
YEL(AC)
YEL(AC)
YEL(AC)
RED (CATHODE, DC+)
(ANODE, DC-)

CASE 155A


0.406
± 0.01 DIA
4 PLACES
8.0 ± 0.06
6.25 ± 0.06
4.0 ± 0.06
YEL
1.75 ± 0.06
RED
DC+
1.25
0.63
0.38 TYP
0.38 TYP
0.13
1.0
6.5
± 0.06
1/4-20
thread
5.0
1.56
6.0
± 0.06
4.5
0.219
± 0.01 DIA
8 HOLES
1.72
0.343 ± 0.01 DIA
8 PLACES
0.59
0.38
0.5
1.25
0.19
1.0
SQ TYP
3.75
Tolerances unless specified: ± 0.03
CONTACT SURFACE
YEL(AC)
YEL(AC)
RED (CATHODE, DC+)
(ANODE, DC-)

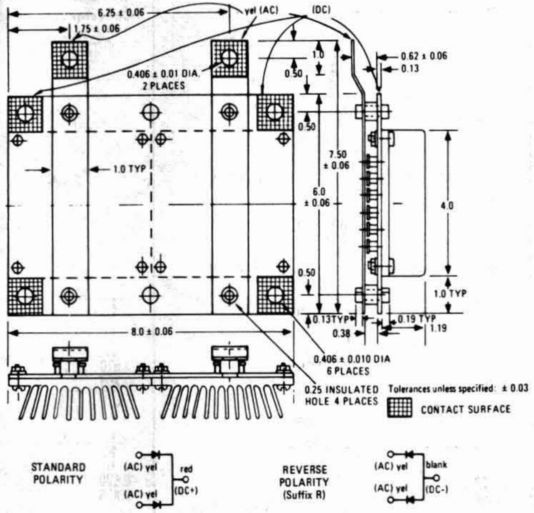
CASE 156


6.25 ± 0.06
4.0 ± 0.06
1.75 ± 0.06
yel (AC)
DC
0.406 ± 0.01 DIA
3 PLACES
0.62 ± 0.06
0.13
0.50
TYP
1.0
0.50
0.50
1.0
TYP
7.50
± 0.06
6.0
± 0.06
4.0
0.50
1.0 TYP
0.13 TYP
0.19
TYP
0.38
1.19
8.0 ± 0.06
0.406 ± 0.010 DIA
4 PLACES
0.25 INSULATED
HOLE 6 PLACES
STANDARD
POLARITY
(AC) yel
(AC) yel
(AC) yel
red
(DC+)
REVERSE
POLARITY
(Suffix R)
(AC) yel
(AC) yel
(AC) yel
blank
(DC-)

Tolerances unless specified: ± 0.03

▦ CONTACT SURFACE

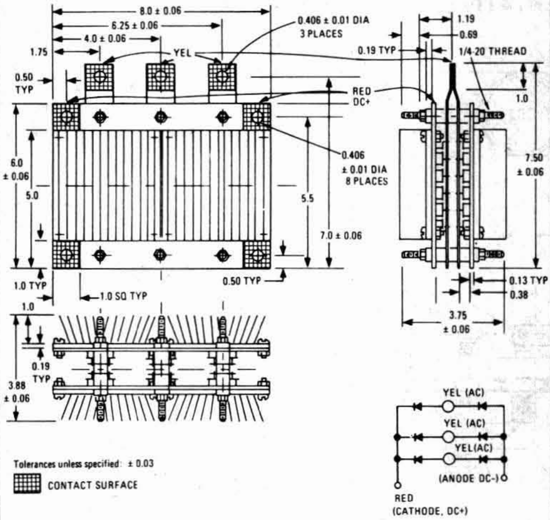
CASE 156A


6.25 ± 0.06
1.75 ± 0.06
yel (AC)
(DC)
0.406 ± 0.01 DIA.
2 PLACES
0.62 ± 0.06
0.13
1.0
0.50
0.50
1.0 TYP
7.50
± 0.06
6.0
± 0.06
4.0
0.50
1.0 TYP
0.13TYP
0.19 TYP
0.38
1.19
8.0 ± 0.06
0.406 ± 0.010 DIA
6 PLACES
0.25 INSULATED
HOLE 4 PLACES
STANDARD
POLARITY
(AC) yel
(AC) yel
red
(DC+)
REVERSE
POLARITY
(Suffix R)
(AC) yel
(AC) yel
blank
(DC-)

Tolerances unless specified: ± 0.03

▦ CONTACT SURFACE

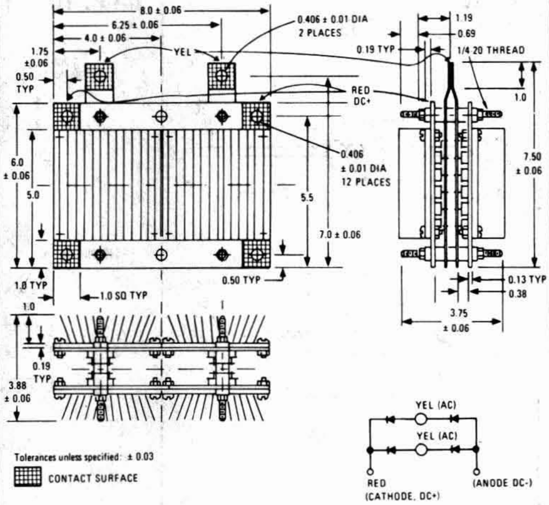
CASE 157


8.0 ± 0.06
6.25 ± 0.06
4.0 ± 0.06
1.75
YEL
0.406 ± 0.01 DIA
3 PLACES
1.19
0.69
0.19 TYP
1/4-20 THREAD
0.50
TYP
RED
DC+
1.0
6.0
± 0.06
5.0
0.406
± 0.01 DIA
8 PLACES
5.5
7.50
± 0.06
7.0 ± 0.06
1.0 TYP
1.0 SQ TYP
0.50 TYP
0.13 TYP
0.38
3.75
± 0.06
1.0
0.19
TYP
3.88
± 0.06
YEL (AC)
YEL (AC)
YEL(AC)
(ANODE DC-)
RED
(CATHODE, DC+)

Tolerances unless specified: ± 0.03

▦ CONTACT SURFACE

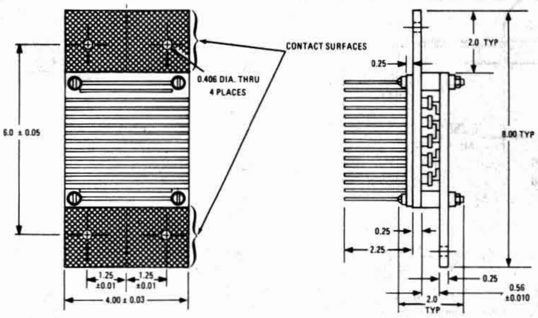
CASE 157A


8.0 ± 0.06
6.25 ± 0.06
4.0 ± 0.06
1.75
±0.06
YEL
0.406 ± 0.01 DIA
2 PLACES
1.19
0.69
0.19 TYP
1/4-20 THREAD
0.50
TYP
RED
DC+
1.0
6.0
± 0.06
5.0
0.406
± 0.01 DIA
12 PLACES
5.5
7.50
± 0.06
7.0 ± 0.06
1.0 TYP
1.0 SQ TYP
0.50 TYP
0.13 TYP
0.38
3.75
± 0.06
1.0
0.19
TYP
3.88
± 0.06
YEL (AC)
YEL (AC)
RED
(CATHODE, DC+)
(ANODE DC-)

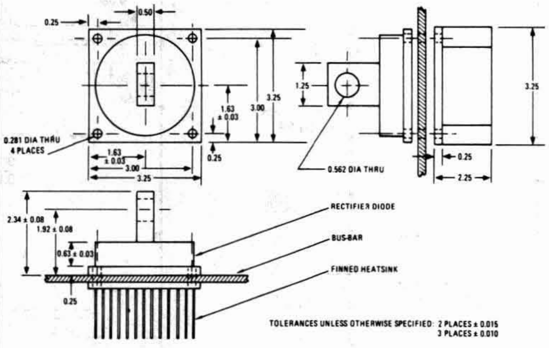
Tolerances unless specified: ± 0.03

▦ CONTACT SURFACE

CASE 158


CONTACT SURFACES
0.406 DIA. THRU
4 PLACES
6.0 ± 0.05
1.25
±0.01
1.25
±0.01
4.00 ± 0.03
2.0 TYP
0.25
8.00 TYP
0.25
2.25
0.25
0.56
±0.010
2.0
TYP

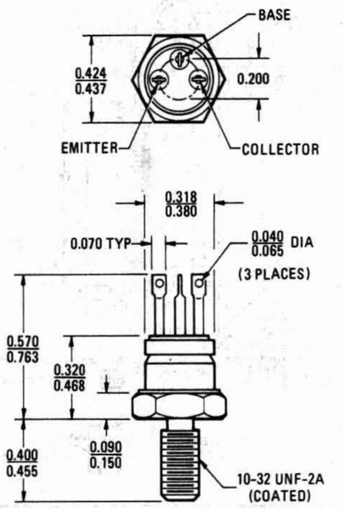
CASE 159


0.25
0.50
1.25
1.63
± 0.03
3.00
3.25
0.281 DIA THRU
4 PLACES
1.63
± 0.03
3.00
3.25
0.25
0.562 DIA THRU
3.25
0.25
2.25
2.34 ± 0.08
1.92 ± 0.08
0.63 ± 0.03
0.25
RECTIFIER DIODE
BUS-BAR
FINNED HEATSINK

TOLERANCES UNLESS OTHERWISE SPECIFIED: 2 PLACES ± 0.015
3 PLACES ± 0.010

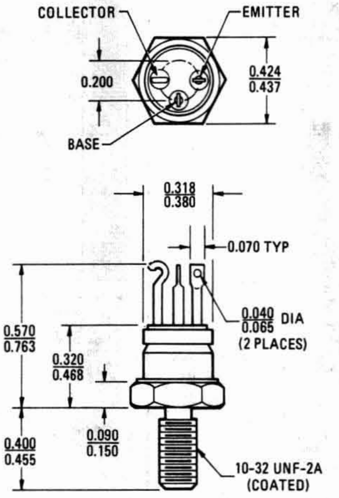
CASE 160 TO-59 PACKAGE

All leads isolated from case


BASE
0.424
0.437
0.200
EMITTER
COLLECTOR
0.318
0.380
0.070 TYP
0.040
0.065
DIA
(3 PLACES)
0.570
0.763
0.320
0.468
0.090
0.150
0.400
0.455
10-32 UNF-2A
(COATED)

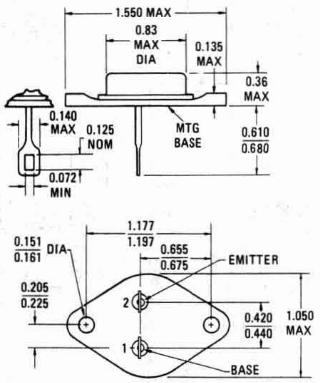
CASE 160A TO-59 PACKAGE

Collector connected to case


COLLECTOR
EMITTER
0.200
0.424
0.437
BASE
0.318
0.380
0.070 TYP
0.040
0.065
DIA
(2 PLACES)
0.570
0.763
0.320
0.468
0.090
0.150
0.400
0.455
10-32 UNF-2A
(COATED)

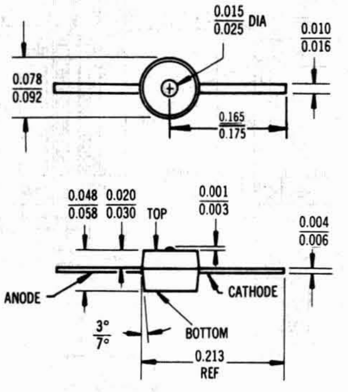
CASE 161 TO-41 PACKAGE

Collector connected to case


1.550 MAX
0.83
MAX
DIA
0.135
MAX
0.36
MAX
0.140
MAX
0.125
NOM
MTG
BASE
0.610
0.680
0.072
MIN
1.177
1.197
0.151
0.161
DIA
0.655
0.675
EMITTER
0.205
0.225
2
0.420
0.440
1.050
MAX
1
BASE

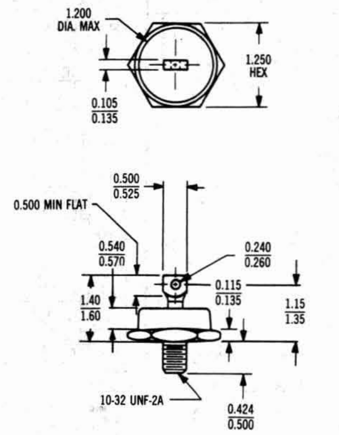
CASE 166

(Formerly Case 28A)

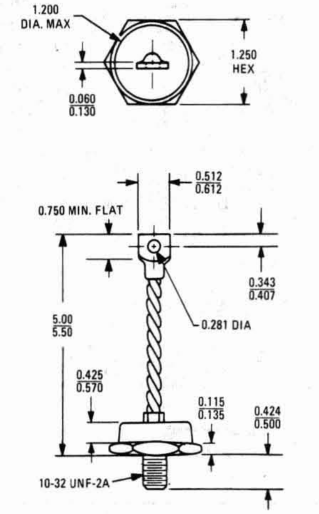

0.015
0.025
DIA
0.010
0.016
0.078
0.092
0.165
0.175
0.048
0.058
0.020
0.030
TOP
0.001
0.003
0.004
0.006
ANODE
CATHODE
3°
7°
BOTTOM
0.213
REF

Cathode identified by color dot on top of package.

CASE 167 TENTATIVE

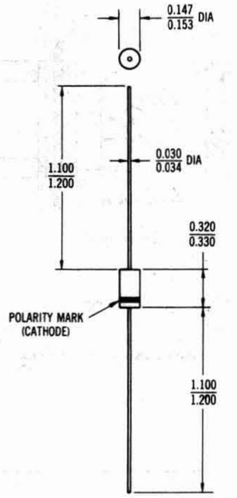

1.200
DIA. MAX
1.250
HEX
0.105
0.135
0.500
0.525
0.500 MIN FLAT
0.540
0.570
0.240
0.260
0.115
0.135
1.40
1.60
1.15
1.35
10-32 UNF-2A
0.424
0.500

CASE 168

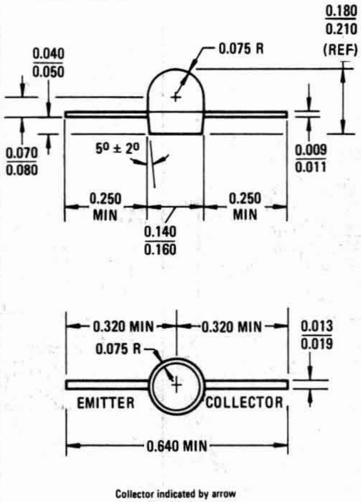

1.200
DIA. MAX
1.250
HEX
0.060
0.130
0.512
0.612
0.750 MIN. FLAT
0.343
0.407
5.00
5.50
0.281 DIA
0.425
0.570
0.115
0.135
0.424
0.500
10-32 UNF-2A

CASE 169

(Formerly Case 59A)

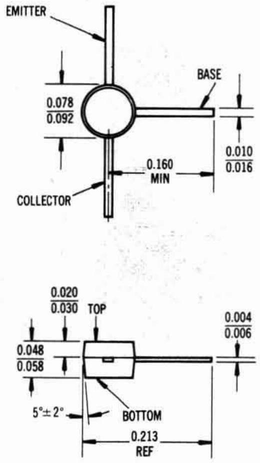

0.147
0.153
DIA
0.030
0.034
DIA
1.100
1.200
0.320
0.330
POLARITY MARK
(CATHODE)
1.100
1.200

CASE 171

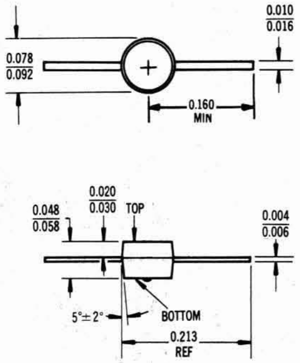

0.180
0.210
(REF)
0.040
0.050
0.075 R
0.070
0.080
5° ± 2°
0.009
0.011
0.250
MIN
0.250
MIN
0.140
0.160
0.320 MIN
0.320 MIN
0.013
0.019
0.075 R
EMITTER
COLLECTOR
0.640 MIN

Collector indicated by arrow on bottom of device.

CASE 172

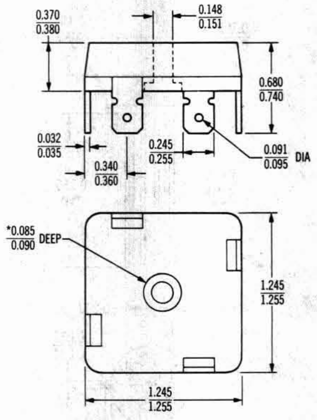

EMITTER
BASE
0.078
0.092
0.010
0.016
0.160
MIN
COLLECTOR
0.020
0.030
TOP
0.004
0.006
0.048
0.058
5°±2°
BOTTOM
0.213
REF

CASE 173


0.010
0.016
0.078
0.092
0.160
MIN
0.020
0.030
TOP
0.048
0.058
0.004
0.006
5°± 2°
BOTTOM
0.213
REF

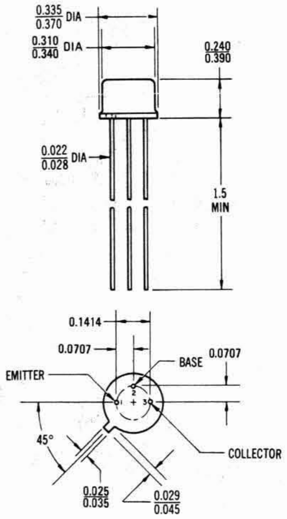
Collector indicated by arrow on bottom of device.

CASE 179 TENTATIVE

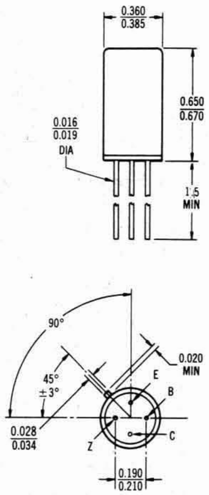

0.370
0.380
0.148
0.151
0.680
0.740
0.032
0.035
0.245
0.255
0.091
0.095
DIA
0.340
0.360
*0.085
0.090
DEEP
1.245
1.255
1.245
1.255

*Hole and countersink for #6 socket-head screw.

CASE 180

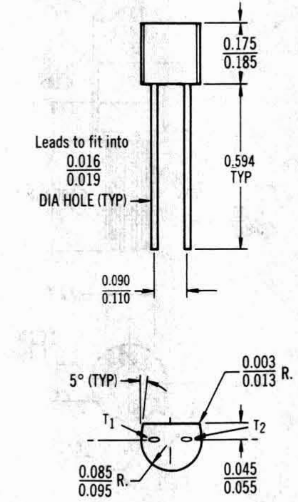

0.335
0.370
DIA
0.310
0.340
DIA
0.240
0.390
0.022
0.028
DIA
1.5
MIN
0.1414
0.0707
BASE
0.0707
EMITTER
1
2
3
45°
COLLECTOR
0.025
0.035
0.029
0.045

CASE 181

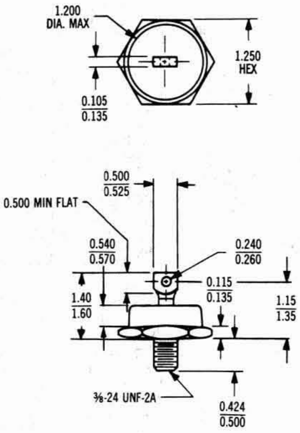

0.360
0.385
0.650
0.670
0.016
0.019
DIA
1.5
MIN
90°
0.020
MIN
45°
±3°
E
B
C
Z
0.028
0.034
0.190
0.210

CASE 182

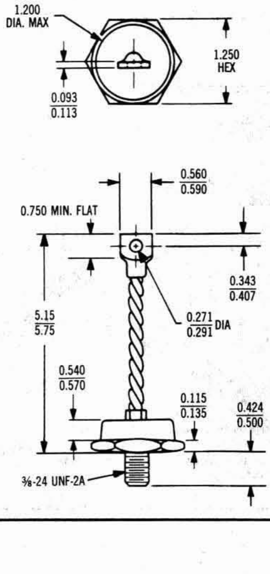
(Formerly Case 29B)


0.175
0.185
Leads to fit into
0.016
0.019
DIA HOLE (TYP)
0.594
TYP
0.090
0.110
5° (TYP)
0.003
0.013
R.
T1
T2
0.085
0.095
R.
0.045
0.055

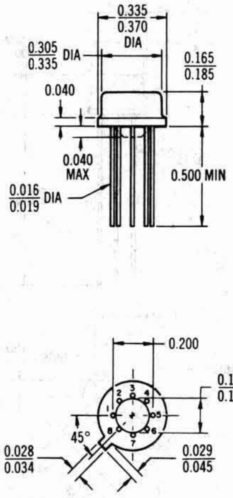
CASE 189 TENTATIVE


1.200
DIA. MAX
1.250
HEX
0.105
0.135
0.500
0.525
0.500 MIN FLAT
0.540
0.570
0.240
0.260
0.115
0.135
1.40
1.60
1.15
1.35
3/8-24 UNF-2A
0.424
0.500

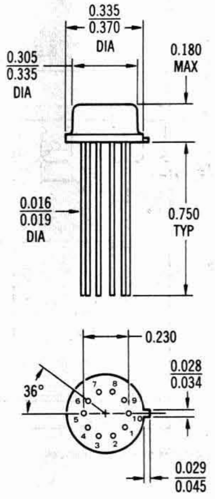
CASE 190 TENTATIVE


1.200
DIA. MAX
1.250
HEX
0.093
0.113
0.560
0.590
0.750 MIN. FLAT
0.343
0.407
5.15
5.75
0.271
0.291
DIA
0.540
0.570
0.115
0.135
0.424
0.500
3/8-24 UNF-2A

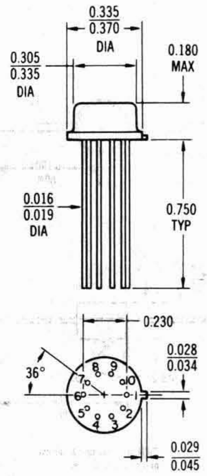
CASE 601 TO-99 PACKAGE
(Formerly Case 96)


0.335
0.370
DIA
0.305
0.335
DIA
0.165
0.185
0.040
0.040
MAX
0.500 MIN
0.016
0.019
DIA
0.200
0.140
0.160
1 2 3 4 5 6 7 8
45°
0.028
0.034
0.029
0.045

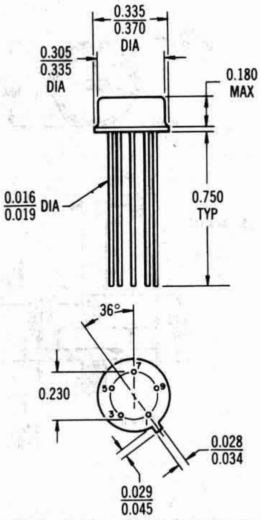
CASE 602A
(Formerly Case 71A)


0.335
0.370
DIA
0.305
0.335
DIA
0.180
MAX
0.016
0.019
DIA
0.750
TYP
0.230
0.028
0.034
36°
1 2 3 4 5 6 7 8 9 10
0.029
0.045

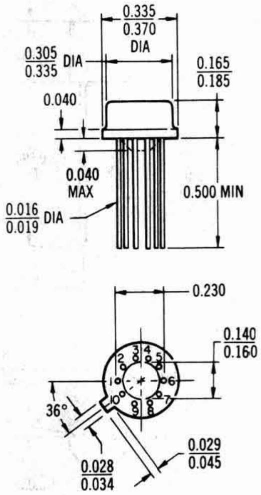
CASE 602B
(Formerly Case 71)


0.335
0.370
DIA
0.305
0.335
DIA
0.180
MAX
0.016
0.019
DIA
0.750
TYP
0.230
0.028
0.034
36°
1 2 3 4 5 6 7 8 9 10
0.029
0.045

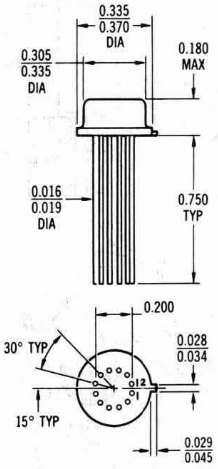
CASE 602C
(Formerly Case 89)


0.335
0.370
DIA
0.305
0.335
DIA
0.180
MAX
0.016
0.019
DIA
0.750
TYP
36°
0.230
1 3 5 7 9
0.028
0.034
0.029
0.045

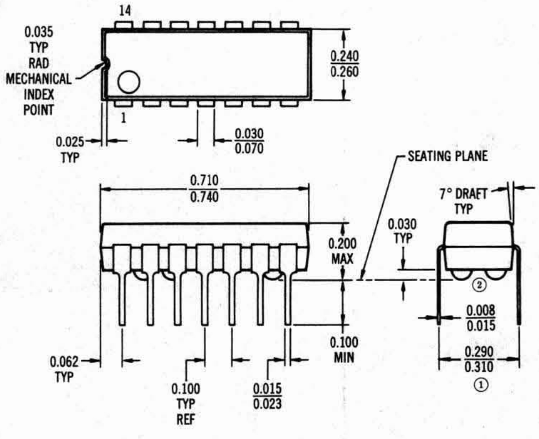
CASE 603 TO-100 PACKAGE
(Formerly Case 96A)


0.335
0.370
DIA
0.305
0.335
DIA
0.165
0.185
0.040
0.040
MAX
0.500 MIN
0.016
0.019
DIA
0.230
0.140
0.160
1 2 3 4 5 6 7 8 9 10
36°
0.028
0.034
0.029
0.045

CASE 604
(Formerly Case 98)


0.335
0.370
DIA
0.305
0.335
DIA
0.180
MAX
0.016
0.019
DIA
0.750
TYP
0.200
30° TYP
0.028
0.034
12
1
15° TYP
0.029
0.045

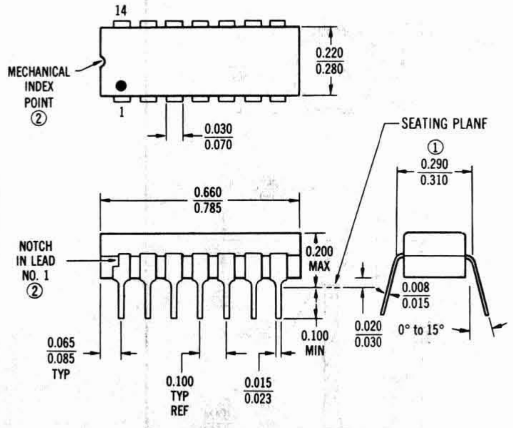
CASE 605 TO-116 PACKAGE (Plastic)
(Formerly Case 93)


14
0.035
TYP
RAD
MECHANICAL
INDEX
POINT
0.240
0.260
1
0.025
TYP
0.030
0.070
SEATING PLANE
0.710
0.740
7° DRAFT
TYP
0.030
TYP
0.200
MAX
②
0.008
0.015
0.100
MIN
0.290
0.310
①
0.062
TYP
0.100
TYP
REF
0.015
0.023

① This dimension is measured at the seating plane.

② 4 insulating stand-offs are provided.

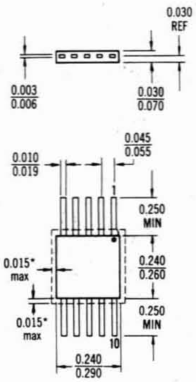
CASE 605C TO-116 PACKAGE (Ceramic)


14
MECHANICAL
INDEX
POINT
②
1
0.220
0.280
0.030
0.070
SEATING PLANE
①
0.290
0.310
0.660
0.785
NOTCH
IN LEAD
NO. 1
②
0.200
MAX
0.008
0.015
0.065
0.085
TYP
0.100
MIN
0.020
0.030
0° to 15°
0.100
TYP
REF
0.015
0.023

① This dimension is measured from the lead centers at the seating plane.

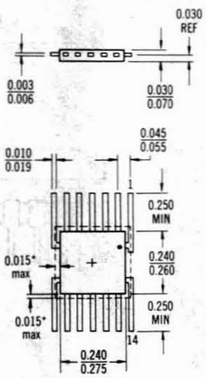
② Lead 1 identified by color dot, mechanical index point, or notch in pin.

CASE 606 TO-91 PACKAGE
(Formerly Case 72)


0.030 REF
0.003/0.006
0.030/0.070
0.045/0.055
0.010/0.019
1
0.250 MIN
0.015* max
0.240/0.260
0.015* max
0.250 MIN
10
0.240/0.290

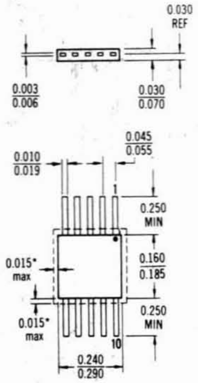
Lead 1 identified by color dot or by shoulder on lead.
All leads electrically isolated from package.
*Tolerance for lid skewing, glass meniscus, and glass overrun.

CASE 607 TO-86 PACKAGE
(Formerly Case 83)


0.030 REF
0.003/0.006
0.030/0.070
0.045/0.055
0.010/0.019
1
0.250 MIN
0.015* max
0.240/0.260
0.015* max
0.250 MIN
14
0.240/0.275

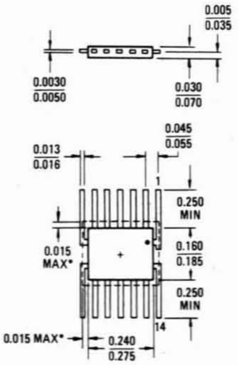
Lead 1 identified by color dot or by elbow on lead.
All leads electrically isolated from package.
*Tolerance for lid skewing, glass meniscus, and glass overrun.

CASE 608 TO-90 PACKAGE
(Formerly Case 73)


0.030 REF
0.003/0.006
0.030/0.070
0.045/0.055
0.010/0.019
1
0.250 MIN
0.015* max
0.160/0.185
0.015* max
0.250 MIN
10
0.240/0.290

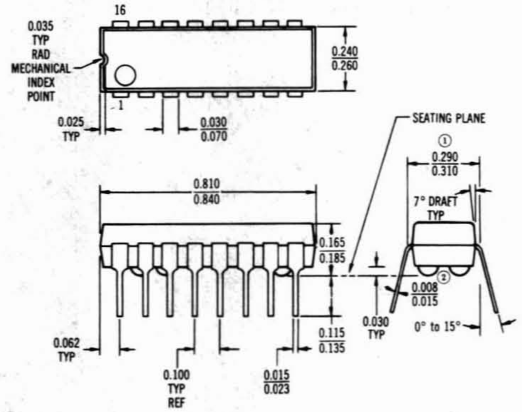
Lead 1 identified by color dot or by shoulder on lead.
All leads electrically isolated from package.
*Tolerance for lid skewing, glass meniscus, and glass overrun.

CASE 609 TO-85 PACKAGE


0.005/0.035
0.0030/0.0050
0.030/0.070
0.045/0.055
0.013/0.016
1
0.250 MIN
0.015 MAX*
0.160/0.185
0.250 MIN
14
0.015 MAX*
0.240/0.275

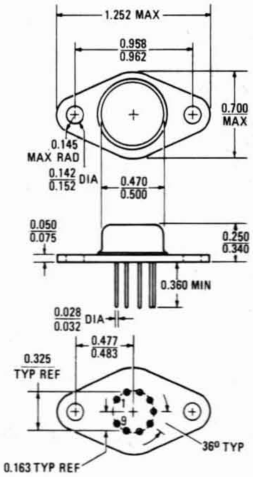
Lead 1 identified by color dot or by elbow on lead.
All leads electrically isolated from package.
*Tolerance for lid skewing, glass meniscus, and glass overrun.

CASE 612 (Plastic)

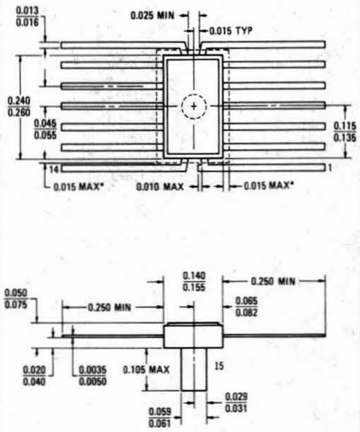

16
0.035 TYP RAD MECHANICAL INDEX POINT
0.240/0.260
1
0.025 TYP
0.030/0.070
SEATING PLANE
①
0.290/0.310
0.810/0.840
7° DRAFT TYP
0.165/0.185
②
0.008/0.015
0.030 TYP
0° to 15°
0.115/0.135
0.062 TYP
0.100 TYP REF
0.015/0.023

① This dimension is measured at the seating plane.
② 4 insulating stand-offs are provided.

CASE 614

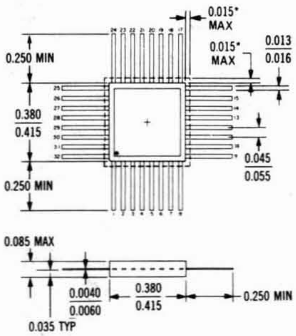

1.252 MAX
0.958/0.962
0.700 MAX
0.145 MAX RAD
0.142/0.152 DIA
0.470/0.500
0.050/0.075
0.250/0.340
0.360 MIN
0.028/0.032 DIA
0.477/0.483
0.325 TYP REF
1
9
36° TYP
0.163 TYP REF

CASE 617


0.013/0.016
0.025 MIN
0.015 TYP
0.240/0.260
0.045/0.055
0.115/0.135
14
1
0.015 MAX*
0.010 MAX
0.015 MAX*
0.140/0.155
0.250 MIN
0.050/0.075
0.250 MIN
0.065/0.082
0.020/0.040
0.0035/0.0050
0.105 MAX
15
0.029/0.031
0.059/0.061

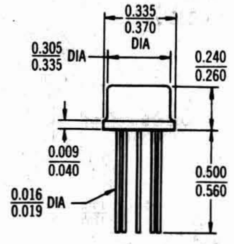
Lead 1 identified by a tab on that lead.
*Tolerance for lid skewing, glass meniscus, and glass overrun.

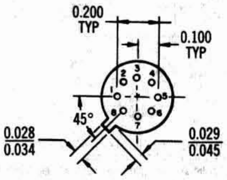
CASE 618


0.015* MAX
0.015* MAX
0.013/0.016
0.250 MIN
0.380/0.415
0.045/0.055
0.250 MIN
0.085 MAX
0.0040/0.0060
0.380/0.415
0.250 MIN
0.035 TYP

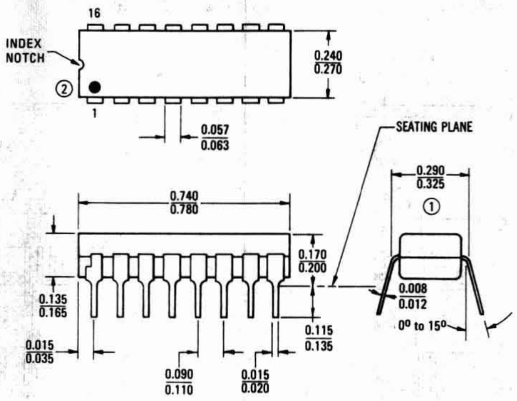
Lead 1 identified by color dot.
All leads electrically isolated from package.
*Tolerance for lid skewing, glass meniscus, and glass overrun.

CASE 619


0.335
0.370
DIA
0.305
0.335
DIA
0.240
0.260
0.009
0.040
0.500
0.560
0.016
0.019
DIA


0.200
TYP
0.100
TYP
1
2
3
4
5
6
7
8
45°
0.028
0.034
0.029
0.045

CASE 620 (Ceramic)


16
INDEX
NOTCH
②
1
0.240
0.270
0.057
0.063
SEATING PLANE
0.290
0.325
①
0.740
0.780
0.170
0.200
0.135
0.165
0.008
0.012
0° to 15°
0.015
0.035
0.115
0.135
0.090
0.110
0.015
0.020

① This dimension is measured from the lead centers at the seating plane with leads vertical.

② Lead 1 identified by color dot, notch in lead, or notch in ceramic.

APPLICATION NOTES

Page No.

Understanding Transistor Response Parameters AN-3
RF Small-Signal Design Using 2-Port Parameters AN-8
Selecting Commercial Power Transistor Heat Sinks AN-16
Mounting Procedure For, And Thermal Aspects of, Thermopad Plastic Power Devices AN-22
A Method of Predicting Thermal Stability AN-25
Avoiding Second Breakdown AN-30
Thermal Response of Semiconductors AN-37
Field-Effect Transistors in Theory and Practice AN-47
Field-Effect Transistors in Chopper and Analog Switching Circuits AN-58
FET Current Regulators – Circuits and Diodes AN-65
Selecting Varactor Diodes AN-75
High-Power Varactor Diodes: Theory and Application AN-80
Epicap VVC Tuning of Resonant Circuits AN-87
SCR Power Control Fundamentals AN-91
Characterization of SCR's as Switches for Line Type Modulators AN-96
Theory and Characteristics of the Unijunction Transistor AN-103
Unijunction Transistor Timers and Oscillators AN-113
Theory and Characteristics of Phototransistors AN-124

UNDERSTANDING TRANSISTOR RESPONSE PARAMETERS

The range of frequencies over which a transistor performs a useful circuit function is limited by inherent parameters. Manufacturers' data sheets often specify only one or two of these parameters, and questions concerning others often arise. Therefore, a clear understanding of these parameters is of value in attempting to answer such questions from the data given.

PARAMETER CHARACTERISTICS AND INTERRELATIONSHIPS

One parameter is h_{fb} (alpha, the common base ac short-circuit forward current gain). As frequency is increased, h_{fb} remains approximately equal to h_{fbo} (the value of h_{fb} at 1 kHz). After the upper frequency is reached, h_{fb} begins to decrease rapidly.

The frequency at which a significant decrease in h_{fb} occurs provides a basis for comparison of the expected high frequency performance of different transistors. The common base current gain cutoff frequency, $f_{\alpha b}$, is defined as that frequency at which h_{fb} is 3 dB below h_{fbo}. Expressed in magnitude, h_{fb} at $f_{\alpha b}$, is 70.7 per cent of h_{fbo}. Power gains, current gains, and voltage gains for a few common decibel values are found in Table 1. A curve of h_{fb} versus frequency for a transistor with an $f_{\alpha b}$ of 1 MHz is shown in Fig. 1.

This curve has the following significant characteristics: (1) at frequencies below $f_{\alpha b}$, h_{fb} is nearly constant and approximately equal to h_{fbo}, (2) h_{fb} begins to decrease significantly in the region of $f_{\alpha b}$, (3) above $f_{\alpha b}$, the rate of decrease in h_{fb} with increasing frequency approaches 6 dB per octave in the limit.

The curve of common base current gain versus frequency for any transistor has these characteristics, and the same general appearance as the curve of Fig. 1.

The common emitter parameter which corresponds to $f_{\alpha b}$, is $f_{\alpha e}$, the common emitter current gain cutoff frequency.

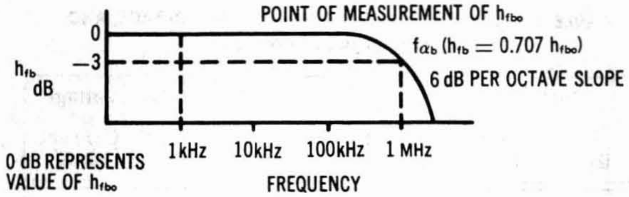


FIGURE 1 — GRAPH REPRESENTS A CURVE OF A COMMON BASE CURRENT GAIN PLOTTED AGAINST FREQUENCY VARIATIONS.

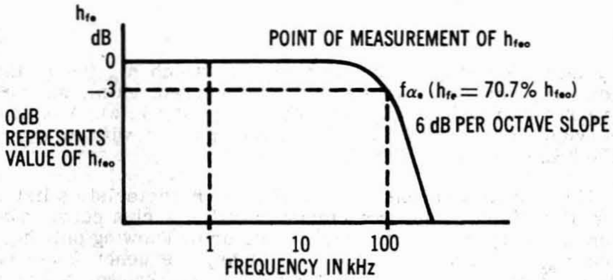


FIGURE 2 — COMMON EMITTER CURRENT GAIN IS PLOTTED AGAINST FREQUENCY IN THE CURVE SHOWN.

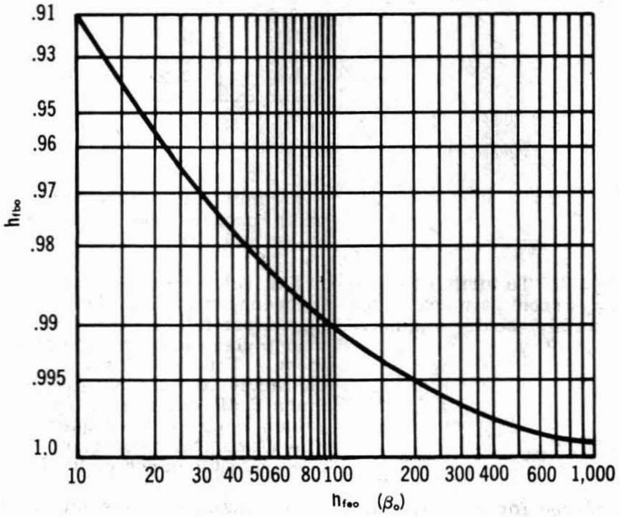


FIGURE 3 — THE RELATIONSHIP BETWEEN h_{feo} AND h_{fbo} IS GIVEN BY THE GRAPH SHOWN.

GLOSSARY OF SYMBOLS

Symbol	Definition
h_{fb}	Common base ac forward current gain (alpha)
h_{fbo}	Value of h_{fb} at 1 kHz
h_{fe}	Common emitter ac forward current gain (beta)
h_{feo}	Value of h_{fe} at 1 kHz
$f_{\alpha b}$	Common base current gain cutoff frequency. Frequency at which h_{fb} has decreased to a value 3 dB below h_{fbo}. ($h_{fb} = 0.707\ h_{fbo}$)
$f_{\alpha e}$	Common emitter current gain cutoff frequency. Frequency at which h_{fe} has decreased to a value of 3 dB below h_{feo} ($h_{fe} = 0.707\ h_{feo}$)
f_T	Gain bandwidth product. Frequency at which $h_{fe} = 1$ (0 dB)
G_{pe}	Common emitter power gain
f_{max}	Maximum frequency of oscillation. Frequency at which $G_{pe} = 1$ (0 dB)
K_θ	Excess phase shifter factor. Factor which is a function of excess phase shift of current in the base of a transistor.

By definition, $f_{\alpha e}$ is the frequency at which h_{fe} (beta, the common emitter of ac short-circuit current gain), has decreased 3 dB below h_{feo} (the value of h_{fe} at 1 kHz). A typical curve of h_{fe} versus frequency for a transistor with an $f_{\alpha e}$ of 100 kHz is shown in Fig. 2.

This curve also has the significant characteristics listed for Fig. 1. These characteristics allow such a curve to be constructed for a particular transistor by knowing only h_{feo} and $f_{\alpha e}$. From the curve, h_{fe} at any frequency could be determined. Furthermore, if $f_{\alpha e}$, is not known, a curve could also be constructed if h_{feo} and h_{fe} at any frequency above $f_{\alpha e}$ were known. Thus to determine h_{fe} at any frequency, it is necessary to know only h_{feo} and either $f_{\alpha e}$ or h_{fe} at some frequency f, where f is greater than $f_{\alpha e}$.

Sometimes h_{feo} is needed and only h_{fbo} is given, or vice versa. The quantities h_{fbo} and h_{feo} are related by the following:

$$h_{feo} = \frac{h_{fbo}}{1 - h_{fbo}} \qquad (1)$$

$$h_{fbo} = \frac{h_{feo}}{h_{feo} + 1} \qquad (2)$$

Equations 1 and 2 are plotted in Fig. 3. To further facilitate computations, the low frequency current gain scales of Fig. 7 - 10 contain both an h_{fbo} and an h_{feo} scale, and may be entered with a knowledge of either quantity.

RELATIONSHIPS BETWEEN $f_{\alpha e}$ AND $f_{\alpha b}$

Suppose two transistors are considered for a particular application where performance at high frequencies is of interest. The data sheets are compared and it is discovered that one specifies $f_{\alpha b}$ and the other $f_{\alpha e}$. What preliminary comparisons can be made from this without making any laboratory measurements?

Phillips[1] gives a discussion of the relationships between $f_{\alpha e}$ and $f_{\alpha b}$ with the following result:

$$f_{ae} = K_\theta (1 - h_{fbo})\, f_{\alpha b} \qquad (3)$$

where K_θ is a function of excess phase shift in the base region and has some value between 0.5 and 1.0.

Most transistors have a K_θ in the 0.8 to 1.0 range. An exception is the germanium MADT types which have a K_θ of 0.6. Alloy transistors have a K_θ of 0.82.

The nomograms provide solutions for values of K_θ of 0.9, 0.8, and 0.6. If more specific information on K_θ is not available, a value of 0.8 is recommended.

The quantity $f_{\alpha e}$ is normally a much lower frequency than $f_{\alpha b}$ for the same transistor. For example, consider the Motorola 2N1141 germanium transistor. The data sheets give typical values $f_{\alpha b} = 1{,}000$ MHz and $h_{fbo} = 0.98$. Substituting in Eq. 3 yields $f_{\alpha e} = 0.80\ (1 - 0.98)\ 1{,}000 = 16$ MHz.

This result is in approximate agreement with the h_{fe} versus frequency curve of the manufacturer's 2N1141 data sheet.

For the practical application of Eq. 3, refer to Fig. 7 and 9. When any two of the quantities $f_{\alpha e}$, $f_{\alpha b}$, h_{fbo}, or h_{feo} are known, use the nomograms to find the third quantity.

TABLE 1 — CONVERSION TABLE FOR POWER, VOLTAGE, AND CURRENT RATIOS INTO DECIBELS.

dB	Power Ratio	Voltage or Current Ratio	dB	Power Ratio	Voltage or Current Ratio
0	1.00	1.00	10	10.0	3.2
0.5	1.12	1.06	15	31.5	5.6
1.0	1.26	1.12	20	100	10
1.5	1.41	1.19	25	316	18
2.0	1.58	1.26	30	1,000	32
3.0	2.00	1.41	40	10,000	100
4.0	2.51	1.58	50	10^5	316
5.0	3.16	1.78	60	10^6	1,000
6.0	3.98	2.00			
7.0	5.01	2.24			
8.0	6.31	2.51			
9.0	7.94	2.82			

A common high-frequency parameter is f_T, the gain bandwidth product and is defined as that frequency at which $h_{fe} = 1$ (0 dB).

The value f_T is sometimes specified indirectly on high-frequency transistor data sheets. This is done by specifying h_{fe} at some frequency above $f_{\alpha e}$, thus f_T is then obtained by multiplying the magnitude of h_{fe} by the frequency of measurement. This relationship arises from the 6 dB per octave characteristic of the h_{fe} versus frequency curve above $f_{\alpha e}$. Since 6 dB represents a current gain magnitude of 2, h_{fe} is halved each time frequency is doubled, and vice versa. Therefore, the product of h_{fe} and frequency of the sloping portion of the curve yields f_T.

For example, consider the Motorola 2N2217 silicon star annular transistor. The data sheet gives a typical h_{fe} of 4.0 at 100 MHz. Multiplication of h_{fe} times the frequency of measurement yields $f_T = 4.0 \times 100 = 400$ MHz. This is in agreement with the data sheet which specifies a typical f_T of 400 MHz.

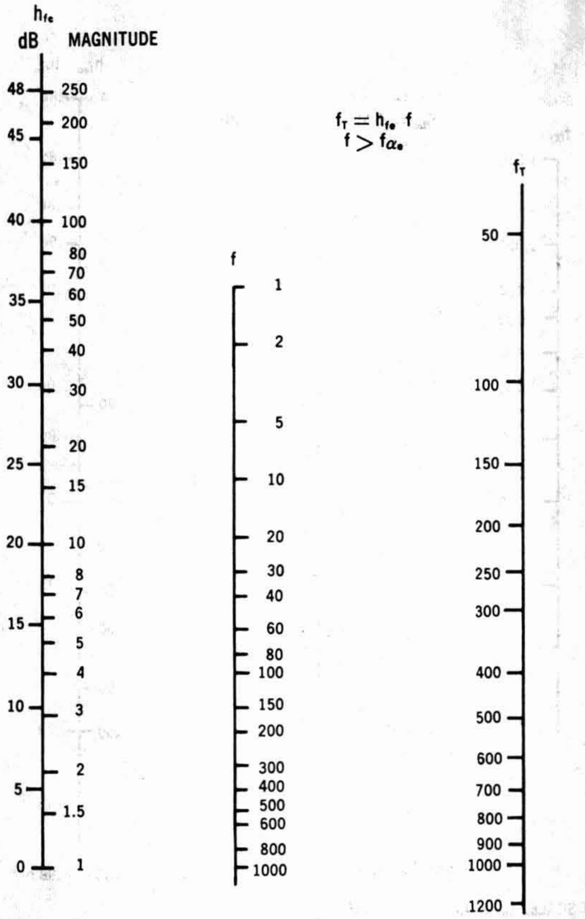


FIGURE 4 — THIS NOMOGRAM IS USEFUL IN FINDING h_{fe} WHEN A FREQUENCY $f > f_{\alpha e}$.

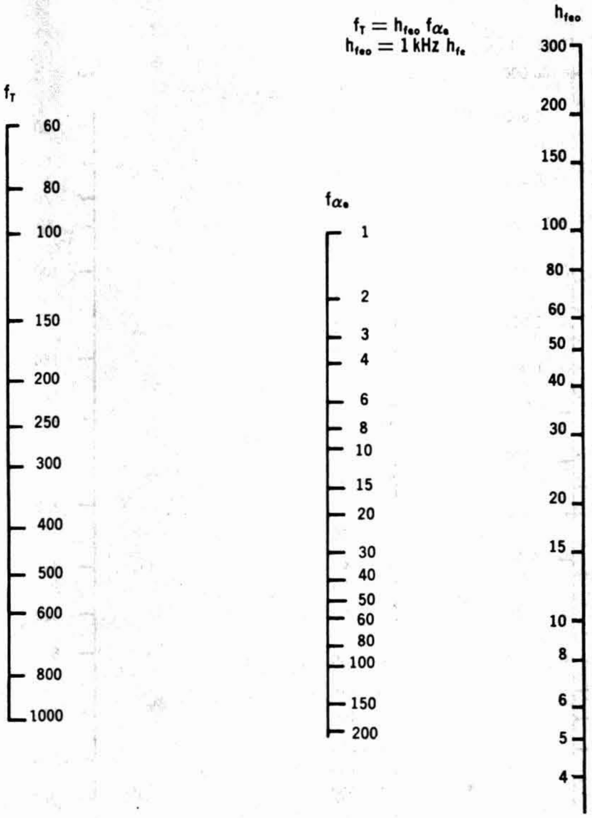


FIGURE 5 — THE QUANTITY f_T IS FOUND FROM THIS NOMOGRAM ONCE $f_{\alpha e}$ AND h_{feo} ARE KNOWN.

The parameter f_T is also equal to the product of h_{feo} and $f_{\alpha e}$, expressed by

$$f_T = h_{feo} \times f_{\alpha e} \tag{4}$$

with h_{feo} known, Eq. 4 provides a simple means of finding $f_{\alpha e}$ when f_T is known or vice versa. (see Fig. 5.)

Phillips also develops the following relationship between $f_{\alpha b}$ and f_T:

$$f_T = K_\theta\, h_{fbo}\, f_{\alpha b} \tag{5}$$

where K_θ is the same quantity as in Eq. 3. Notice that since K_θ lies between 0.5 and 1.0, the f_T of a transistor is approximately equal to or slightly less than its $f_{\alpha b}$. (see Fig. 8 and 10.)

RULES FOR DETERMINING h_{fe}

The following rules summarize how to determine h_{fe} at some frequency f:

Rule 1: When $f < f_{\alpha e}$, $h_{fe} \approx h_{feo}$

Rule 2: When $f \approx f_{\alpha e}$, $h_{fe} \approx 0.7\, h_{feo}$

Rule 3: When $f > f_{\alpha e}$, consider h_{fe} to be decreasing at 6 dB per octave at frequency f and use Fig. 4 to find h_{fe}.

Rule 4: (A) If h_{fbo} not h_{feo} is known, use Fig. 3 to find h_{feo}.

(B) If f_T is not known, use Fig. 5 to find f_T if h_{feo} and $f_{\alpha e}$ are known or Fig. 8 to find f_T if $f_{\alpha b}$ is known (Fig. 10 for MADT types).

(C) If $f_{\alpha e}$ is not known, use Fig. 5 to find $f_{\alpha e}$ if f_T is known (Fig. 7 to find $f_{\alpha e}$ if $f_{\alpha b}$ is known (Fig. 9 for MADT types).

Though common emitter current gain is equal to 1 at f_T, there may still be considerable power gain at f_T due to different input and output impedance levels. Thus, f_T is not necessarily the highest useful frequency of operation of a transistor, and an additional parameter, the maximum frequency of oscillation (f_{max}), is sometimes encountered. The term f_{max} is the frequency at which common emitter power gain is equal to 1, and is related to f_T by

$$f_{max} \approx \sqrt{\frac{f_T}{8\pi\, r'_b C_c}} \tag{6}$$

where r'_b is the base resistance and C_c is the collector capacitance.

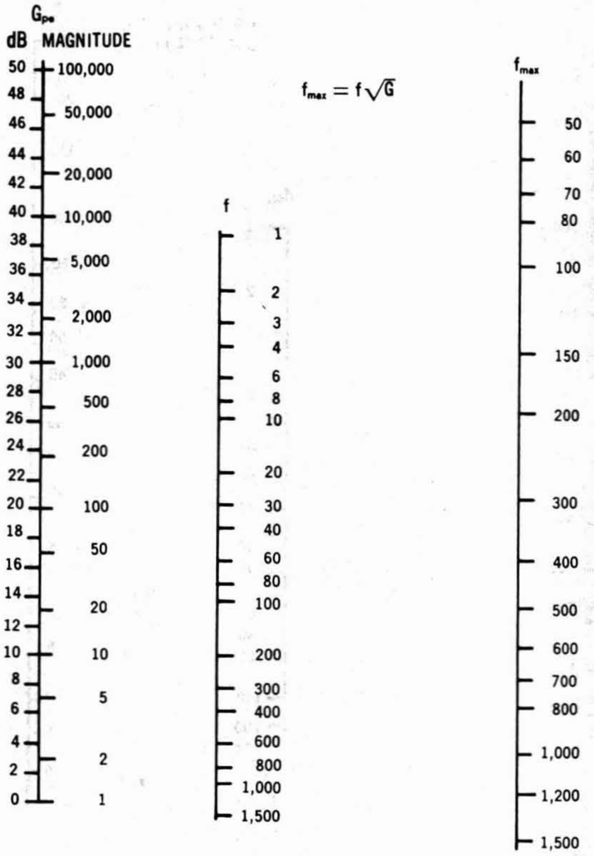
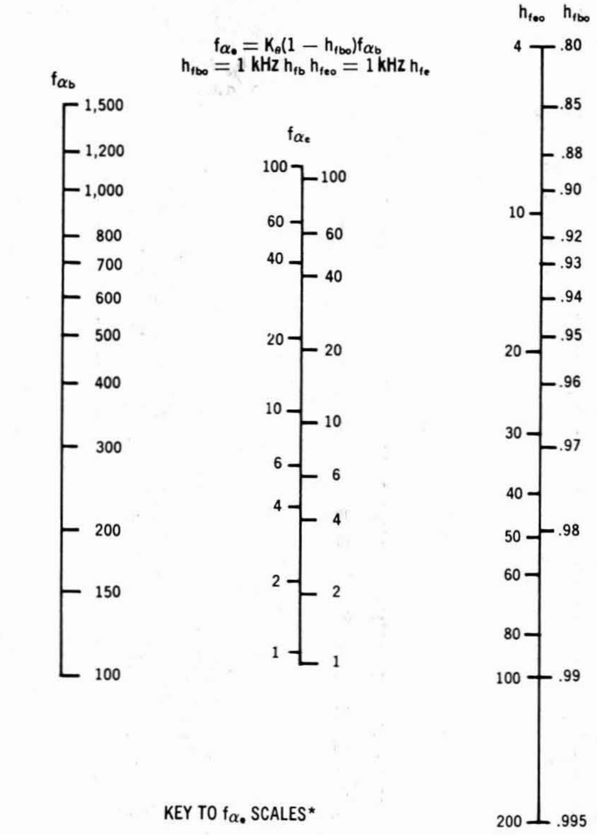


FIGURE 6 — MAXIMUM FREQUENCY IS FOUND FROM THIS NOMOGRAM KNOWING THE FREQUENCY AND POWER GAIN.


$f\alpha_e = K_\theta(1 - h_{fbo})f\alpha_b$
$h_{fbo} = 1$ kHz h_{fb} $h_{feo} = 1$ kHz h_{fe}
$f\alpha_b$
$f\alpha_e$
h_{feo} h_{fbo}

KEY TO $f\alpha_e$ SCALES*

LEFT SCALE, $K_\theta = 0.8$ RIGHT SCALE, $K_\theta = 0.9$

*FOR MADT TYPES, SEE FIG. 9

FIGURE 7 — ONCE $f_{\alpha b}$ IS KNOWN THIS NOMOGRAM IS USED TO FIND $f_{\alpha e}$.

A plot of common emitter power gain versus frequency also has the characteristics shown in Fig. 1. This leads to another gain bandwidth product

$$f_{max} \approx f\sqrt{\text{Power Gain}} \qquad (7)$$

where f is the frequency of measurement and power gain is expressed in magnitude not in decibels. Hence, f_{max} may be found by measuring power gain at some frequency on the 6 dB per octave portion of the power gain versus frequency curve, and multiplying the square root of the power gain with the frequency of measurement (see Fig. 6). The symbol for common emitter power gain is G_{pe}.

The parameters are voltage and current dependent, and operating point must be considered in all cases. For example, the high-frequency h_{fe} measurement at one collector voltage and current must not be used to calculate f_T directly at another voltage and/or current without considering the added effects of the different operating point.

The parameter $f_{\alpha e}$ for present high frequency transistors usually lies in the region between 10 and 50 MHz. The term h_{fe}, measured at any frequency above this region is assumed on the 6 dB per octave portion of h_{fe} versus frequency curve and is used to calculate f_T directly.

Power gain measured at any frequency above 50 MHz is assumed on the 6 dB per octave portion of the power gain versus frequency curve and is used to calculate f_{max} directly.

INSTRUCTIONS FOR CURVES AND NOMOGRAMS

The nomograms assume no shift in operating point. Known parameters used to find an unknown must be measured at the same collector voltage and collector current as the desired unknown.

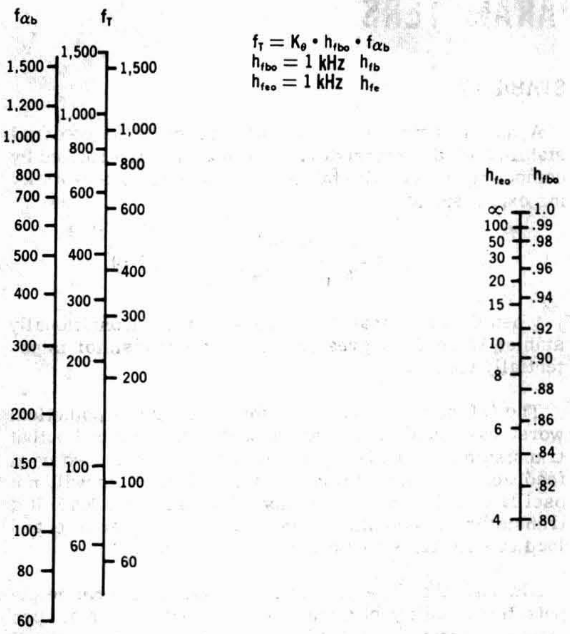
Frequency scales on the nomograms are calibrated in numbers only without units. Furthermore, all nomograms contain two frequency scales. Decimal points may be shifted on the frequency scales of any nomogram as long as they are shifted the same amount on both scales (i. e., both frequency scales of a nomogram must be multiplied by 10 to the same power). This enables the same nomogram to be used for both high and low-frequency transistors.

The nomograms assume that both power gain and current gain decrease with increasing frequency at a rate of 6 dB per octave at high frequencies.

All power gain and current gain scales (except h_{fbo} and h_{feo}) are calibrated in both actual magnitudes and decibel values for convenience.

EXAMPLE 1

To find h_{feo} when h_{fbo} is known or vice versa, enter Fig. 3 with the known value and read the unknown directly. Given: $h_{fbo} = 0.96$. Find: h_{feo}. Answer = 24.


fαb
fT
fT = Kθ • hfbo • fαb
hfbo = 1 kHz hfb
hfeo = 1 kHz hfe
1,500
1,200
1,000
800
700
600
500
400
300
200
150
100
80
60
hfeo
hfbo
∞
100
50
30
20
15
10
8
6
4
1.0
.99
.98
.96
.94
.92
.90
.88
.86
.84
.82
.80

KEY TO f_T SCALES*

LEFT SCALE $K_\theta = 0.8$ RIGHT SCALE $K_\theta = 0.9$

*FOR MADT TYPES, SEE FIG. 9

FIGURE 8 — THIS NOMOGRAM REPRESENTS f_T, $f_{\alpha b}$, AND EITHER h_{fbo} OR h_{feo}.

EXAMPLE 2

Figure 4 is a nomogram of f_T and h_{fe} at some frequency f, where f > $f_{\alpha e}$. Given: h_{fe} at 100 MHz is 6 dB. Find: h_{fe} at 75 MHz. Answer: 4, or 12 dB.

EXAMPLE 3

There are no special instructions for the nomogram of Fig. 5, merely use it to find the unknown parameter when any two are known. Given: h_{feo} = 40 and f_T = 400 MHz. Find: $f_{\alpha e}$. Answer: 10 MHz.

EXAMPLE 4

Figure 6 is a nomogram of f_{max} and common emitter power gain measured at some frequency f where power gain is known to be decreasing at 6 dB per octave. Given: power gain at 500 MHz is 6 dB. Find: f_{max}. Answer: 800 MHz. Given: f_{max} = 1000 MHz. Find: power gain at 250 MHz. Answer: 12 dB.

EXAMPLE 5

Fig. 7 is a nomogram of $f_{\alpha b}$, $f_{\alpha e}$, and either h_{fbo} or h_{feo}. To account for variations in this relationship with different transistor types, there are two $f_{\alpha e}$ scales, one for $K_\theta = 0.8$ and one for $K_\theta = 0.9$. Given: $f_{\alpha e}$ = 1 MHz and h_{fbo} = 0.90. Find: $f_{\alpha e}$. Answer: 80 kHz (assuming $K_\theta = 0.8$). For MADT types, see Fig. 9.

EXAMPLE 6

Figure 8 is a nomogram of f_T, $f_{\alpha b}$, and either h_{fbo} or h_{feo}. To account for variations in this relationship with different transistor types, there are two f_T scales, one for $K_\theta = 0.8$ and one for $K_\theta = 0.9$. Given: f_T = 400 MHz and h_{fbo} = 0.90. Find: $f_{\alpha b}$. Answer: 555 MHz (assuming $K_\theta = 0.8$). For MADT types, see Fig. 10.

EXAMPLE 7

Figure 9 is a nomogram which is identical to Fig. 7 except that it is for use with MADT transistors (see instructions for Fig. 7).

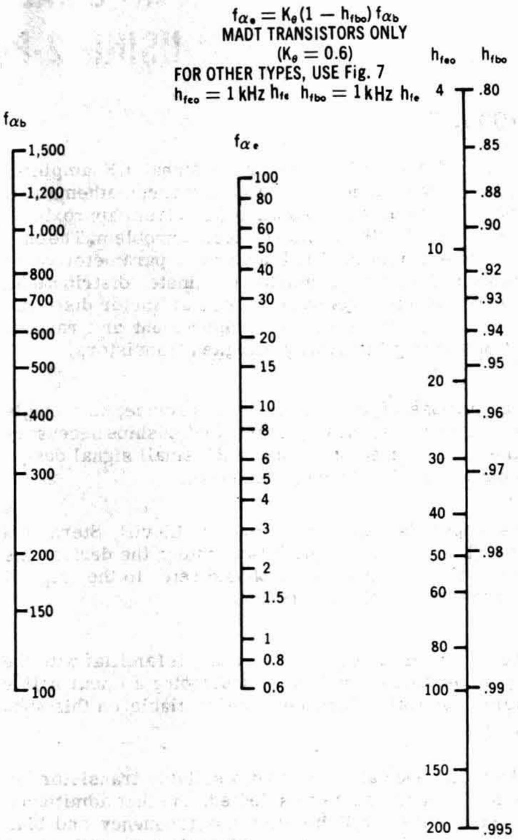

fαe = Kθ(1 − hfbo) fαb
MADT TRANSISTORS ONLY
(Kθ = 0.6)
FOR OTHER TYPES, USE Fig. 7
hfeo = 1 kHz hfe hfbo = 1 kHz hfe
fαb
1,500
1,200
1,000
800
700
600
500
400
300
200
150
100
fαe
100
80
60
50
40
30
20
15
10
8
6
5
4
3
2
1.5
1
0.8
0.6
hfeo
hfbo
4
10
20
30
40
50
60
80
100
150
200
.80
.85
.88
.90
.92
.93
.94
.95
.96
.97
.98
.99
.995

FIGURE 9 — THIS NOMOGRAM IS IDENTICAL TO FIGURE 7 BUT IS USED FOR MADT TRANSISTORS.

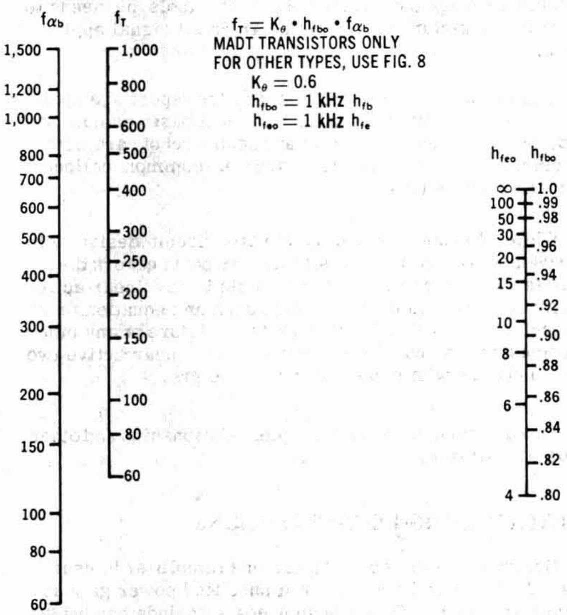

fαb
fT
fT = Kθ • hfbo • fαb
MADT TRANSISTORS ONLY
FOR OTHER TYPES, USE FIG. 8
Kθ = 0.6
hfbo = 1 kHz hfb
hfeo = 1 kHz hfe
1,500
1,200
1,000
800
700
600
500
400
300
200
150
100
80
60
1,000
800
600
500
400
300
250
200
150
100
80
60
hfeo
hfbo
∞
100
50
30
20
15
10
8
6
4
1.0
.99
.98
.96
.94
.92
.90
.88
.86
.84
.82
.80

FIGURE 10 — IDENTICAL TO FIGURE 8. THIS NOMOGRAM IS USED ONLY FOR MADT TRANSISTORS.

EXAMPLE 8

Figure 10 is a nomogram which is identical to Fig. 8 except that it is for use with MADT transistors (see instructions for Fig. 8).

REFERENCE

1. A. B. Phillips, "Transistor Engineering", McGraw-Hill Book Company, Inc., New York, N. Y., Chapter 14.

RF SMALL-SIGNAL DESIGN USING 2-PORT PARAMETERS

INTRODUCTION

Design of the solid-state small-signal RF amplifier using two port parameters is a systematic, mathematical procedure, with an exact solution (free from approximation) available for the complete design problem. The only sources of error in the final design are parameter variations resulting from transistor parameter distributions and strays in the physical circuit. Parameter distributions result from limits in measurement and random variations among identically designed transistors.

The purpose of this paper is to provide, in a single working reference, the important relationships necessary for the complete solution of the RF small signal design problem using admittance parameters.

The paper is based on work by Linvill, Stern, and others. Those who may wish to consider the derivations of some of the expressions should refer to the original work presented in the references.

The report assumes that the reader is familiar with the two port parameter method of describing a linear active network. Several references are available on this subject.[1,2]

It has also been assumed that a suitable transistor for the task at hand has been selected, and that admittance parameters are available for the frequency and bias point which will be used. Device selection will not be covered as a separate topic in this report; rather, a thorough understanding of the material in the report should provide the designer with the tools he needs to select transistors for a particular small signal application.

The equations given in the text of the report are applicable to the common emitter, common base, or common collector configuration, if the applicable set of parameters (common emitter, common base, or common collector parameters) is used.

While directed primarily toward circuit design with conventional junction transistors, two port network theory has the advantage of being applicable to any linear active network. The same design approach and equations may therefore be used with field effect transistors or any other devices which may be described as a linear active two port network with measurable parameters.

Finally, various parameter interrelationships and other data are given in the Appendix.

GENERAL DESIGN CONSIDERATIONS

Design of the RF small signal tuned amplifier is usually based on a requirement for a specified power gain at a given frequency. Other design goals include bandwidth, stability, and input-output isolation. After a basic circuit type is selected, the applicable design equations can be solved.

Circuits may be categorized according to feedback (neutralization, unilateralization, or no feedback), and matching at transistor terminals (circuit admittances either matched or mismatched to transistor input and output admittances). Each of these circuit categories will be discussed, including the applicable design equations and the considerations leading to the selection of a particular configuration.

STABILITY

A major factor in the overall design is the potential stability of the transistor. This may be determined by computing the Linvill stability factor[2] C using the following expression: †

$$C = \frac{|y_{12}\,y_{21}|}{2g_{11}\,g_{22} - \mathrm{Re}\,(y_{12}y_{21})} \qquad (1)$$

When C is less than 1, the transistor is unconditionally stable. When C is greater than 1, the transistor is potentially unstable.

The C factor is a test for stability under a hypothetical worst case condition; that is, with both input and output transistor terminals open circuited. With no external feedback, an unconditionally stable transistor will not oscillate with any combination of source and load. If a transistor is potentially unstable, certain source and load combinations will produce oscillations.

Although the C factor may be used to determine the potential stability of a transistor, the conditions of open circuited source and load which are assumed in the C factor test are not applicable to a practical amplifier. Consequently it is also desirable to compute the relative stability of actual amplifier circuits, and Stern[3] has defined a stability factor k for this purpose. The k factor is similar to the C factor except that it also takes into account finite source and load admittances connected to the transistor. The expression for k is:

$$k = \frac{2\,(g_{11} + G_s)\,(g_{22} + G_L)}{|y_{12}y_{21}| + \mathrm{Re}\,(y_{12}y_{21})} \qquad (2)$$

If k is greater than one, the circuit will be stable. If k is less than one, the circuit will be unstable.

Note that the C factor simply predicts potential stability of a transistor with an open circuited source and load, while the k factor provides a precise stability computation for a specific circuit.

Stability considerations will be discussed further in the descriptions of each basic circuit type to follow.

GENERAL DESIGN EQUATIONS

There are a number of design equations which are applicable to most types of amplifiers. These equations will be discussed first. Descriptions of specific amplifier types will then follow, and each will contain additional design equations applicable to that particular amplifier.

POWER GAIN

The general expression for power gain is:

$$G = \frac{|y_{21}|^2\,\mathrm{Re}\,(Y_L)}{|Y_L + y_{22}|^2\,\mathrm{Re}\,\left(y_{11} - \frac{y_{12}y_{21}}{y_{22} + Y_L}\right)} \qquad (3)$$

Equation 3 applies to circuits with no external feedback. It can also be used with circuits which have external feedback if the composite y parameters of both transistor and feedback network are substituted for the transistor y parameters in the equation. The composite y parameters are determined by considering the transistor and the feedback network to be two "black boxes" in parallel:

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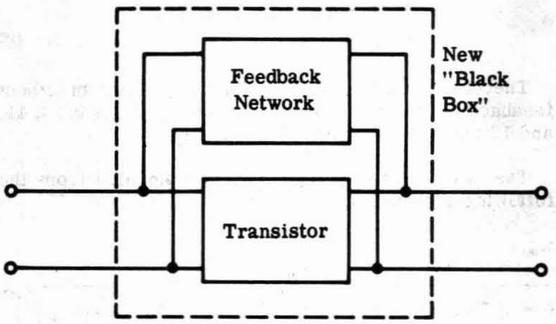
† $\mathrm{Re}\,(Y_{12}Y_{21})$ = Real part of $(Y_{12}Y_{21})$



For example, the above combination of transistor and feedback network may be characterized as a single "black box" by the following equations:[†]

$$\begin{aligned} y_{11c} &= y_{11t} + y_{11f} \\ y_{12c} &= y_{12t} + y_{12f} \\ y_{21c} &= y_{21t} + y_{21f} \\ y_{22c} &= y_{22t} + y_{22f} \end{aligned} \qquad (4)$$

Where:

y_{11c}, y_{12c}, y_{21c}, y_{22c} are the composite y parameters of the parallel combination of transistor and feedback network.

y_{11t}, y_{12t}, y_{21t}, y_{22t} are the y parameters of the transistor.

y_{11f}, y_{12f}, y_{21f}, y_{22f} are the y parameters of the feedback network.

Note that, since this approach treats the transistor and feedback network combination as a single "black box" with y_{11c}, y_{12c}, y_{21c}, and y_{22c} as its y parameters, the composite y parameters may therefore be substituted in any of the design equations applicable to a linear, active, two port analysis.

The neutralized and unilateralized amplifiers are special cases of this general concept, and equations associated with those special cases will be given later.

Equation 3 provides a solution for power gain of the linear active network (transistor) only. Input and output networks are considered to be part of the source and load, respectively. Two important points should therefore be kept in mind:

(1) Power gain computed from equation 3 will not take into account network losses. Input network loss reduces power delivered to the transistor. Power lost in the output network is computed as useful power output, since the load admittance Y_L is the combination of the output network and its load.

(2) Power gain is independent of source admittance. An input mismatch results in less input power being delivered to the transistor. Accordingly, note that equation 3 does not contain the term Y_s.

The power gain of a transistor together with its associated input and output networks may be computed by measuring the input and output network losses, and subtracting them from the power gain computed with equation 3.

In some cases it may be desirable to include the effects of input matching in power gain computations. A convenient term is transducer gain G_T, defined as output power delivered to a load by the transistor, divided by the maximum input power available from the source.

The equation for transducer gain is:

$$G_T = \frac{4 \operatorname{Re}(Y_s) \operatorname{Re}(Y_L) \left| y_{21} \right|^2}{\left| (y_{11} + Y_s)(y_{22} + Y_L) - y_{12} y_{21} \right|^2} \qquad (5)$$

In this equation, Y_L is the composite transistor load admittance-composed of both output network and its load, and Y_s is the composite transistor source admittance-composed of both input network and its source. Therefore, transducer gain includes the effects of the degree of admittance match at the transistor input terminals but does not take into account input and output network losses.

As in equation 3, the composite y parameters of a transistor feedback network combination may be substituted for the transistor y parameters when such a combination is used.

The Maximum Available Gain MAG is an often used transistor figure-of-merit. The MAG is the theoretical power gain of a transistor with its reverse transfer admittance y_{12} set equal to zero, and its source and load admittances conjugately matched to y_{11} and y_{22}, respectively.

If $y_{12} = 0$, the transistor exhibits an input admittance equal to y_{11} and an output admittance equal to y_{22}.[†] The equation for MAG is, therefore, obtained by solving the general power gain expression, equation 3, with the conditions

$$\begin{aligned} y_{12} &= 0 \\ y_L &= y_{22}^{*} \\ \text{and } y_s &= y_{11}^{*} \end{aligned}$$

which yields:

$$\mathrm{MAG} = \frac{\left| y_{21} \right|^2}{4 \operatorname{Re}(y_{11}) \operatorname{Re}(y_{22})} \qquad (6)$$

MAG is a figure of merit only, since it is physically impossible to reduce y_{12} to zero without changing the other parameters of the transistor. An external feedback network may be used to achieve a composite y_{12} of zero, but then the other composite parameters will also be modifed according to the relationships given in the discussion of the composite transistor - feedback network "black box."

TRANSISTOR INPUT AND OUTPUT ADMITTANCES

The expression for the input admittance of a transistor is:

$$Y_{IN} = y_{11} - \frac{y_{12} \, y_{21}}{y_{22} + Y_L} \qquad (7)$$

[†] Refer to Seshu and Balabanian, "Linear Network Analysis, "John Wiley and Sons, 1959, P321

[†] Obtained by solving the equations for transistor Y_{IN} and Y_{OUT} with y_{12} equal to zero. These equations are given later in the report.

The expression for the output admittance of a transistor is:

$$Y_{OUT} = y_{22} - \frac{y_{12}\, y_{21}}{y_{11} + Y_s} \tag{8}$$

When the feedback parameter y_{12} is not zero, Y_{IN} is dependent on load admittance and Y_{OUT} is dependent on source admittance.

AMPLIFIER STABILITY

One of the major considerations in RF amplifier design is stability. The stability of a final design can be assured by including stability computations and considering stability in all design decisions relating to feedback and transistor source and load admittances.

The potential stability of the transistor should first be computed using equation 1 .

The various alternatives concerning input - output matching and neutralization - unilateralization will now be discussed for both the unconditionally stable transistor and the potentially unstable transistor.

THE UNCONDITIONALLY STABLE TRANSISTOR

When the Linvill stability factor of the transistor as determined by equation 1 is less than one, the transistor is unconditionally stable. Oscillations will not occur using any combination of source and load admittances without external feedback. Stability is therefore eliminated as a factor in the remainder of the design, and complete freedom is possible with regard to matching and neutralization to optimize the amplifier for other performance requirements.

AMPLIFIERS WITHOUT FEEDBACK

The amplifier with no feedback is a logical choice for the unconditionally stable transistor in many applications since it may offer the advantages of fewer components and a simple tuning procedure.

Source and load admittances may be selected for maximum gain and/or any number of other requirements. Power gain and transducer gain may be computed using equations 3 and 5 , respectively; input and output admittances may be computed using equations 7 and 8 , respectively.

The amplifier stability factor may be computed using equation 2 . While amplifier stability was assured from the beginning by the use of an unconditionally stable transistor, the designer may still wish to perform this computation to provide some insight into danger of instability under adverse environmental conditions, source and load variations, etc.

G_{max}

G_{max}, the highest transducer gain possible without external feedback, forms a special case of the no feedback amplifier.

The source and load admittances required to achieve G_{max} may be computed from the following:

$$G_s = \frac{1}{2\,\mathrm{Re}\,(y_{22})} \left\{ \left[2\,\mathrm{Re}\,(y_{11})\,\mathrm{Re}\,(y_{22}) - \mathrm{Rc}\,(y_{12}y_{21}) \right]^2 - \left| y_{12}y_{21} \right|^2 \right\}^{\frac{1}{2}} \tag{9}$$

$$B_s = -\,\mathrm{Im}(y_{11}) + \frac{\mathrm{Im}(y_{21}y_{12})}{2\,\mathrm{Re}(y_{22})} \tag{10}$$

$$G_L = \frac{1}{2\,\mathrm{Re}(y_{11})} \left\{ \left[2\,\mathrm{Re}\,(y_{11})\,\mathrm{Re}\,(y_{22}) - \mathrm{Re}\,(y_{12}y_{21}) \right]^2 - \left| y_{12}y_{21} \right|^2 \right\}^{\frac{1}{2}} \tag{11}$$

$$B_L = -\,\mathrm{Im}(y_{22}) + \frac{\mathrm{Im}(y_{21}y_{12})}{2\,\mathrm{Re}(y_{11})} \tag{12}$$

Therefore, if the maximum possible power gain without feedback is desired for an amplifier, equations 9, 10, 11, and 12 are used to compute Y_s and Y_L.

The magnitude of G_{max} may be computed from the following expression:

$$G_{max} = \frac{\left| y_{21} \right|^2}{2\,\mathrm{Re}(y_{11})\,\mathrm{Re}(y_{22}) - \mathrm{Re}(y_{12}y_{21}) + \left\{ \left[2\,\mathrm{Re}(y_{11})\,\mathrm{Re}(y_{22}) - \mathrm{Re}(y_{12}y_{21}) \right]^2 - \left| y_{12}y_{21} \right|^2 \right\}^{\frac{1}{2}}} \tag{13}$$

Equations 9, 10, 11, and 12 can be obtained by differentiating equation 5 with respect to G_s, B_s, G_L, and B_L, and setting the four derivatives equal to zero. The G_s, B_s, G_L, and B_L thus computed can then be substituted in equation 5 to obtain the expression for G_{max}, equation 13.

THE LINVILL METHOD

The amplifier without feedback design problem may also be solved graphically using a technique developed by J.G. Linvill.† Linvill's technique is very useful for a certain class of problems. Since it is so fully discussed in many good references we will not go into it further here. An advantage of the Linvill technique is that it provides a reasonably rapid graphic solution relating gain, bandwidth, and stability. A disadvantage is its scope of usefulness, since the standard Linvill solution applies only to an amplifier with no external feedback and with Y_s conjugately matched to the transistor input admittance, Y_{IN}.

THE UNILATERALIZED AMPLIFIER

Unilateralization consists of employing an external feedback network to achieve a composite y_{12} of zero.

While unilateralization is perhaps most often used to achieve stability with a potentially unstable transistor, other circuit considerations may also warrant the use of unilateralization with the unconditionally stable transistor. For example, the input-output isolation afforded by unilateralization may be desirable in a particular design.

Design equations for the unilateralized case are obtained by first computing the composite y parameters of the transistor - feedback network combination and then substituting the composite parameters in the general equations.

Referring to the discussion on composite y parameters and setting up the basic condition that y_{12c} must equal zero, the other composite y parameters can be computed. Assuming that a passive feedback network is being used, then

$$y_{11f} = y_{22f} = -y_{12f} = -y_{21f}$$

$$\text{and since } y_{12c} = 0,\ y_{12t} + y_{12f} = 0$$

$$\text{then } y_{12t} = -y_{12f},$$

$$\text{and } y_{12t} = -y_{12f} = y_{11f} = y_{22f} = -y_{21f}$$

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† Application Note AN166 Motorola Semiconductor Products, Inc. Dept T1C, 5005 E. McDowell Rd., Phoenix, Arizona. See also reference 6 in the bibliography.

Substituting the above results in equations 4 yields the following:

$$y_{11c} = y_{11t} + y_{12t}$$

$$y_{22c} = y_{22t} + y_{12t}$$

$$y_{12c} = y_{12t} - y_{12t} = 0$$

$$y_{21c} = y_{21t} - y_{12t}$$

Substituting these composite y parameters in equations 7, 8, 3, 16, and 5 respectively, yields equations 14, 15, 16, 17 and 18 for the unilateralized case:

Unilateralized input admittance

$$Y_{IN} = y_{11} + y_{12} \qquad (14)$$

Unilateralized output admittance

$$Y_{OUT} = y_{22} + y_{12} \qquad (15)$$

Unilateralized power gain, general expression:

$$G_{PU} = \frac{\left|y_{21} - y_{12}\right|^2 \mathrm{Re}\,(Y_L)}{\left|Y_L + y_{22} + y_{12}\right|^2 \mathrm{Re}(y_{11})} \qquad (16)$$

Unilateralized power gain with Y_L conjugately matched to Y_{OUT}:

$$G_U = \frac{\left|y_{21} - y_{12}\right|^2}{4\,\mathrm{Re}(y_{11} + y_{12})\,\mathrm{Re}\,(y_{22} + y_{12})} \qquad (17)$$

Unilateralized transducer gain:

$$G_{TU} = \frac{4\,\mathrm{Re}(Y_s)\,\mathrm{Re}(Y_L)\left|y_{21} - y_{12}\right|^2}{\left|(y_{11} + y_{12} + Y_s)\,(y_{22} + y_{12} + Y_L)\right|^2} \qquad (18)$$

Note that equations 14, 15, 16, 17, and 18, are given entirely in terms of the transistor y parameters, not those of the feedback network or the composite.

Another benefit of unilateralization is input - output isolation. As can be seen in equations 14 and 15, Y_{IN} is completely independent of Y_L, and Y_{OUT} is similarly independent of Y_s. In a practical sense, this means that in a single or multi-stage amplifier using unilateralized stages, tuning of any one network will not affect tuning in other parts of the circuit. Thus, the troublesome task of having to re-peak an entire amplifier following a change in tuning at a single point can be eliminated.

NEUTRALIZATION

Neutralization consists of employing a feedback network to reduce y_{12} to some value other than zero. Neutralization is generally used for the same purposes as unilateralization, but provides something less than the ideal cancellation of the transistor feedback parameter which unilateralization achieves. A typical example of neutralization might be a feedback network which provides a composite b_{12} of zero while having only a negligible effect on the transistor g_{12}.

The equations for a particular neutralized case would be developed in the same manner as those for the unilateralized case. Since there are an infinite number of possibilities, no specific equations will be given here.

This completes the discussion of design with the unconditionally stable transistor. The potentially unstable transistor will now be considered.

THE POTENTIALLY UNSTABLE TRANSISTOR

When the Linvill stability factor of the transistor as determined by equation 1 is greater than one, the transistor is potentially unstable. Certain combinations of source and load admittances will cause oscillations if no feedback is used. In designing with the potentially unstable transistor, steps must be taken to insure that the amplifier will be stable.

Stability is usually achieved by one or both of two methods:

(1) Using a feedback network which reduces the composite y_{12} to a value which insures stability.

(2) Choosing a source and load admittance combination which provides stability.

A discussion of these basic methods is given below.

USING FEEDBACK TO ACHIEVE STABILITY

Either unilateralization or neutralization may be used to achieve stability. If unilateralization is used, the transistor-feedback network combination will be unconditionally stable. This may be verified by computing the Linvill stability factor of the combination. Since $y_{12c} = 0$, the numerator in equation 1 would be zero.

With stability thus assured, the remainder of the design may then be done to satisfy other requirements placed on the amplifier. After unilateralization has converted the potentially unstable transistor to an unconditionally stable combination, all other aspects of the design are identical to the unilateralized case with the unconditionally stable transistor. Power gains and input and output admittances may be computed using equations 14 through 18.

If neutralization is used to achieve stability, the Linvill stability factor can be used to compute the potential stability of any transistor - neutralization-network combination. Since in this case $y_{12c} \neq 0$, C will have a value other than zero.

After unconditional stability of the transistor-neutralization network combination has been achieved, the design may then be completed by treating the combination as an unconditionally stable transistor, and proceeding with the case of the unconditionally stable transistor in an amplifier without feedback. Power gains, input and output admittances, and the circuit stability factor may be computed by using the composite parameters of the combination in equations 2, 3, 5, 7, and 8.

STABILITY WITHOUT FEEDBACK

A stable design with the potentially unstable transistor is possible without external feedback by proper choice of source and load admittances. This can be seen by inspection of equation 2; G_s and/or G_L can be made large enough to yield a stable circuit regardless of the degree of potential instability of the transistor.

This suggests a relatively simple way to achieve a stable design with a potentially unstable transistor. A circuit stability factor k is selected, and equation 2 is used to arrive at values of G_s and G_L which will provide the desired k. In achieving a particular circuit stability factor, the designer may choose any of the following combinations of matching or mismatching of G_s and G_L to the transistor input and output conductances, respectively:

(1) G_s matched and G_L mismatched

(2) G_L matched and G_s mismatched

(3) Both G_s and G_L mismatched

Often a decision on which combination to use will be dictated by other performance requirements or practical considerations.

Once G_s and G_L have been chosen, the remainder of the design may be completed using the relationships which apply to the amplifier without feedback. Power gain and input and output admittances may be computed using equations 3, 5, 7, and 8.

Although the above procedure may be adequate in many cases, a more systematic method of source and load admittance determination is desirable for designs which demand maximum power gain per degree of circuit stability. Stern has analyzed this problem and developed equations for computing the conductance and susceptance of both Y_s and Y_L for maximum power gain for a particular circuit stability factor.[3,5] These equations are given here:

$$G_s = \sqrt{\frac{k\left[\left|y_{12}y_{21}\right| + \mathrm{Re}(y_{12}y_{21})\right]}{2}} \cdot \sqrt{\frac{g_{11}}{g_{22}}} - g_{11} \qquad (19)$$

$$G_L = \sqrt{\frac{k\left[\left|y_{12}y_{21}\right| + \mathrm{Re}(y_{12}y_{21})\right]}{2}} \cdot \sqrt{\frac{g_{22}}{g_{11}}} - g_{22} \qquad (20)$$

$$B_s = \frac{(G_s + g_{11})\ Zo}{\sqrt{k\left[\left|y_{12}y_{21}\right| + \mathrm{Re}(y_{12}y_{21})\right]}} - b_{11} \qquad (21)$$

$$B_L = \frac{(G_L + g_{22})\ Zo}{\sqrt{k\left[\left|y_{12}y_{21}\right| + \mathrm{Re}(y_{12}y_{21})\right]}} - b_{22} \qquad (22)$$

Where,

$$Z = \frac{(B_s + b_{11})(G_L + g_{22}) + (B_L + b_{22})\ k(L + M)/2(G_L + g_{22})}{\sqrt{k\ (L + M)}} \qquad (23)$$

$$L = \left|y_{12}y_{21}\right| \qquad (24)$$

$$M = \mathrm{Re}(y_{12}y_{21}) \qquad (25)$$

Defining D as the denominator in equation 5 yields:

$$D = \frac{Z^4}{4} + \frac{\left[k(L + M) + 2M\right]\ Z^2}{2} - 2NZ\sqrt{k(L + M)} + A^2 + N^2 \qquad (26)$$

where,

$$A = \frac{k(L + M)}{2} - M, \qquad (27)$$

$$N = \mathrm{Im}(y_{12}y_{21}), \qquad (28)$$

and,

Z_o = that real value of Z which results in the smallest minimum of D, found by setting,

$$\frac{dD}{dZ} = Z^3 + \left[k(L + M) + 2M\right]\ Z - 2N\sqrt{k(L + M)} \qquad (29)$$

equal to zero.

Computation of Y_S and Y_L using equations 19 through 29 is a bit tedious to be done very frequently, and this may have discouraged wide usage of the complete Stern solution. However, examination of Stern's work suggests some interesting shortcuts:

(A) COMPUTATION OF G_S AND G_L ONLY, USING EQUATIONS 19 AND 20. If a value equal to $-b_{22}$ is then chosen for B_L, the resulting Y_L will be very close to the true Y_L for maximum gain. The transistor Y_{IN} can then be computed from Y_L using equation 7, and B_S can be set equal to $-I_m(Y_{IN})$.

Computation of B_S and B_L comprise by far the more complex portion of the Stern solution. This alternate method therefore permits the designer to closely approximate the exact Stern solution for Y_S and Y_L while avoiding that portion of the computations which are the most complex and time consuming. Further, the circuit can be designed with tuning adjustments for varying B_S and B_L, thereby creating the possibility of experimentally achieving the true B_S and B_L for maximum gain as accurately as if all the Stern equations had been solved.

(B) MISMATCHING G_S TO g_{11} AND G_L TO g_{22} BY AN EQUAL RATIO YIELDS A TRUE STERN SOLUTION FOR G_S AND G_L. This can be derived from equations 19 and 20, which lead to the following result:

$$\frac{G_L}{g_{22}} = \frac{G_s}{g_{11}} \qquad (30)$$

If a mismatch ratio, R, is defined as follows,

$$R = \frac{G_L}{g_{22}} = \frac{G_s}{g_{11}} \qquad (31)$$

then R may be computed for any particular circuit stability factor using the equation:

$$(1 + R)^2 = k\left[\frac{\left|y_{21}y_{12}\right| + \mathrm{Re}(y_{12}y_{21})}{2\ g_{11}\ g_{22}}\right] \qquad (32)$$

Equation 32 was derived from equations 2 and 31. Having thus determined R, G_S and G_L can be quickly found using equation 31.

B_S and B_L can then be determined in the manner described above in alternate method (A).

This alternate method may be advantageous if source and load admittances and power gains for several different values of k are desired. Once the R for a particular k has been determined, the R for any other k may be quickly found from the equation

$$\frac{(1 + R_1)^2}{(1 + R_2)^2} = \frac{k_1}{k_2} \qquad (33)$$

where R_1 and R_2 are values of R corresponding to k_1 and k_2, respectively.

(C) COMPUTER DESIGN. The complete Stern design problem may be programmed into a computer. Power gain, circuit stability factor, Y_s and Y_L can be obtained from the computer for any value of k. MAG, G_U, and the Linvill stability factor of the transistor may also be included in the program.

After employing either the complete Stern solution or an alternate method to obtain Y_S and Y_L for the potentially unstable transistor in an amplifier without feedback, power gains and input and output admittances may be obtained using equations 3, 5, 7, and 8.

SENSITIVITY

In all but the unilateralized amplifier, Y_{IN} is a function of load admittance. Thus Y_{IN} changes with output circuit tuning, and this can be troublesome. Consequently, it is sometimes desirable to compute the extent of variation of Y_{IN} with changes in Y_L. A term, sensitivity δ, has been defined to provide a measure of this characteristic, and is equal to per cent change in Y_{IN} divided by per cent change in Y_L. The equation for sensitivity is:

$$\delta = \left|\frac{Y_L}{y_{22} + Y_L}\right| \cdot \left|\frac{g_{11}}{y_{11}}\right| \cdot \frac{K}{\left|\frac{y_{22} + Y_L}{g_{22}} + \frac{g_{11}}{y_{11}}\ K\ e^{j\theta}\right|} \qquad (34)$$

where,

$$K = \left|\frac{y_{21}\ y_{12}}{g_{11}\ g_{22}}\right|$$

$$\theta = \arg\ (-y_{12}y_{21})\ \cdot$$

$$K\ e^{j\theta} = K\ (\cos\theta + j\ \sin\theta)$$

A more complete discussion of sensitivity is given in reference 7.

SUMMARY

The small signal amplifier performance of a transistor is completely described by two port admittance parameters. Based on these parameters, equations for computing the stability, gain, and optimum source and load admittances for the unilateralized, neutralized, and no-feedback amplifier cases have been discussed.

The unconditionally stable transistor will not oscillate with any combination of source and load admittances, and circuits using a stable transistor may be optimized for other performance requirements without fear of oscillations.

The potentially unstable transistor requires that steps be taken to guarantee a stable design. Stability is usually achieved by unilateralization, neutralization, or selection of source and load admittances which result in a stable amplifier.

Unilateralization and neutralization reduce the composite reverse transfer admittance. They may be used to achieve stability, input - output isolation, or both.

Maximum power gain per degree of circuit stability without feedback may be achieved using Stern's equations.

The degree of input - output isolation is described by the term sensitivity, which makes it possible to compute changes in input admittance for any change in load admittance.

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GLOSSARY

C = Linvill's stability factor
k = Stern's stability factor
G_s = Real part of the source admittance
G_L = Real part of the load admittance
B_s = Imaginary part of the source admittance
B_L = Imaginary part of the load admittance
g_{11} = Real part of y_{11}
g_{22} = Real part of y_{22}
G = Generalized power gain
Y_L = Complex load admittance
Y_s = Complex source admittance
G_T = Transducer gain
MAG = Maximum available gain
$*$ = Conjugate
Y_{IN} = Input admittance
Y_{OUT} = Output admittance
G_{max} = Maximum gain without feedback
G_U = Unilateralized gain
G_{TU} = Unilateralized transducer gain
δ = Sensitivity

APPENDIX I

A. Conversions among parameter types for y, z, h, and g parameters.

h to y

$$y_{11} = \frac{1}{h_{11}} \qquad y_{12} = \frac{-h_{12}}{h_{11}} \qquad y_{21} = \frac{h_{21}}{h_{11}} \qquad y_{22} = \frac{\Delta h}{h_{11}}$$

where $\Delta h = h_{11}\,h_{22} - h_{12}\,h_{21}$

y to h

$$h_{11} = \frac{1}{y_{11}} \qquad h_{12} = \frac{-y_{12}}{y_{11}} \qquad h_{21} = \frac{y_{21}}{y_{11}} \qquad h_{22} = \frac{\Delta y}{y_{11}}$$

where $\Delta y = y_{11}\,y_{22} - y_{12}\,y_{21}$

h to z

$$z_{11} = \frac{\Delta h}{h_{22}} \qquad z_{12} = \frac{h_{12}}{h_{22}} \qquad z_{21} = \frac{-h_{21}}{h_{22}} \qquad z_{22} = \frac{1}{h_{22}}$$

z to h

$$h_{11} = \frac{\Delta z}{z_{22}} \qquad h_{12} = \frac{z_{12}}{z_{22}} \qquad h_{21} = \frac{-z_{21}}{z_{22}} \qquad h_{22} = \frac{1}{z_{22}}$$

where $\Delta z = z_{11}\,z_{22} - z_{12}\,z_{21}$

h to g

$$g_{11} = \frac{h_{22}}{\Delta h} \qquad g_{12} = \frac{-h_{12}}{\Delta h} \qquad g_{21} = \frac{-h_{21}}{\Delta h} \qquad g_{22} = \frac{h_{11}}{\Delta h}$$

where $\Delta h = h_{11}\,h_{22} - h_{12}\,h_{21}$

g to h

$$h_{11} = \frac{g_{22}}{\Delta g} \qquad h_{12} = \frac{-g_{12}}{\Delta g} \qquad h_{21} = \frac{-g_{21}}{\Delta g} \qquad h_{22} = \frac{g_{11}}{\Delta g}$$

where $\Delta g = g_{11}\,g_{22} - g_{12}\,g_{21}$

z to y

$$y_{11} = \frac{z_{22}}{\Delta z} \qquad y_{12} = \frac{-z_{12}}{\Delta z} \qquad y_{21} = \frac{-z_{21}}{\Delta z} \qquad y_{22} = \frac{z_{11}}{\Delta z}$$

where $\Delta z = z_{11} z_{22} - z_{12} z_{21}$

y to z

$$z_{11} = \frac{y_{22}}{\Delta y} \qquad z_{12} = \frac{-y_{12}}{\Delta y} \qquad z_{21} = \frac{-y_{21}}{\Delta y} \qquad z_{22} = \frac{y_{11}}{\Delta y}$$

where $\Delta y = y_{11} y_{22} - y_{12} y_{21}$

z to g

$$g_{11} = \frac{1}{z_{11}} \qquad g_{12} = \frac{-z_{12}}{z_{11}} \qquad g_{21} = \frac{z_{21}}{z_{11}} \qquad g_{22} = \frac{\Delta z}{z_{11}}$$

where $\Delta z = z_{11} z_{22} - z_{12} z_{21}$

g to z

$$z_{11} = \frac{1}{g_{11}} \qquad z_{12} = \frac{-g_{12}}{g_{11}} \qquad z_{21} = \frac{g_{21}}{g_{11}} \qquad z_{22} = \frac{\Delta g}{g_{11}}$$

where $\Delta g = g_{11} g_{22} - g_{12} g_{21}$

g to y

$$y_{11} = \frac{\Delta g}{g_{22}} \qquad y_{12} = \frac{g_{12}}{g_{22}} \qquad y_{21} = \frac{-g_{21}}{g_{22}} \qquad y_{22} = \frac{1}{g_{22}}$$

where $\Delta g = g_{11} g_{22} - g_{12} g_{21}$

y to g

$$g_{11} = \frac{\Delta y}{y_{22}} \qquad g_{12} = \frac{y_{12}}{y_{22}} \qquad g_{21} = \frac{-y_{21}}{y_{22}} \qquad g_{22} = \frac{1}{y_{22}}$$

where $\Delta y = y_{11} y_{22} - y_{12} y_{21}$

B. Conversions among common emitter, common base, and common collector parameters of the same type for y, and h parameters.

Common emitter y parameters in terms of common base and common collector y parameters.

$$y_{11e} = y_{11b} + y_{12b} + y_{21b} + y_{22b} = y_{11c}$$

$$y_{12e} = -(y_{12b} + y_{22b}) = -(y_{11c} + y_{12c})$$

$$y_{21e} = -(y_{21b} + y_{22b}) = -(y_{11c} + y_{21c})$$

$$y_{22e} = y_{22b} = y_{11c} + y_{12c} + y_{21c} + y_{22c}$$

Common base y parameters in terms of common emitter and common collector y parameters.

$$y_{11b} = y_{11e} + y_{12e} + y_{21e} + y_{22e} = y_{22c}$$

$$y_{12b} = -(y_{12e} + y_{22e}) = -(y_{21c} + y_{22c})$$

$$y_{21b} = -(y_{21e} + y_{22e}) = -(y_{12c} + y_{22c})$$

$$y_{22b} = y_{22e} = y_{11c} + y_{12c} + y_{21c} + y_{22c}$$

Common collector y parameters in terms of common emitter and common base y parameters.

$$y_{11c} = y_{11e} = y_{11b} + y_{12b} + y_{21b} + y_{22b}$$

$$y_{12c} = -(y_{11e} + y_{12e}) = -(y_{11b} + y_{21b})$$

$$y_{21c} = -(y_{11e} + y_{21e}) = -(y_{11b} + y_{12b})$$

$$y_{22c} = y_{11e} + y_{12e} + y_{21e} + y_{22e} = y_{11b}$$

Common emitter h parameters in terms of common base and common collector h parameters.

$$h_{11e} = \frac{h_{11b}}{(1 + h_{21b})(1-h_{12b}) + h_{22b} h_{11b}} \approx \frac{h_{11b}}{1 + h_{21b}} = h_{11c}$$

$$h_{12e} = \frac{h_{11b} h_{22b} - h_{12b}(1+h_{21b})}{(1 + h_{21b})(1-h_{12b}) + h_{22b} h_{11b}} \approx \frac{h_{11b} h_{22b}}{1 + h_{21b}} - h_{12b} = 1-h_{12c}$$

$$h_{21e} = \frac{-h_{21b}(1-h_{12b}) - h_{22b} h_{11b}}{(1 + h_{21b})(1-h_{12b}) + h_{22b} h_{11b}} \approx \frac{-h_{21b}}{1 + h_{21b}} = -(1 + h_{21c})$$

$$h_{22e} = \frac{h_{22b}}{(1 + h_{21b})(1-h_{12b}) + h_{22b} h_{11b}} \approx \frac{h_{22b}}{1 + h_{21b}} = h_{22c}$$

Common base h parameters in terms of common emitter and common collector h parameters.

$$h_{11b} = \frac{h_{11e}}{(1 + h_{21e})(1-h_{12e}) + h_{11e} h_{22e}} \approx \frac{h_{11e}}{1 + h_{21e}}$$

$$= \frac{h_{11c}}{h_{11c} h_{22c} - h_{21c} h_{12c}} \approx \frac{-h_{11c}}{h_{21c}}$$

$$h_{12b} = \frac{h_{11e} h_{22e} - h_{12e}(1 + h_{21e})}{(1 + h_{21e})(1-h_{12e}) + h_{11e} h_{22e}} \approx \frac{h_{11e} h_{22e}}{1 + h_{21e}} - h_{12e}$$

$$= \frac{h_{21c}(1-h_{12c}) + h_{11c} h_{22c}}{h_{11c} h_{22c} - h_{21c} h_{12c}} \approx (h_{12c} - 1) - \frac{h_{11c} h_{22c}}{h_{21c}}$$

$$h_{21b} = \frac{-h_{21e}(1-h_{12e}) - h_{11e} h_{22e}}{(1 + h_{21e})(1-h_{12e}) + h_{11e} h_{22e}} \approx \frac{-h_{21e}}{1 + h_{21e}}$$

$$= \frac{h_{12c}(1 + h_{21c}) - h_{11c} h_{22c}}{h_{11c} h_{22c} - h_{21c} h_{12c}} \approx \frac{-(1 + h_{21c})}{h_{21c}}$$

$$h_{22b} = \frac{h_{22e}}{(1 + h_{21e})(1-h_{12e}) + h_{11e} h_{22e}} \approx \frac{h_{22e}}{1 + h_{21e}}$$

$$= \frac{h_{22c}}{h_{11c} h_{22c} - h_{21c} h_{12c}} \approx \frac{h_{22c}}{h_{21c}}$$

Common collector h parameters in terms of common base and common emitter h parameters.

$$h_{11c} = \frac{h_{11b}}{(1 + h_{21b})(1-h_{12b}) + h_{22b}h_{11b}} \approx \frac{h_{11b}}{1 + h_{21b}} = h_{11e}$$

$$h_{12c} = \frac{1 + h_{21b}}{(1 + h_{21b})(1-h_{12b}) + h_{22b}h_{11b}} \approx 1 = 1-h_{12e}$$

$$h_{21c} = \frac{h_{12b} - 1}{(1 + h_{21b})(1-h_{12b}) + h_{22b}h_{11b}} \approx \frac{-1}{1 + h_{21b}} = -(1 + h_{21e})$$

$$h_{22c} = \frac{h_{22b}}{(1 + h_{21b})(1-h_{12b}) + h_{22b}h_{11b}} \approx \frac{h_{22b}}{1 + h_{21b}} = h_{22e}$$

Expressions for voltage gain, current gain, input impedance, and output impedance in terms of y, z, h, and g parameters.

Voltage Gain

$$A_V = \frac{z_{21}Z_L}{\Delta z + z_{11}Z_L} = \frac{-y_{21}}{y_{22} + Y_L} = \frac{-h_{21}Z_L}{h_{11} + \Delta h Z_L} = \frac{g_{21}Z_L}{g_{22} + Z_L}$$

Current Gain

$$A_I = \frac{-z_{21}}{z_{22} + Z_L} = \frac{-y_{21}Y_L}{\Delta y + y_{11}Y_L} = \frac{-h_{21}Y_L}{h_{22} + Y_L} = \frac{-g_{21}}{\Delta g + g_{11}Z_L}$$

Input Impedance

$$Z_{IN} = \frac{\Delta z + z_{11}Z_L}{z_{22} + Z_L} = \frac{y_{22} + Y_L}{\Delta y + y_{11}Y_L} = \frac{\Delta h + h_{11}Y_L}{h_{22} + Y_L}$$

$$= \frac{g_{22} + Z_L}{\Delta g + g_{11}Z_L}$$

Output Impedance

$$Z_{OUT} = \frac{\Delta z + z_{22}Z_s}{z_{11} + Z_s} = \frac{y_{11} + Y_s}{\Delta y + y_{22}Y_s} = \frac{h_{11} + Z_s}{\Delta h + h_{22}Z_s}$$

$$= \frac{\Delta g + g_{22}Y_s}{g_{11} + Y_s}$$

Conversion between y parameters and s (scattering) parameters:

$$s_{11} = \frac{(1-y_{11})(1+y_{22}) + y_{12}y_{21}}{(1+y_{11})(1+y_{22}) - y_{12}y_{21}} \dagger$$

$$s_{12} = \frac{-2y_{12}}{(1+y_{11})(1+y_{22}) - y_{12}y_{21}} \dagger$$

$$s_{21} = \frac{-2y_{21}}{(1+y_{11})(1+y_{22}) - y_{12}y_{21}} \dagger$$

$$s_{22} = \frac{(1+y_{11})(1-y_{22}) + y_{21}y_{12}}{(1+y_{11})(1+y_{22}) - y_{12}y_{21}} \dagger$$

$$y_{11} = \left[\frac{(1+s_{22})(1-s_{11}) + s_{12}s_{21}}{(1+s_{11})(1+s_{22}) - s_{12}s_{21}}\right]\frac{1}{Z_o}$$

$$y_{12} = \left[\frac{-2s_{12}}{(1+s_{11})(1+s_{22}) - s_{12}s_{21}}\right]\frac{1}{Z_o}$$

$$y_{21} = \left[\frac{-2s_{21}}{(1+s_{11})(1+s_{22}) - s_{12}s_{21}}\right]\frac{1}{Z_o}$$

$$y_{22} = \left[\frac{(1+s_{11})(1-s_{22}) + s_{12}s_{21}}{(1+s_{22})(1+s_{11}) - s_{12}s_{21}}\right]\frac{1}{Z_o}$$

where Z_o = the characteristic impedance of the transmission lines used in the scattering parameter system, usually 50 ohms.

Conversion between h parameters and s parameters:

$$s_{11} = \frac{(h_{11}-1)(h_{22}+1) - h_{12}h_{21}}{(h_{11}+1)(h_{22}+1) - h_{12}h_{21}} \dagger\dagger$$

$$s_{12} = \frac{2h_{12}}{(h_{11}+1)(h_{22}+1) - h_{12}h_{21}} \dagger\dagger$$

$$s_{21} = \frac{-2h_{21}}{(h_{11}+1)(h_{22}+1) - h_{12}h_{21}} \dagger\dagger$$

$$s_{22} = \frac{(1+h_{11})(1-h_{22}) + h_{12}h_{21}}{(h_{11}+1)(h_{22}+1) - h_{12}h_{21}} \dagger\dagger$$

$$h_{11} = \left[\frac{(1+s_{11})(1+s_{22}) - s_{12}s_{21}}{(1-s_{11})(1+s_{22}) + s_{12}s_{21}}\right]Z_o$$

$$h_{12} = \frac{2s_{12}}{(1-s_{11})(1+s_{22}) + s_{12}s_{21}}$$

$$h_{21} = \frac{-2s_{21}}{(1-s_{11})(1+s_{22}) + s_{12}s_{21}}$$

$$h_{22} = \left[\frac{(1-s_{22})(1-s_{11}) - s_{12}s_{21}}{(1-s_{11})(1+s_{22}) + s_{12}s_{21}}\right]\frac{1}{Z_o}$$

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† In converting from y to s parameters, the y parameters must first be multiplied by Z_o, and then substituted in the equations for conversion to s parameters.

†† In converting from h to s parameters, the h parameters must first be normalized to Z_o in the following manner and then substituted in the equations for conversion to s parameters:

Parameter	To Normalize
h_{11}	divide by Z_o
h_{12}	use as is
h_{21}	use as is
h_{22}	multiply by Z_o

SELECTING COMMERCIAL POWER TRANSISTOR HEAT SINKS

INTRODUCTION

Among the vast number of commercial power transistor heat sinks (over 200 catalog types), there are several factors which influence choice of types for given applications. The photograph in Figure 1 is a good illustration of the wide variety available (illustrated by code number in Figure 2). The results of tests compare the thermal resistance of various heat sinks with variations in weight, area, volume, shape and color and a selection chart will facilitate the best choice of heat sink. A list of heat sink suppliers (all that were known at the time of this article) as well as a bibliography of temperature control articles, is given at the end of this article.

TEST PROCEDURES

Tests were organized to establish the heat sink-to-ambient thermal resistance of 31 different types, and the weight, area and volume were measured for each.

TO-3 and TO-36 power transistor packages were used depending upon the hole pattern in the samples. The bench test setup was as indicated in Figure 3. A correlation setup was also used in a closed oven, but with such close results that the open air bench test was used for convenience. All types were tested with the fins held in a vertical plane.

A constant power, usually 5 or 10 watts, was dissipated in the transistor. Regulated current and voltage were supplied from sources such as shown in Figure 4. The current and voltage were measured to an accuracy of 2 per cent. The ambient temperature was measured with a bulb type mercury thermometer at a point six inches away from the lower edge of the heat sink. The heat sink temperatures were measured by staking a thermocouple into a small silicone grease-filled hole. The case temperature of TO-36 "doorknob" transistors was measured by staking a thermocouple into a hole drilled into the stud to a depth almost level with the round mounting base. The case temperatures of the TO-3 "diamond" transistors were measured by soldering a thermocouple to a solder lug which was fastened between the case and one of the mounting screws. These methods are detailed in Figure 5. The heat sink temperatures were calculated by subtracting an estimated interface thermal resistance of 0.2°C/W between heat sink and transistor.

No attempt was made to investigate the various considerations of restricted air flow, surface temperature, nearby reflecting surfaces, etc. In actual practice almost each installation is unique, and transistor cases in prototype equipment should be monitored with a thermocouple under the worst conditions.

TEST RESULTS

Tables Ia and Ib are comprehensive listings of test results in order of heat sink code number. From these tables important factors about a heat sink may be obtained, such as shape, size, weight, exposed surface area, and volume, which allow the designer to determine whether a particular heat sink fits into his packaging plan. The finish and thermal resistance are also included.

To compare performance of cylindrical-fin heat sinks with that of flat-fin types, the area versus thermal resistance has been plotted in Figure 6. The graph in Figure 6 shows four average slopes of thermal resistance versus total surface areas for: (1) square sheets of bright 1/8 inch aluminum; (2) flat vertical-finned, black-finished types (these are usually aluminum extrusions); (3) vertical cylindrical fluted types, black finish (aluminum castings); (4) cylindrical horizontal fins, black finish (sheet metal rings). It should be noted that heat sinks 2, 3, 12, and 14 have flat vertical fins but are not painted black, and thus have somewhat higher thermal resistance due to less heat radiation.

The empirical expression, $\theta_{SA} = 32.6A^{-.472}$, fits the "square aluminum" line, where A is total surface area in square inches, and θ_{SA} is in °C/W. Both the flat-finned

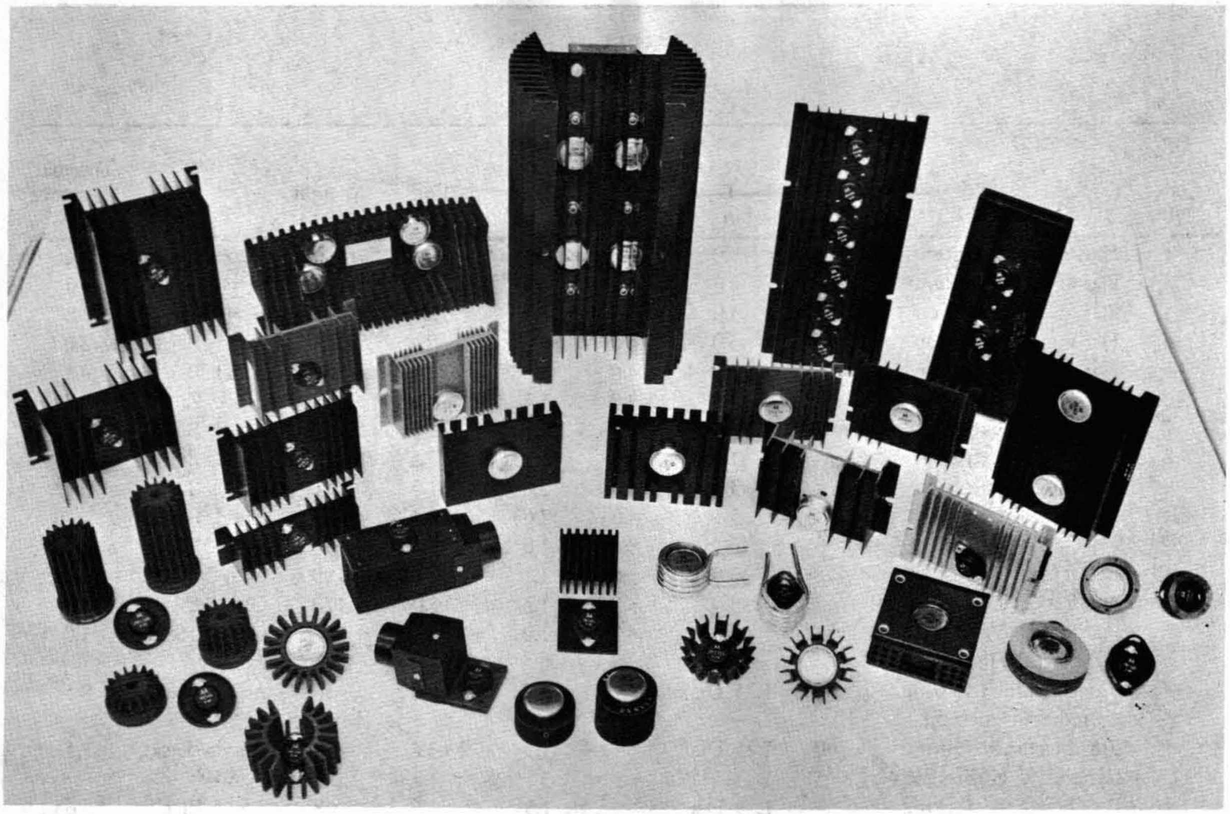


Figure 1 — A wide variety of power transistor heat sinks.

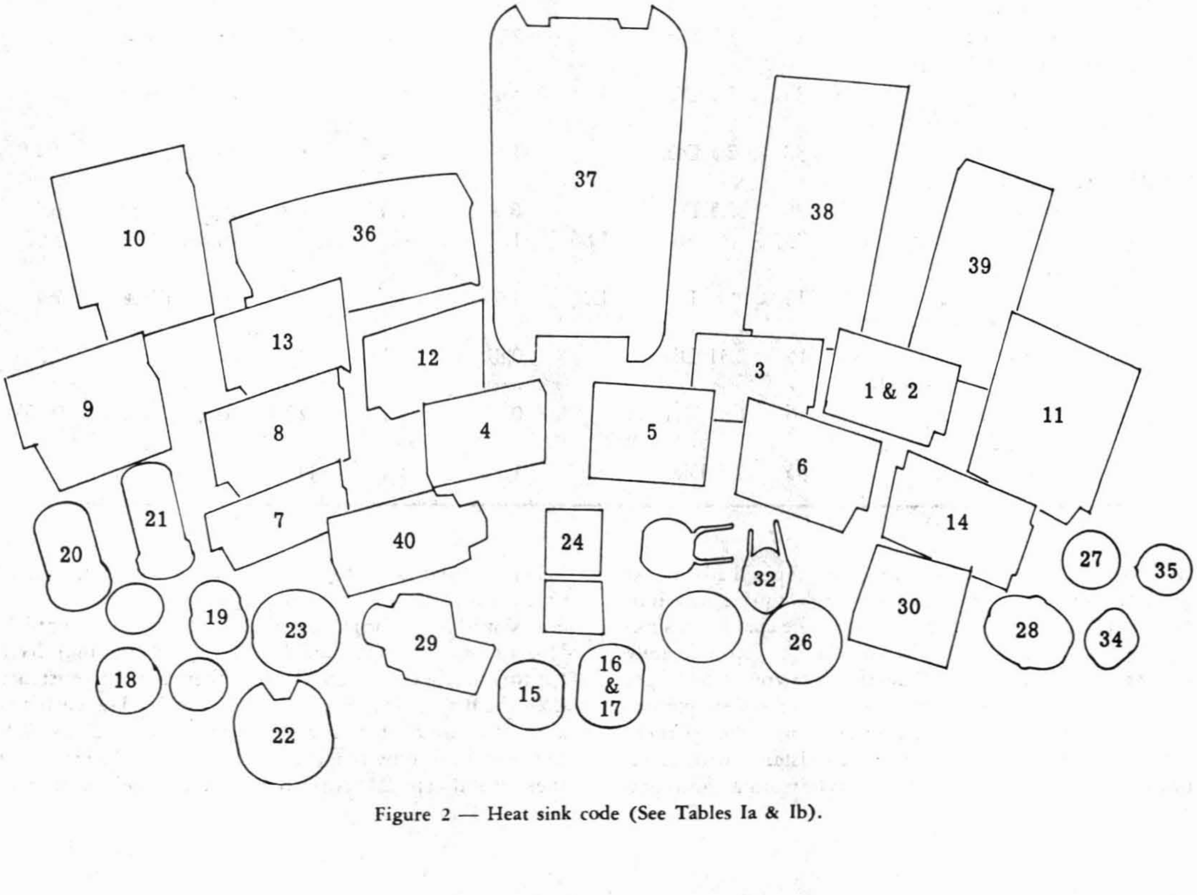

37
10
36
38
39
13
12
3
1 & 2
9
11
8
4
5
6
21
7
14
20
40
24
32
27
35
19
23
30
29
28
26
34
18
16
&
17
15
22

Figure 2 — Heat sink code (See Tables Ia & Ib).

TABLE Ia

FREE AIR TYPES

Fig. 1 & 2 Code No.	Shape	Surface Area (sq. in)	L (in.)	Volume Displacement W (in.)	H (in.)	Vol. (cu. in)	Weight (grams)	Finish	Thermal Resistance °C/W
1	Flat-finned Extrusion	65	3.0	3.6	1.0	10.8	114	Anod. Black	2.4
2	Flat-finned Extrusion	65	3.0	3.6	1.0	10.8	114	Bright Alum.	3.0
3	Flat-finned Extrusion	65	3.0	3.6	1.0	10.8	114	Gray	2.8
4	Flat-finned Extrusion	60	3.0	4.0	.69	8.3	123	Anod. Black	2.8
5	Flat-finned Extrusion	95	3.0	4.0	1.28	15.3	189	Anod. Black	2.1
6	Flat-finned Extrusion	64	3.0	3.8	1.3	15.0	155	Black Paint	2.2
7	Flat-finned Extrusion	83	3.0	4.0	1.25	15.0	140	Anod. Black	2.2
8	Flat-finned Extrusion	44	1.5	4.0	1.25	7.5	75	Anod. Black	3.0
9	Flat-finned Extrusion	137	3.0	4.0	2.63	31.5	253	Anod. Black	1.45
10	Flat-finned Extrusion	250	5.5	4.0	2.63	58.0	461	Anod. Black	1.10
11	Flat-finned Extrusion	130	6	3.6	1.0	21.5	253	Anod. Black	1.75
12	Flat-finned Extrusion	78	3.0	3.8	1.1	12.5	190	Gray MMI	2.9
13	Flat-finned Extrusion	62	3.0	3.8	1.3	15.0	170	Gray MMI	2.2
14	Flat-finned Extrusion	78	3.0	4.5	1.0	13.5	146	Gold Alodine	3.0
15	Cylindrical Horizontal Fin, Machined Casting	30	1.75 Dia.		0.84	2.0	40	Anod. Black	8.5
16	Cylindrical Horizontal Fin, Machined Casting	50	1.75 Dia.		1.5	3.6	67	Anod. Black	7.1
17	Cylindrical Horizontal Fin, Machined Casting	37	1.75 Dia.		1.5	3.6	48	Anod. Black	6.65
18	Cylindrical Vertical Fins, Casting	7.5	1.5 Dia.		0.9	4.4	33	Anod. Black	8.1
19	Cylindrical Vertical Fins, Casting	12	1.5 Dia.		1.4	6.9	51	Anod. Black	7.0
20	Cylindrical Vertical Fins, Casting	25	1.5 Dia.		2.9	14.2	112	Anod. Black	5.6
21	Cylindrical Vertical Fins, Casting	35	1.5 Dia.		3.4	16.7	132	Anod. Black	5.1
22	Cylindrical Vertical Fins, Casting	32	2.5 Dia.		1.5	7.4	94	Anod. Black	4.5
23	Cylindrical Vertical Fins, Casting	20	2.5 Dia.		0.5	2.45	48	Anod. Black	6.6
24	Flat-Finned Casting	23	1.86	1.86	1.2	4.15	87	Anod. Black	5.06
25	Square Vertical Fin, Sheet Metal	12	1.7	1.7	1.0	2.9	19	Anod. Black	7.4
26	Cylindrical Vertical Fin, Sheet Metal	15	2.31 Dia.		0.81	3.35	18	Black	7.1
27	Cylindrical Horizontal Fin, Sheet Metal	6	1.81 Dia.		0.56	1.44	20	Anod. Black	9.15
28	Cylindrical Horizontal Fin, Sheet Metal	55	2.5 Dia.		1.1	5.4	115	Gold Irridate	7.9

types and vertical fluted cylindrical types had almost identical slopes, compared to the single square fin, indicating that for a given change in area, the change in sink-to-ambient thermal resistance would be approximately the same for both types. The ring horizontal fin types showed a much steeper slope although these were mounted with the fins in the vertical plane. This indicates there is relatively little change in thermal resistance with variations in the surface area of the ring horizontal fin types.

Figure 7 shows the thermal resistance plotted as a function of volume displacement. According to these tests, heat sinks No. 2 (bright aluminum), No. 3 (gray finish), No. 12 (gray MMI), and No. 14 (gold alodine) have approximately 0.3 to 0.8°C/W higher thermal resistance than the flat vertical fins with black finish. The performance of cylindrical vertical fin casting types 22, 23, flat-finned casting type No. 24, and a cylindrical vertical fin sheet metal type 25, corresponds very closely with that

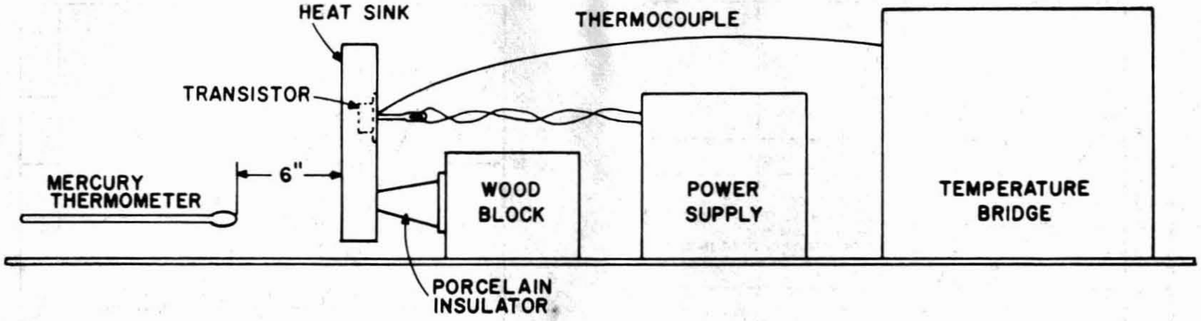

HEAT SINK
THERMOCOUPLE
TRANSISTOR
MERCURY THERMOMETER
6"
WOOD BLOCK
POWER SUPPLY
TEMPERATURE BRIDGE
PORCELAIN INSULATOR

Figure 3 — Bench test set-up.

TABLE Ib

Fig. 1 & 2 Code No.	Conditions	Thermal Resistance
	AIR COOLED TYPES	
29	10 cu ft/min of air	0.4°C/W
30	10 cu ft/min of air	1.2°C/W
	WATER COOLED TYPES	
31	0.04 cu ft/min	0.45°C/W
MISCELLANEOUS TYPES — NO TEST RESULTS		
32-40*		

* *Numbers 36 and 37 are not directly available from heat sink manufacturers. These were heat sinks designed for specific applications.*

of the square, 1/8 inch bright aluminum heat sink with respect to volume.

Another important consideration is the heat sink weight. The thermal resistance as a function of weight is plotted in Figure 8. The correlation line for flat vertical fins is very similar to the area and volume results. This is to be expected, since all the heat sinks were made of aluminum of about the same thickness. The correlation lines for both cylindrical types (vertical and horizontal fins) are similar to the area results. However, the weight results approach the square aluminum fin performance more so than did the area results. Thus, from weight considerations there is an advantage of using the flat vertical fin design.

According to Figures 6, 7, and 8, the flat extruded fin type heat sink is the most efficient for heat transfer. Of the flat fin types tested, the thermal resistance ranged from about 3°C/W with a surface area of 44 sq. in. to 1.1°C/W with an area of 250 sq. in. The same change in thermal resistance occurs with change in volume of the flat fin types. Since the slope of thermal resistance for 1/8 inch aluminum sheets is approximately the same as the black flat fins, the aluminum sheets painted black would probably offer similar performance and less cost.

Heat transfer, and consequently thermal resistance, is dependent mainly on exposed surface area, and changes in shape and volume offer relatively little advantage. The

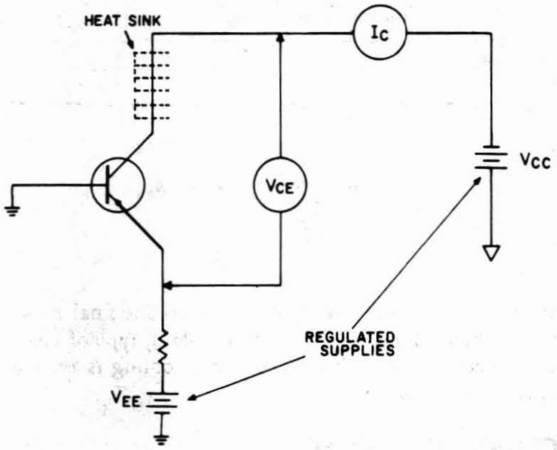
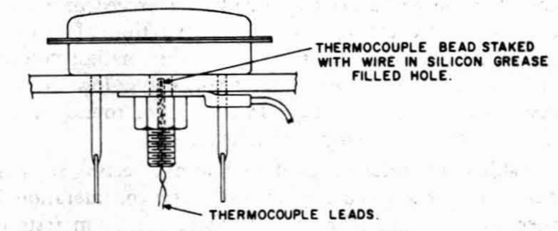
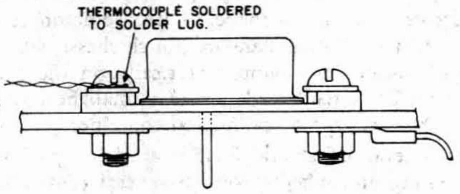

HEAT SINK
Ic
VCE
Vcc
REGULATED SUPPLIES
VEE

Figure 4 — Electrical circuit.


THERMOCOUPLE BEAD STAKED WITH WIRE IN SILICON GREASE FILLED HOLE.
THERMOCOUPLE LEADS.

DOOR KNOB (TO 36)


THERMOCOUPLE SOLDERED TO SOLDER LUG.

DIAMOND (TO 3)

Figure 5 — Thermocouple attachment.

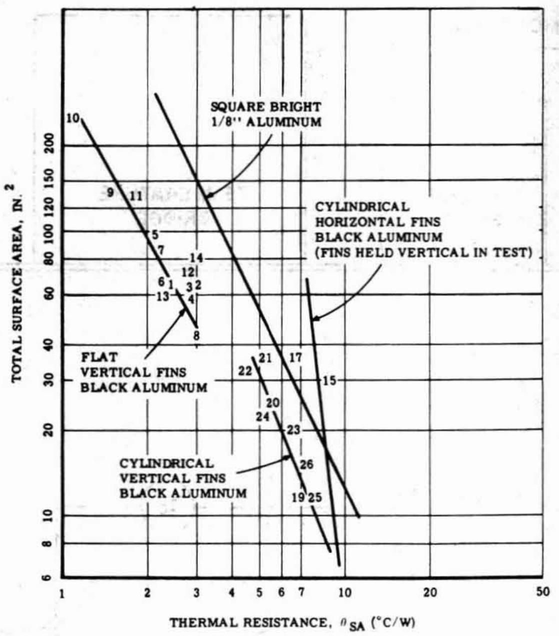


Figure 6 — Surface area vs. θ_{SA}.

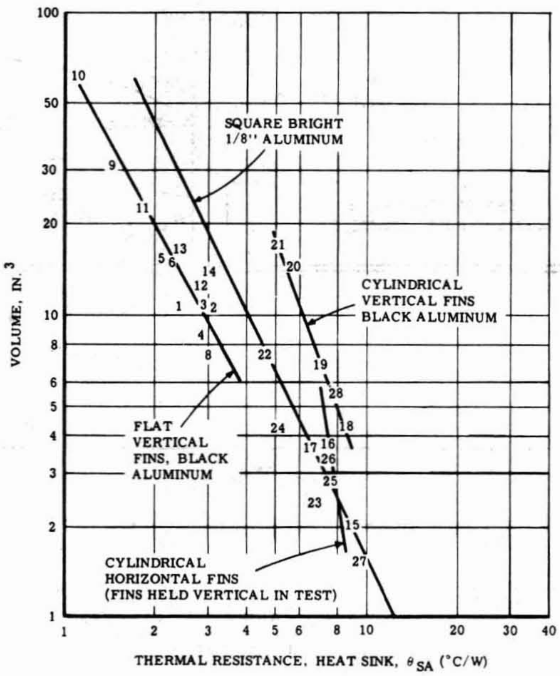


Figure 7 — Volume vs. θ_{SA}.

shape is important only in that it affects the final packaging configuration. Of course power level, type of chassis, and whether or not blowers or water cooling is available, must also be considered.

CHOICE OF HEAT SINK

As has been noted, many considerations affect the choice of the best heat sink to do a specific job. The value of necessary thermal resistance is, of course, the primary consideration and a designer should not exceed maximum thermal resistances in making his selection. However, it is not always easy to use one with the smallest volume and least area which would have adequately low thermal resistance. Indeed the shape factor, flat or round, etc., is the reason for so many available types.

Table II provides a logical method of selecting the best heat sink for a given application. First consideration is thermal resistance. The results listed are from tests in free air. In the equipment package there are air restrictions, chassis heat conduction, and other heat sources which were not considered in these tests. Thus several other types having a lower thermal resistance than required should be considered to assure a safety margin after packaging. A choice should also be maintained in the second consideration — shape. Three common conditions are listed — (1) the standard 3 inch chassis where the heat sink would be mounted vertically on the side of the chassis; (2) circuit card, where a small heat sink is useful; (3) some type of cylindrical container.

Other considerations should include availability of air or water cooling and whether or not several transistors are to be stacked. The following list of heat sink manufacturers, compiled at the time of this article, should be contacted for additional information and exact specifications.

TABLE II

Heat Sink Selection Guide

Consideration	Conditions	Heat Sink Choice (by code number — see Tables Ia & Ib & Figures 1 & 2)
Thermal Resistance	0 to 0.5°C/W	31 (water cooled)
	0.51 to 1.0	(Note 1)
	1.01 to 2.0	9, 10, 11
	2.01 to 3.0	1, 2, 3, 4, 5, 6, 7, 8, 12, 13, 14
	3.01 to 5.0	22
	5.01 to 7.0	17, 19, 20, 21, 23, 24
	7.01 to 10.0	15, 18, 25, 26, 27, 28
Shape Factor	3" Chassis	1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14
	Circuit Card	15, 18, 25, 26, 27, 28, 33
	Cylindrical Container	16, 17, 19, 20, 21, 22, 23
Blower	Self Channeled Air	29, 30, 40
	Forced Air	All except 18, 19, 20, 21, 31, 32
Water	Circulating Water	31, 32
Stacked Sinks	Easily Stacked	4, 5, 14, 30
Price & Availability	This we leave to the reader	

1. Many of the heat sinks will fall in these lower categories if blown air is used.

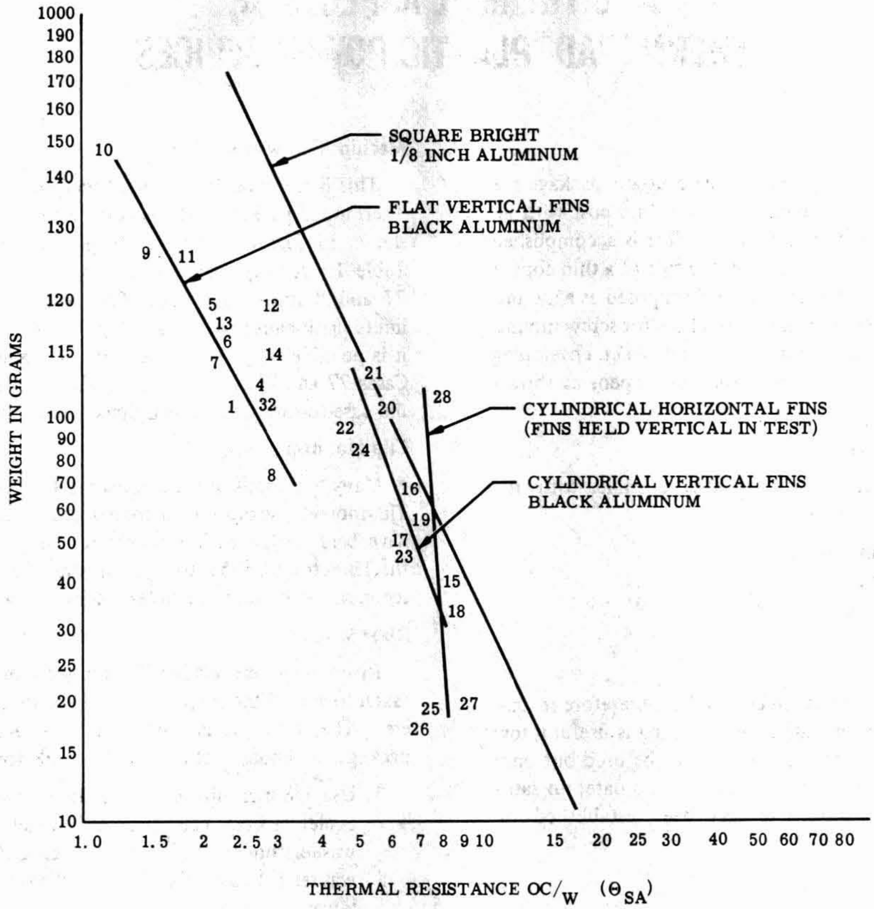


Figure 8 — θ_{SA} vs. weight.

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MOUNTING PROCEDURE FOR, AND THERMAL ASPECTS OF, THERMOPAD* PLASTIC POWER DEVICES

INTRODUCTION

The Motorola Thermopad* plastic power package has been designed to feature minimum size and cost with no compromise in thermal resistance. This is accomplished by mounting the silicon chip on one side of a thin copper sheet with the tin-plated opposite side exposed as a mounting surface. The copper sheet has a hole for screw mounting. Plastic is molded around the copper sheet, enveloping the chip but leaving the mounting hole open, as shown in Figure 1.

MOUNTING METHODS

The various mounting methods possible with the Thermopad package are as follows.

1. Machine screw
2. Retainer clip
3. Sheet-metal screw
4. Rivet
5. Solder

The first two methods are best and are therefore recommended. The sheet-metal-screw mounting is useful if low torques are maintained. Riveting may be used but only under carefully controlled conditions. To date, no satisfactory soldering procedure has been established by Motorola.

Machine-Screw Mounting

This is the most widely used method for mounting the Thermopad package. The necessary mounting hardware is shown in Figure 2 and the dimensions are tabulated in Table 1. A torque of 6 inch-lb is recommended for Case 77 and 8 inch-lb for Case 90. Exceeding these torque limits significantly may cause chipping of the plastic. While it is possible to go to a maximum of 8 and 12 inch-lb for Cases 77 and 90, respectively, no significant reduction in the case-to-sink thermal resistance will result.

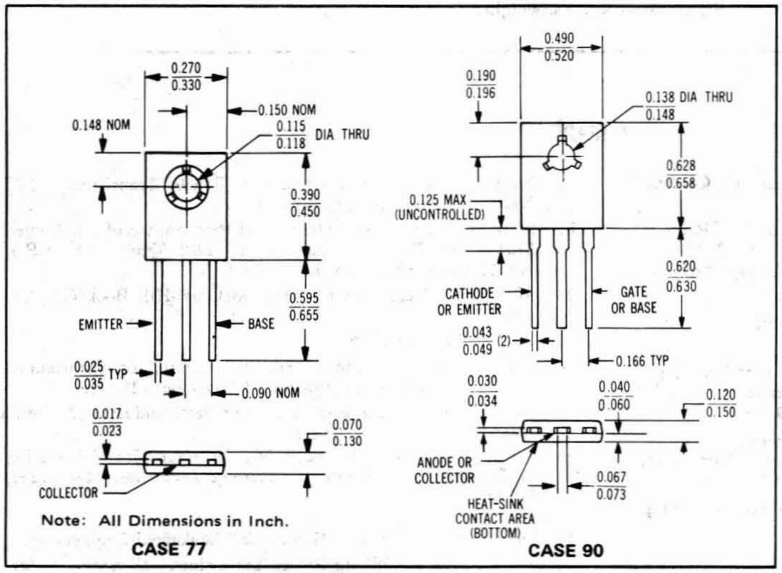
Clip Mounting

Many variations of metal clips can be used to secure the Thermopad packages to a chassis or a heat sink. Several have been tested with excellent results. One such clip is the Tinnerman C50595-011, as illustrated in Figure 3. The recommended mounting holes are also shown.

Rivet Mounting

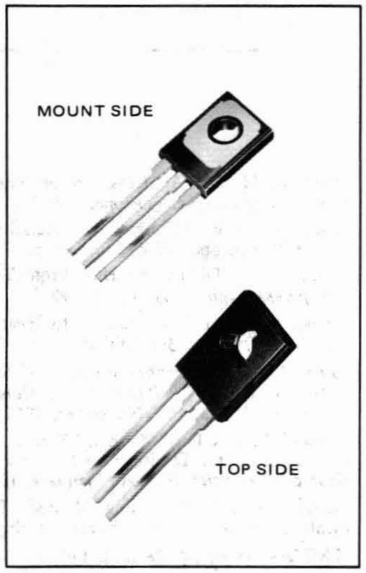
Rivets may be used for Thermopad mounting if care is taken to spread the force across the plastic by use of washers. The following is a useful method for the Case 90 package, a similar method would work for the Case 77.

1. Use 1/8-inch diameter semitubular rivet and eyelet of brass backed by 0.330-inch OD washers under head and rolled end. Omit top washer if heads of 0.330-inch diameter or larger are used.



0.270
0.330
0.150 NOM
0.148 NOM
0.115
0.118
DIA THRU
0.390
0.450
0.595
0.655
EMITTER
BASE
0.025
0.035
TYP
0.090 NOM
0.017
0.023
0.070
0.130
COLLECTOR
Note: All Dimensions in Inch.
CASE 77
0.490
0.520
0.190
0.196
0.138 DIA THRU
0.148
0.628
0.658
0.125 MAX
(UNCONTROLLED)
0.620
0.630
CATHODE OR EMITTER
GATE OR BASE
0.043
0.049
(2)
0.166 TYP
0.030
0.034
0.040
0.060
0.120
0.150
ANODE OR COLLECTOR
HEAT-SINK CONTACT AREA (BOTTOM)
0.067
0.073
CASE 90

FIGURE 1a – Outline Dimensions for Thermopad Packages



MOUNT SIDE
TOP SIDE

FIGURE 1b – Perspective View of Thermopad Package

Circuit diagrams external to Motorola products are included as a means of illustrating typical semiconductor applications; consequently, complete information sufficient for construction purposes is not necessarily given. The information in this Application Note has been carefully checked and is believed to be entirely reliable. However, no responsibility is assumed for inaccuracies. Furthermore, such information does not convey to the purchaser of the semiconductor devices described any license under the patent rights of Motorola Inc. or others.

2. Stack up flat and/or square to prevent pressure points.
3. Apply pressure by hydraulic or pneumatic force averaging 500 lbs (max 550 lbs).

BENDING LEADS

Care should be taken with Thermopad transistors when bending leads. The leads may be bent but not directly at the case, since any pulling of the leads during bending may crack the plastic mold. The recommended procedure is to clamp the leads firmly between the case and the point of bending, or use a forming tool so that no axial motion of the lead is allowed with respect to the case. Similarly, no twisting of the lead should be done directly at the case. A lead bend radius greater than 1/16 inch is recommended for Case 77, and one greater than 1/10 inch for Case 90.

When desired, leads should be spread in a direction perpendicular to the plane of the leads rather than within the plane (see Figure 5), unless a forming tool is used.

TEST SOCKETS

Test sockets are convenient for testing and breadboarding Thermopad transistors. Two sockets are available from the Loranger Mfg. Company (Warren, Pa. 16365) as follows:

Case 77: Socket LMC2447

Case 90: Socket LMC2475

THERMAL ASPECTS

Thermopad packages mounted by machine screws, clips, and rivets have been tested by temperature cycling between –65 and 150°C (five cycles of 30 min each, with 5-min

TABLE I
Hardware Dimensions for Machine-Screw Mounting of Thermopad Packages

PACKAGE	CASE 77	CASE 90
Screw Size	4-40	6-32
Dished Lock Washer (Shakeproof)	WD 19523 Mot 04A52200F01	WD 19522 Mot 04A52200F02
Mica Washer Size	1/8 in. ID, 7/16 OD	1/8 in. ID, 3/4 in. OD

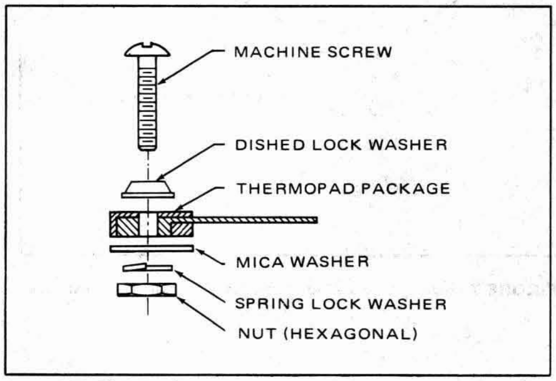

MACHINE SCREW
DISHED LOCK WASHER
THERMOPAD PACKAGE
MICA WASHER
SPRING LOCK WASHER
NUT (HEXAGONAL)

FIGURE 2 – Hardware for Machine-Screw Mounting of Thermopad Packages

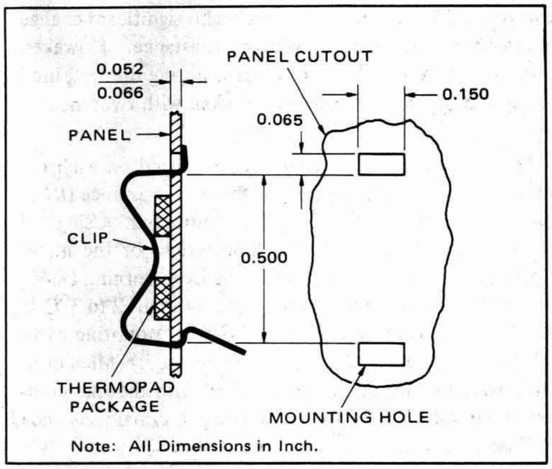

PANEL CUTOUT
0.052
0.066
0.150
0.065
PANEL
CLIP
0.500
THERMOPAD PACKAGE
MOUNTING HOLE
Note: All Dimensions in Inch.

FIGURE 3 – Mounting Thermopad Packages with the Tinnerman C50595-011 Mounting Clip

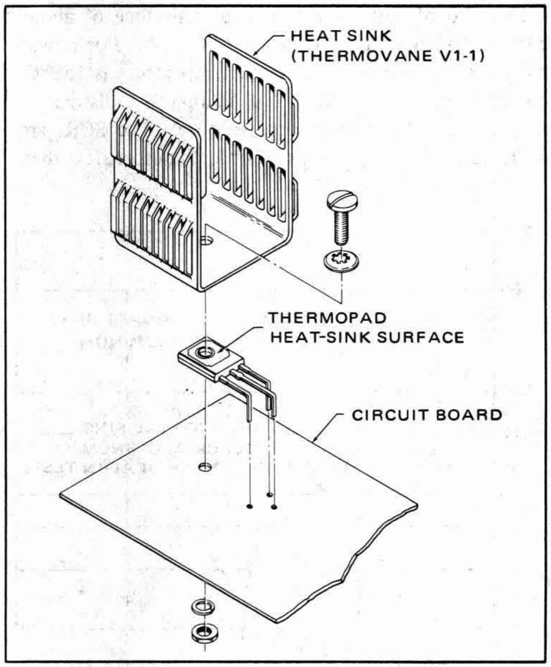

HEAT SINK (THERMOVANE V1-1)
THERMOPAD HEAT-SINK SURFACE
CIRCUIT BOARD

FIGURE 4 – Using Commercial Heat Sink with Thermopad Transistors

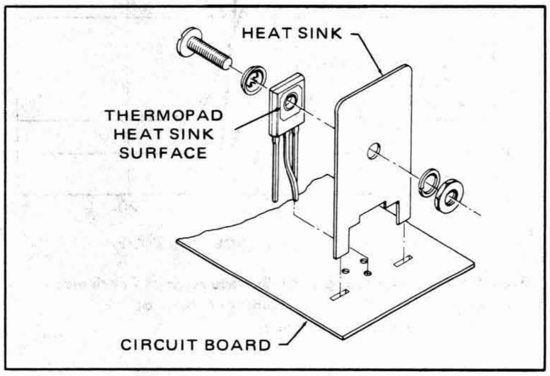

HEAT SINK
THERMOPAD HEAT SINK SURFACE
CIRCUIT BOARD

FIGURE 5 – Using Fabricated Heat Sink with Thermopad Transistors

stopover at 25°C). The tests revealed no significant change in interface (case-to-sink) thermal resistance. However, some of the riveted devices loosened during the test, indicating that special care should be taken with rivet mounting.

The internal thermal resistances are listed on each device data sheet but the interface thermal resistance (θCS) is a function of how the devices are mounted. Using the recommended torque with machine screws or the metal clip, and a thermal compound such as Dow-Corning D340, the Case 77 interface thermal resistance is about 2 to 3°C/W, and the Case 90 about 0.8 to 1.2°C/W. (Mounting without thermal compound is not recommended.) Mica insulating washers of 2-mil thickness used with thermal compound will add 3°C/W to the interface thermal resistance for Case 77 and about 1°C/W for Case 90.

For pulse applications, the packages can be used without a heat sink. The Case 77 with the leads soldered into a circuit board will have a thermal resistance of about 100°C/W and the Case 90 less than 90°C/W. For power transistors, the maximum junction temperature is 150°C, thus somewhat more than 1.0 W may be dissipated, depending on the ambient temperature. The SCRs are usually rated at a $T_{J(max)}$ = 100°C, therefore, less than 1.0 W could be dissipated. At higher power levels, heat sinking becomes necessary.

Commercial heat sinks, such as the Thermovane V1-1 (The Staver Co., L.I., N.Y.) illustrated in Figure 4, can be used with Thermopad packages. These, and other suitable commercial heat sinks are available with thermal resistances of less than 10°C/W to about 50°C/W. If heat sinks are fabricated from sheet metal as illustrated in Figure 5, the diagram shown in Figure 6 may prove useful. The heat sink can be a flat sheet or shaped into an "L" or "U" configuration with or without fins. The total area in square inches needed for a given application will vary depending on the choice of material and the amount of air flow. Another heat sink could be a metal chassis as shown in Figure 7.

In any prototype mounting, the temperature rise between sink and junction must be checked. First, the heat-sink temperature is measured with a thermocouple firmly attached (preferably soldered) to the heat sink. The junction temperature is then estimated by adding the sink-to-case and case-to-junction thermal resistances, multiplying this sum by the power dissipation, and adding the product to the heat-sink temperature.

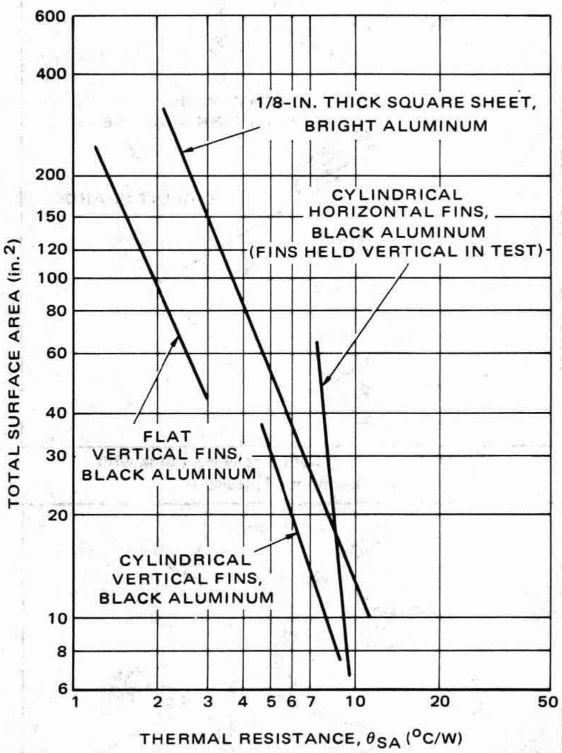


FIGURE 6 – Calculating Total Surface Area of Fabricated Heat Sink from Required Value of Thermal Resistance

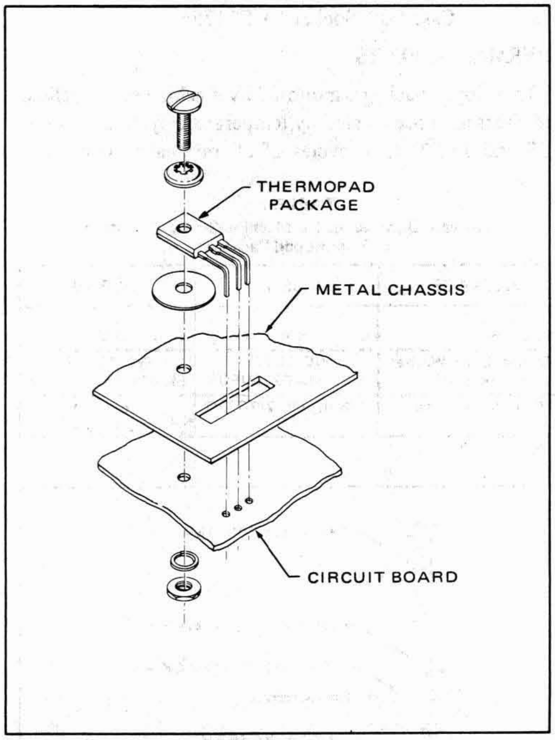


FIGURE 7 – Using Chassis Mounting for Thermopad Transistors

A METHOD OF PREDICTING THERMAL STABILITY

THERMAL STABILITY

Some of the most important considerations in designing reliable audio power amplifiers are the precautions that are taken to assure thermal stability over the operating temperature ranges. If all the factors influencing thermal stability are evaluated and incorporated into the design, thermal runaway and possible destruction of the transistors will be avoided. In many cases, transistor data sheets do not supply all the necessary information for determining the stability of biasing a Class A or Class B audio amplifier stage. In these cases "rule of thumb" information becomes useful in supplementing the data sheet information. Both germanium and silicon transistor characteristics, which influence thermal stability in biasing the collector current over a temperature range, will be discussed and a simple graphing method of tying all the information together to assure safe thermal design over a temperature range will be shown.

COLLECTOR-BASE LEAKAGE CURRENT I_{CBO}

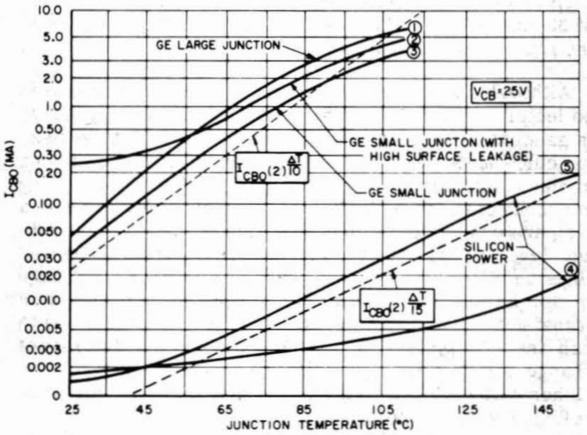


FIGURE 1 — CHANGE OF I_{CBO} WITH JUNCTION TEMPERATURE

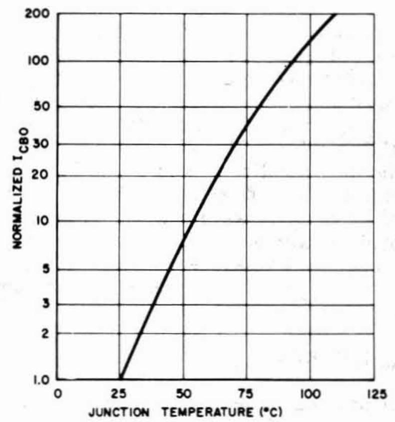


FIGURE 2 — NORMALIZED I_{CBO} VS JUNCTION TEMPERATURE ($V_{CB}=2V$)

The change of I_{CBO} with temperature is a very important consideration in designing a biasing circuit for a transistor operating over a range of temperature. Figure 1 shows the typical change of I_{CBO} with temperature for a number of different power transistors. The measurements were made at 1/2 BV_{CEO} to show the effects of surface conditions that would be present in a practical application. Curve #2 and #3 show the same type of germanium power transistor with approximately the same 2 volt I_{CBO}, however, the transistor in Curve #2 has a high surface leakage component. Curve #1 shows a larger junction germanium transistor with a higher initial I_{CBO}. The dotted line indicates the increase in I_{CBO} caused by the "rule of thumb" for germanium of doubling I_{CBO} every 10°C increase in temperature.

Curve #4 and #5 show the typical increase in I_{CBO} for two different types of diffused base silicon power transistors. Curve #4 is for a transistor which has all junctions brought to one surface, is passivated with silicon oxide to reduce leakage and has an annular ring to eliminate "channeling." Curve #5 is for a lower cost mesa process that has a higher inherent leakage component. It is apparent from the shape of Curve #4 that most of the I_{CBO} measured at room temperature is due to surface effects. It is also apparent that the small change in I_{CBO} for silicon would not be an important consideration unless very high source impedance is used in the biasing network.

With reference to Figure 1, it can be seen that if the 2 volt I_{CBO} for a germanium transistor is doubled every 10° C rise in temperature, and then add the surface component caused by operating at higher voltage, the value obtained would not be far from the actual measured value. The slope of the I_{CBO} curve for silicon can also be closely approximated by doubling the 2 V I_{CBO} every 15°C rise in temperature.

A much closer prediction of the change of I_{CBO} with temperature in germanium transistors is shown by the use of a normalized I_{CBO} curve as shown in Figure 2. This curve is based upon the similarity of the slopes of the I_{CBO} curves for germanium transistors as indicated by the low surface leakage devices in Figure 1. The 2 volt I_{CBO} at room temperature is multiplied by the values shown on the vertical scale to obtain the 2 volt I_{CBO} at other temperature levels. Surface components must be added as a constant at every temperature level to obtain accuracy at higher voltage levels, although a small positive temperature coefficient is apparent in the surface component.

CURRENT GAIN VERSUS TEMPERATURE

Because the change of gain with temperature is a characteristic that influences the change of bias for a transistor over a temperature range, these variations with temperature should be known, especially when high source impedances are used in the biasing network. Figure 3 shows the variation of I_C vs. I_B for a germanium power transistor over a temperature range of -40 to +100°C. The dotted line indicates the actual base current readings obtained at 100°C. However, because I_{CBO} is flowing through the base in the opposite direction, we must add the I_{CBO} current to the meter reading in order to obtain the actual gain component of base current, as shown by the solid line. This solid line curve is more useful in determining the increase in transistor gain characteristics with temperature by eliminating the highly variable I_{CBO} component. This curve shows that transistor gain increases approximately 50 per cent in the Class B biasing current range when the temperature is raised from 25°C to 100°C.

The gain of the transistor increases as the voltage across it is increased and is directly related to the output impedance of the device. Because output impedance will change with temperature, This same germanium transistor will show approximately 100 per cent increase in gain at a voltage level equal to 1/2 BV_{CEO} over the same temperature increase of 25°C to 100°C. If this information is not stated on the data sheet for the device,

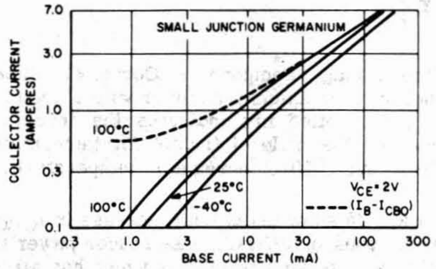


FIGURE 3 — COLLECTOR CURRENT VS BASE CURRENT

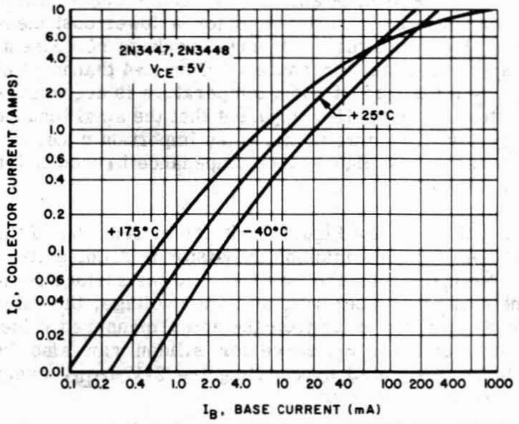


FIGURE 4 — TYPICAL I_C VS I_B FOR SILICON POWER TRANSISTORS

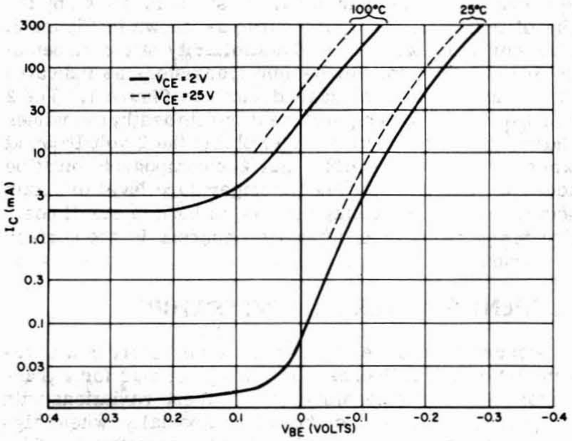


FIGURE 5 — TRANSCONDUCTANCE VS TEMPERATURE

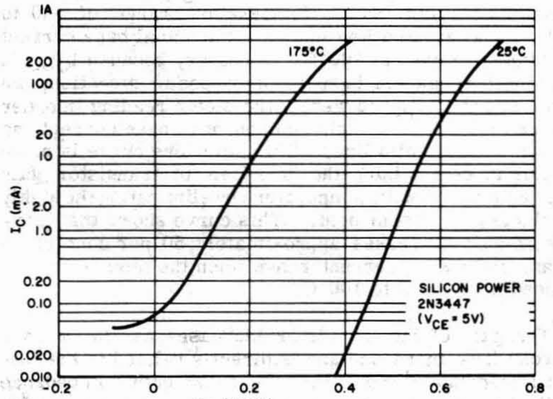


FIGURE 6 — TRANSCONDUCTANCE VS TEMPERATURE

the above information would be approximately true and can be used for most germanium power transistors at Class B bias current levels.

Figure 4 shows the I_C vs. I_B information for a typical diffused silicon power transistor over the temperature span of -40°C to +175°C. This information shows that in the range of Class B biasing currents there will be approximately an increase of 100 per cent in current gain when the temperature is raised from 25°C to 175°C. At higher voltages this change will be somewhat greater; however, the effect of output impedance changes will be less than on germanium devices.

V_{BE} VERSUS TEMPERATURE

The change of V_{BE} with temperature is a most important consideration in determining biasing of germanium transistors with low source impedance in the biasing network. Figure 5 shows the transconductance curve vs. temperature of a typical germanium power transistor at current levels within the range of Class B biasing current levels. The solid line curves indicate the change in V_{BE} at V_{CE} = 2 volts from 25°C to 100°C. In the range of 30 mA to 300 mA collector current, V_{BE} changes at the rate of approximately 2 mv/°C.

Although there is a change in V_{BE} with an increase in collector voltage (Figure 5), the slope of the V_{BE} curve is generally not greatly affected at 25°C over the collector current ranges that are important in Class B biasing of the transistor. However, if the slope of the V_{BE} curve is changed at higher temperatures because of a temperature effect on the output impedance at high voltage levels, this effect must be considered. The dotted lines in Figure 5 show the change in V_{BE} with a change in temperature for a high output impedance germanium transistor when operating at a collector voltage equal to half the BV_{CEO} rating. This indicates that the rate of change for this transistor is increased at 2.2 mv/°C at higher voltage levels. If these characteristics at higher voltage levels are not known, 2.2 mv/°C would be a useful temperature coefficient for V_{BE} in the range of Class B biasing.

Figure 6 shows the effects of temperature on the transconductance of a typical diffused silicon power transistor. This information shows that in the range of collector currents most important in biasing Class B audio amplifiers, the V_{BE} changes 2.2 mv/°C over a temperature span of 25°C to 175°C. This change in V_{BE} with temperature is shown at a collector voltage of 5 V. Because of the very high output impedance of silicon power transistors in the range of Class B biasing current levels, 2.2 mv/°C would be valid except at very high voltage levels. At higher current levels associated with Class A biasing, this may not be true depending upon the characteristics of the transistor.

THERMAL RESISTANCE

The thermal resistance of junction to ambient (Θ_{JA}) plays an important role in thermal stability design. For each incremental increase in power dissipation of the transistor, there will be a resultant increase in the junction temperature and hence a change in the temperature dependent characteristics of the transistor. When transistors are used with heat sinks, the long thermal time constant of most heat sinks will cause the characteristic changes to be very slow. The thermal resistance of the transistor and heat sink should be known if thermal stability is to be properly evaluated.

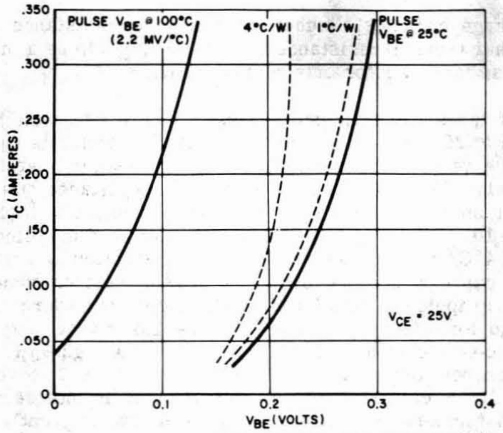


FIGURE 7 — TRANSCONDUCTANCE (7.5 AMP. GERMANIUM)

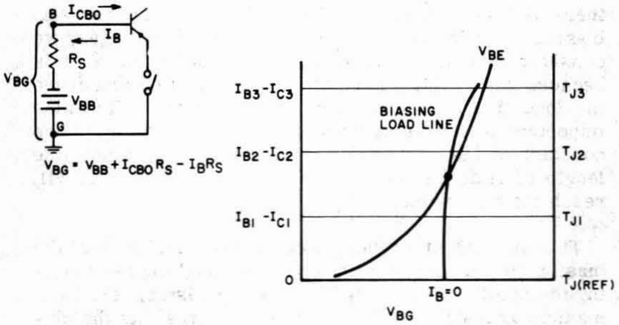


FIGURE 8 — CONSTRUCTION OF A BIASING-LOAD LINE

THERMAL STABILITY

When all the temperature dependent factors are obtained, we need some simple mechanism for combining them into a resultant conclusion for thermal stability. The transconductance curve is proposed as the starting point as shown in Figure 7. Because the transconductance curve information supplied by the transistor data sheet is considered to be obtained by pulsing, we must modify this transconductance by the effects of increasing junction temperature as dc collector current is increased. The power dissipated at all collector current levels will cause an increase in transistor junction temperature from the reference temperature, depending upon the thermal resistance to the reference point. The V_{BE} curve is reduced at any particular collector current level by the relationship $(.0022)\ I_C\ V_{CE}\ \Theta_{JA}$ (or Θ_{JC}),

where

.0022 in volts is the change in V_{BE} per °C change in temperature and is a "rule of thumb"

I_C = collector current

V_{CE} = collector to emitter voltage

Θ_{JA} or Θ_{JC} = thermal resistance of junction to ambient or junction to case, depending upon the reference point.

The curve in Figure 7 shows the effects of dc power dissipation modifying the V_{BE} curve based upon two arbitrary thermal resistances, 1°C/watt and 4°C/watt. In addition, the pulse V_{BE} curve is shown @ 100°C by reducing V_{BE} at the rate of 2.2 mv/°C. The modified transconductance curves become the starting point for predicting the biasing current levels at different operating temperatures.

After the transconductance curve has been constructed, the next step is to construct the biasing load line. The construction of the biasing load line is illustrated in Figure 8. With reference to the equivalent circuit of Figure 8, it can be seen that the base to ground voltage $V_{BG} = V_{BB} + I_{CBO}\ R_S - I_B\ R_S$ with emitter switch closed. The vertical scale of the transconductance curve of Figure 8 shows that there is a direct linear relationship of collector current, base current, and junction temperature due to power dissipation and thermal resistance. The biasing load line will start at some voltage level on the horizontal scale at $I_B = 0$ dependent upon V_{BB} + (initial) $I_{CBO}R_S$ when the emitter switch is open. When the emitter switch is closed, V_{BG} will change to a value determined by base current and the change in I_{CBO} as collector current increases the junction temperature; thus the bias load line is constructed by inserting the values of I_{CBO} and I_B for each temperature level into the equation, $(V_{BG} = V_{BB} + I_{CBO}R_S - I_BR_S)$. The point at which this constructed bias load line intersects the constructed V_{BE} curve will determine the collector current of the transistor.

If there were no significant increase in I_{CBO} or decrease in I_B due to temperature, the bias load line will be a straight line for a linear gain transistor. However, the change in I_{CBO} due to each incremental increase in collector current will, in many cases, overcome the change in base current and give an increasing voltage load line as shown in Figure 8.

As an illustration, the basic circuit and graph of Figure 9 show the method for determining the thermal stability of a particular transistor operating with a 2 volt collector supply and with a thermal resistance of 1°C/watt. In this case, the change in V_{BE} per degree change in temperature was measured to be 2 mv/°C. The transistor had a dc gain of 100 with a measured increase of 50 per cent over the temperature range of 25°C to 100°C at 2 V. Because in most practical cases, emitter resistance is used in Class B audio circuits to reduce the change in bias current with temperature, the transconductance curve is constructed to include the I_CR_E voltage drop across a .5 Ω resistor.

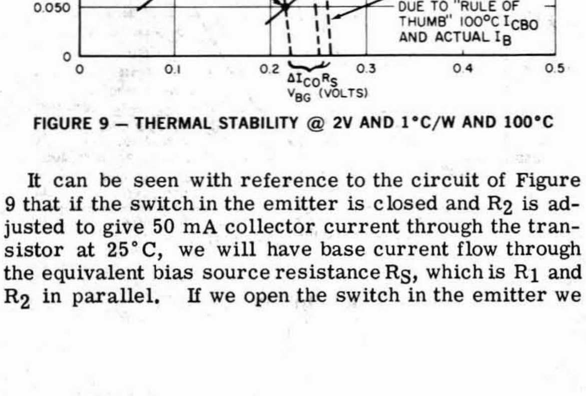


FIGURE 9 — THERMAL STABILITY @ 2V AND 1°C/W AND 100°C

It can be seen with reference to the circuit of Figure 9 that if the switch in the emitter is closed and R_2 is adjusted to give 50 mA collector current through the transistor at 25°C, we will have base current flow through the equivalent bias source resistance R_S, which is R_1 and R_2 in parallel. If we open the switch in the emitter we will have an interruption of this base current and a resultant rise in voltage between the base point and ground, dependent upon the bias source resistance and the value of base current and I_{CBO} that was flowing. ($V_{BG} = V_{BB} + I_{CBO} - I_BR_S$) In this case the source impedance is 10 Ω and the transistor has a dc gain of 100 with .5 mA base current flowing at the 50 mA point of intersection with the 25°C transconductance curve. The bias voltage (V_{BG}) change will be 5 mv since the change in I_{CBO} will be very small at these low temperatures. Constructing a bias load line from the 50 mA point with this voltage change has already been discussed.

If the temperature of the transistor case is raised to 100°C, the change in I_{CBO} will be approximately 3 mA. This is based upon an I_{CBO} of 22 μA at room temperature and the normalized curve of Figure 2. This I_{CBO} current flowing through the biasing source resistance will increase the bias voltage on the horizontal scale. When the switch is closed a bias load line is constructed to intersect the 100°C transconductance curve based upon the 100°C dc current gain, increase in I_{CBO}, and the bias source resistance. The dc gain at 100°C is 150 which determines that there will be 10 mv drop in bias voltage (V_{BG}) for every 150 mA increase in collector current. Because there is a further increase in I_{CBO} as collector current flows when the emitter switch is closed, the bias load line is constructed to intersect the 100°C transconductance curve based upon $V_{BG} = V_{BB} + I_{CBO}R_S - I_BR_S$. The construction of this load line using the incremental change in I_{CBO} and I_B is shown by the load line intersection of the 100°C transconductance curve.

The actual measurements showed that the biasing current changed from 50 mA at 25°C case temperature to 242 mA at 100°C case temperature for this transistor. The graphing predicted that this transistor would reach a final value of 237.5 mA, which is very close. When the collector voltage is raised to 25 volts, the measured value was from 50 mA to 290 mA. Using a 2.2 mv/°C change in V_{BE} and a 100 per cent increase in gain over this temperature span, we can again predict the change very closely by repeating the above procedure. The graph in Figure 9 also shows the results of using the "rule by thumb" of doubling I_{CBO} every 10°C rise in temperature.

It is quite apparent that with the low biasing source resistance and the low I_{CBO} at high temperature for the device that was illustrated, the change in V_{BE} was the major cause of collector bias current change. Higher leakage currents, higher bias source resistance and higher thermal resistance will cause I_{CBO} to be a major cause for collector bias current changes.

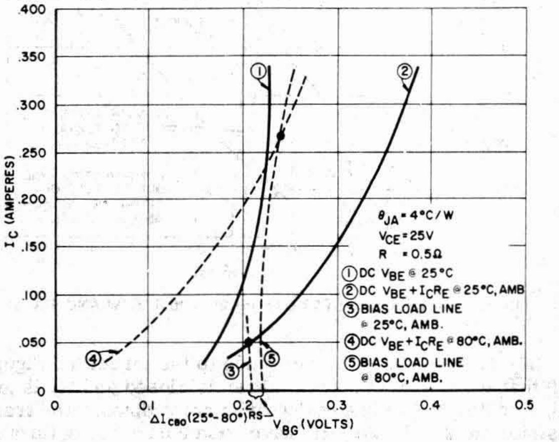


FIGURE 10 — THERMAL STABILITY

If the same transistor is used with a 3°C/watt heat sink at 25 volts collector voltage, the transistor is shown to be very near thermal runaway at these temperature levels. The effects of total thermal resistance of 4°C/watt on thermal stability is shown graphically in Figure 10. The V_{BE} curve is constructed and modified by the 4°C/watt change due to power dissipation as collector current is increased. The biasing current changes are graphically predicted by the same procedure outlined for Figure 9, except we use 2.2 mv/°C and 100 per cent increase in gain. Because of the high Θ_{JA}, the reference temperature is raised from 25°C to only 80°C. It can be seen that the slope of the intersecting high temperature biasing source load line is greatly affected by the rapid rate of increase of I_{CBO} for each incremental increase in collector current. Because there is a tendency to predict a slightly lower change in biasing collector currents at high collector voltages, we consider this case to be a borderline condition. This is because a very little increase in temperature will cause the load line not to intersect the V_{BE} curve. It is also important to note that because of the long thermal time constant of the heat sink, it will take a considerable length of time before the collector biasing current will reach the final value.

This method of graphing the thermal stability of the biasing current levels eliminates the need for determining the highly variable $R_{BB'}$ in the transistor. For germanium transistors, this method requires that the circuit be designed for the lowest possible bias source resistance, and then graph the thermal stability using the highest gain, lowest input impedance and highest leakage transistor for the expected ambient temperature change. Emitter resistance can be added to improve stability if improvement is needed. It is apparent that a bias source impedance that changes with temperature can greatly increase the stability. With this method of predicting biasing changes with temperature, the desired temperature coefficients can be determined.

Up to this point, we have ignored the effects of power supply variations on the bias voltage levels. In the next example for a silicon transistor, this important effect will be shown and must be considered in all design predictions.

If I_{CBO} change with temperature for a silicon transistor is low enough to be ignored, graphing the silicon

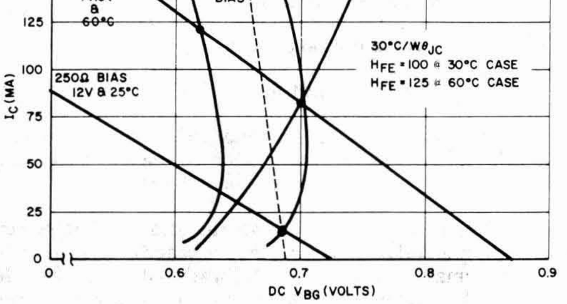


FIGURE 11 — THERMAL STABILITY — SMALL SIGNAL SILICON

transistor stability is somewhat simpler in procedure. The graph in Figure 11 shows the constructed dc transconductance curves for a small signal silicon transistor for minimum battery voltage at 30°C case and for maximum battery voltage at 60°C case based upon 30°C/watt Θ_{JC}. It is apparent that the 25 Ω biasing load line will not intersect the high battery voltage high temperature V_{BE} curve without even considering the effects of battery voltage level on bias source voltage. If we increase the bias source resistance to 250 Ω, it can be seen that we intersect both V_{BE} curves even when the bias source voltage is increased in direct proportion to battery voltage change. The slope of the biasing load line is based upon a gain of 100 at 30°C case, and 125 at 60°C case for this particular product. At 100 mA with a 60°C case temperature and 30°C/watt thermal resistance, the junction temperature will be approximately 105°C.

This particular Class B amplifier was designed for 2 watts output and bias power will be the determining factor for heat sink design when collector currents are over 50 mA. It is apparent that it is desirable to add an emitter resistor or increase the bias source impedance for a lower collector current change. When the transistor is driven from a higher source impedance, biasing current levels for crossover distortion can be somewhat lower.

The indications from Figure 11 are that low leakage silicon transistors can be made to have the best stability when biased with a high bias source impedance. The highest value for this source impedance is dependent upon the point at which the I_{CBO} component begins to cause significant change in the input bias voltage. Some silicon transistors may have a high surface leakage component that may be temperature dependent and must be considered if accurate collector current changes are to be predicted.

CONCLUSION

Predicting the thermal stability of audio amplifier bias can be a simple procedure if the temperature dependent characteristics can be determined or closely predicted by simple "rule of thumb" procedures that are outlined in the main text. The method of graphing thermal stability of biasing circuits can be summarized as follows:

1. Obtain the pulse transconductance curve (I_C vs. V_{BE}) for the transistor to be used from the data sheet. Modify the transconductance curve for the dc power dissipation within the bias collector current range by reducing V_{BE} in accordance with $\Delta V_{BE} = (.0022)\ (V_{CE}\ I_C)\ \Theta_{JA}$. If an emitter resistance is used, construct the final room temperature transconductance curve by including $I_C R_E$ at all collector current levels.

2. Determine collector biasing level as determined by Class A power output or elimination of crossover distortion in Class B circuits. Determine the change in bias source voltage with and without base current plus I_{CBO}. Construct the bias source load line from this source voltage change to intersect the bias current point on the room temperature transconductance curve and the zero current point on the horizontal scale ($V_{BG} = V_{BB} + I_{CBO}R_S - I_B R_S$).

3. Determine the change in temperature to be encountered and construct a new transconductance curve at the higher temperature. This is accomplished by reducing V_{BE} by a constant amount equal to ($T_{Hi\ temp}$ - T25°C) (.0022). If there is a possible collector voltage change, modify this curve for the highest power dissipation.

4. Determine the change in I_{CBO} for the change in ambient or case temperature. Multiply this change by the bias source impedance and add to the open circuit bias source voltage (V_{BG}) on the horizontal scale. If there is an increase in bias source voltage due to power supply variations, add this change also to the open circuit bias voltage. If there is a temperature coefficient to the bias source impedance, subtract this from the open circuit bias voltage that had been obtained up to this point. The change in I_{CBO} can be obtained for germanium transistors using the "rule of thumb" of doubling I_{CBO} every 10°C rise in temperature or by use of a normalized I_{CBO} curve as in Figure 2. The change in I_{CBO} for silicon can be predicted by doubling I_{CBO} for every 15°C rise in temperature.

5. Construct a new bias source load line based upon the gain at high temperatures, the bias source impedance and any additional change in I_{CBO} due to power dissipation at each incremental increase in collector current.

6. If the modified bias source load line does not intersect the high temperature transconductance curve or does intersect with a slope that is almost tangent to the curve, the thermal stability is considered not to be adequate at these temperature levels. The accuracy of predicting thermal stability is dependent upon the accuracy of obtaining the temperature dependent characteristics of the transistor used and in most cases will be predicted about 10 per cent low at high voltage levels. This is close enough for design purpose if worst case design factors are used.

AVOIDING SECOND BREAKDOWN

INTRODUCTION

No designer of power circuits can consider a design sufficiently reliable unless the circuit has been checked to insure that the transistors will not undergo second breakdown. Operating within the power-temperature ratings and insuring against thermal runaway will not alone guarantee circuit reliability.

To avoid second breakdown, it is necessary to maintain the load line within safe voltage-current limits. As will be described later, second breakdown is energy dependent; that is, it is a function of time, voltage, and current. Since transistors can be operated at an infinite number of time intervals and operating points, reliable areas of operation are generally specified by a chart which has time as a parameter.

Second breakdown was first reported in the literature by Thornton and Simmons[1] in January, 1958. Progress in this area has been very slow, although considerably more is known about device behavior today than was known at that time. Many of the theories offered a decade ago have been confirmed, and a clearer understanding of the problem has been achieved. However, the basic problem of the circuit designer is to avoid second breakdown, and to do this he needs device data and must understand how to use it. Nevertheless, some understanding of the basic mechanism will be helpful and can allay any fears the designer may have regarding peak power operation of semiconductors.

Figure 1 shows a sketch of the voltage-current characteristic of a transistor operating in the reverse breakdown mode. Note that at low collector currents, the voltage across the device exceeds the open base breakdown rating. The peak of the curve and the negative resistance region has been termed the first breakdown, or the normal breakdown, and is a result of avalanche action in the transistor. However, as current in the avalanche mode is increased to higher values, a critical current (I_m) is reached at which the voltage across the device drops to a very low level. This behavior is aptly called second breakdown.

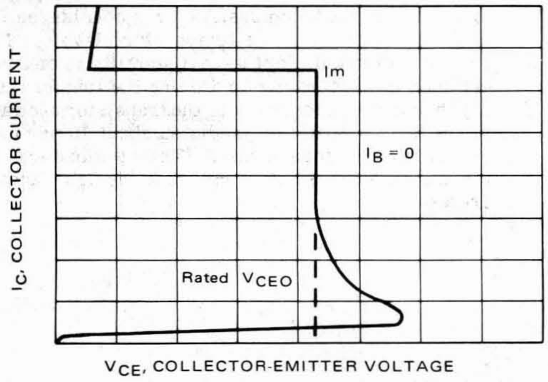


FIGURE 1 – Manifestation of second breakdown in a transistor

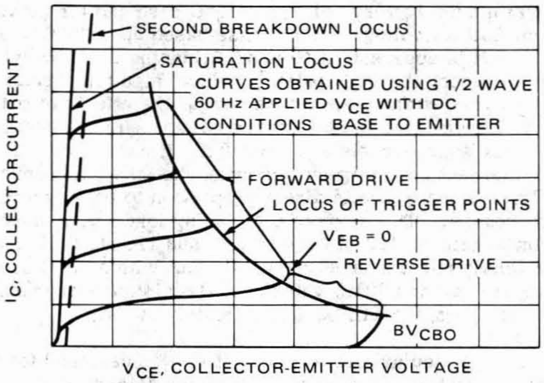


FIGURE 2 – Locus of second breakdown trigger points

It was discovered later that transistors need not be operating in avalanche breakdown in order to encounter second breakdown. Figure 2 shows a family of collector curves, and the locus of critical or trigger currents at which the transistor enters second breakdown. Note that as collector voltage is increased, I_m occurs at lower currents and becomes extremely low as the emitter-base junction becomes reverse biased. It has also been found that the amount of time a power pulse is applied at a particular operating point also determines whether or not second breakdown will occur. The observed behavior is a result of "hot spots" forming in the device as a result of non-uniform current density.

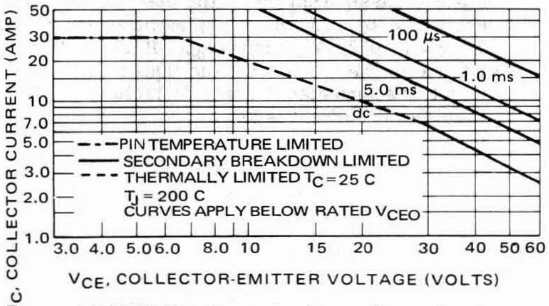


FIGURE 3 – Example of an active region safe operating area

Circuit diagrams external to Motorola products are included as a means of illustrating typical semiconductor applications; consequently, complete information sufficient for construction purposes is not necessarily given. The information in this Application Note has been carefully checked and is believed to be entirely reliable. However, no responsibility is assumed for inaccuracies. Furthermore, such information does not convey to the purchaser of the semiconductor devices described any license under the patent rights of Motorola Inc. or others.

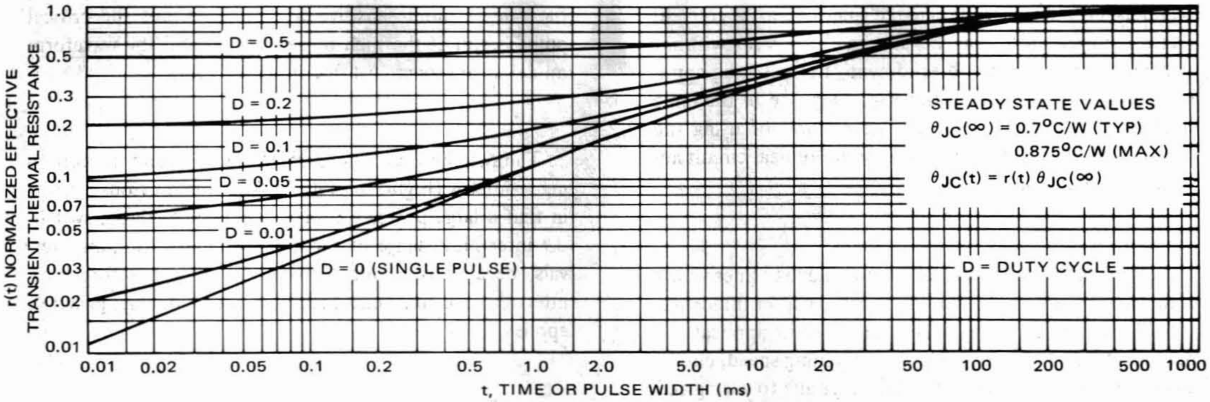


FIGURE 4 – Example of thermal response data

USE OF SAFE AREA DATA

Figure 3 is a typical example of the safe area information presented on Motorola data sheets. The solid lines show second breakdown limitations while the dotted lines represent thermal limitations. For this transistor family, dc currents above 30A cause excessive emitter pin temperatures*; therefore, operation above 30A dc is not recommended. Above 6.5 volts, the allowable dc current is junction temperature limited. If the case temperature (T_c) is 25°C, then power dissipation (P_D) must not exceed 200 watts. The dc curve also shows that the dc power level must be lowered from the 200 W level as voltage increases above 30 volts if second breakdown is to be avoided. At case temperatures higher than 25°C, thermal resistance information must be taken into account to derate the power dissipation limit in order to keep the junction temperature (T_J) below its limits, $T_{J(max)}$. The second breakdown limitation curve is valid when $T_J \leq T_{J(max)}$; therefore the curve is not derated with increases in case temperature. That is, the curve is dependent on junction temperature only.

The various pulse curves given show no thermal limitations for currents to 50A; the transistor power is limited solely by second breakdown. (At higher case temperatures the transient thermal resistance must be used to determine if operation is within $T_{J(max)}$.) The given pulse curves are used if the duty cycle is 10% or less. For higher duty cycles, the curves will gradually degrade to the dc curve.

It is common industry practice to rate power devices at a case temperature of 25°C, even though it is very unlikely that the case would ever be held at 25°C in a practical operating situation. It is instructive to find the effect on the Safe Area Curve for this particular transistor if the case were at 125°C.

From Figure 4, which shows the thermal response of the transistor, the normalized effective thermal resistance, r(t), can be read for a single pulse (D = 0) as 1.0 for dc, 0.23 for 5 ms, 0.13 for 1 ms, and 0.034 for 0.1 ms. The effective thermal resistance, $\theta_{JC}(t)$, is found by multiplying these normalized values by the steady state value of 0.875°C/W. The allowable power is found from $P_D = \frac{T_J - T_C}{\theta_{JC}(t)}$ where $T_J - T_C$ = 75°C in this example. The power levels allowed are respectively 86, 370, 660, and 2500 watts. These values can be used to construct a safe area curve based upon T_C = 125°C as shown by Figure 5.

The second breakdown curves are unchanged; they are already based upon $T_J = T_{J(max)}$. Note that dc operation is entirely thermally limited, and thermal limitations appear on the lower voltage ranges of the longer pulse times. However, at 100 μs, no thermal limitations appear below 50 amperes. Such behavior is typical of most transistors, i.e., dc power becomes thermally limited at fairly low case temperatures, while under short pulse operation power dissipation is limited by secondary breakdown, even at fairly high case temperatures.

The curves are to be interpreted as showing limits of power dissipation which may be sustained for a time in-

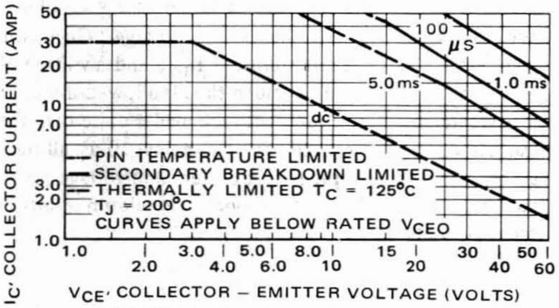


FIGURE 5 – Constructed safe operating area data at T_C = 125°C for transistor of figures 3 and 4

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*On low-level devices, I_C is limited by the bonding wire at low values of V_{CE}.

terval as shown by the designated line, i.e., a 20 volt, 30 ampere power pulse may be sustained for 1 ms without encountering secondary breakdown. In switching applications, the load line may traverse along one of the limit lines for the time indicated. The method of using the curves will be explained by using some typical circuit applications as examples.

Figure 6 shows a number of circuits and load lines which could be encountered. At this point bear in mind that load lines can vary considerably in different applications because of the effect of transistor switching speed, circuit capacitance and inductance values, strays due to wiring and transformer leakage inductance.

The first 5 circuits have typical inductive load lines. The most demanding turns out to be, strangely enough, the transformer-coupled audio amplifier (see Figure 6A). Under normal operation, the load line is resistive and as long as it falls below the dc safe area line (the period of 1/2 of a 20 cps wave is 25 ms or essentially dc), no failures should be encountered. However, should the load be opened with signal applied, a reactive, nearly rectangular, load line could result. It is important that the drive be restricted to keep the collector current within bounds and the whole load line below the dc safe operating area or failure could result.

The solenoid drivers (Figures 6B and C) cause relatively few problems. Peak currents are restrained by R_L and switch off is fast. The collector current remains fairly constant until the clamping level of the diode is reached, and then the current transfers to the diode. The simplest, and a fairly secure way to check for safe area, is to obtain the collector current waveform and make an equivalent rectangular model having the same peak amplitude and a width adjusted to have the same charge (area) as the actual pulse. Assume collector voltage is constant at the clamp level (V_K) – it will generally rise to this level quickly – and see if this condition is within the safe area. For example, suppose the voltage rises from A to B in 1 μs and it takes 10 μs for the current to linearly decay from point B to point C. A 6 μs rectangular pulse of amplitude I_{max} would contain the same charge. Go to the point on the safe area at a current I_{max} and a voltage of V_K (point B) and see how much time is allowed there. If it is greater than the equivalent rectangular pulse then the transistor is safe. Generally at times below 10 μs, all transistors can withstand their rated current and voltage simultaneously so that this mode of operation seldom results in transistor failure.

The power inverter (Figure 6D) and the ignition system (Figure 6E) can be handled in the same way as the relay drivers. The fact that no clamp exists in Figure 6D makes the circuit more sensitive to transients, but the critical point is still at the high power corner, and the waveform modeling approach just described will work.

The switching motor control (Figure 6F) and the switching regulator (Figure 6G) differ from the previous circuits in that a large power transient occurs on both the switch-off interval, because of the inductor, and switch-on intervals, because of diode recovery current; therefore both intervals need to be checked. The same modeling principle applies.

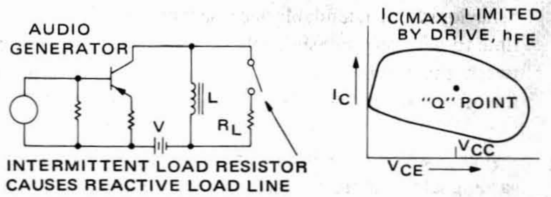
Should both voltage and current change at about the same speed, the foregoing approach may be too conservative. For a more exact analysis it is necessary to plot the load line and note the time between certain intervals. A comparison to the Safe Area curve can then be made. Remember, the pulse curves indicate that the transistor operating point can spend a given time at any one point on the curve or that it may travel along the curve for the same given time.

THE PHYSICAL MECHANISM

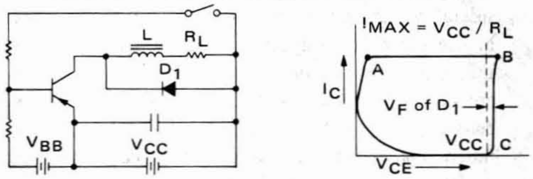
Secondary breakdown – the switch back of voltage from a high to a low level – has been shown to be a fundamental property of any semiconductor material. An interesting experiment[2] was performed using N + N N + plates; that is, the material was a piece of N type silicon to which an N+ type of material was deposited on both sides. This sandwich was not a junction; the N+ material was used merely as a means of obtaining electrical contact to both sides of the N region. It was discovered when voltage was applied that a normal ohmic behavior was observed up to a critical voltage and current at which time the voltage dropped to a very low value. By using temperature sensitive phosphers the material temperature was determined at the time switch-back occurred. It was found that the temperature corresponded to that temperature at which the material enters intrinsic conduction. That is, at a sufficiently high temperature, the semiconductor material undergoes a very rapid change in resistivity becoming essentially a conductor similar to a metal. The temperature of intrinsic conduction is inversely related to resistivity, varying from 200°C to 300°C for resistivity values used in transistors.

It should be pointed out that the temperature of intrinsic conduction does not destroy the material. What occurs in a finished semiconductor device is some very small change in the resistivity profile. Dopants will tend to move from an area of high concentration to areas of low concentration. Most semiconductor materials are in a state of chemical instability; that is, given sufficient time, changes

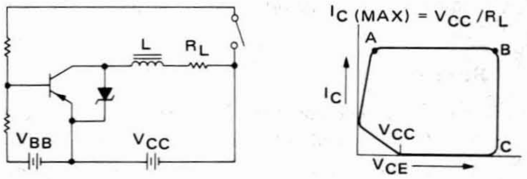
(A) CLASS A AUDIO AMPLIFIER


AUDIO GENERATOR
L
V
R_L
INTERMITTENT LOAD RESISTOR CAUSES REACTIVE LOAD LINE
$I_{C(MAX)}$ LIMITED BY DRIVE, h_{FE}
I_C
"Q" POINT
V_{CC}
V_{CE}

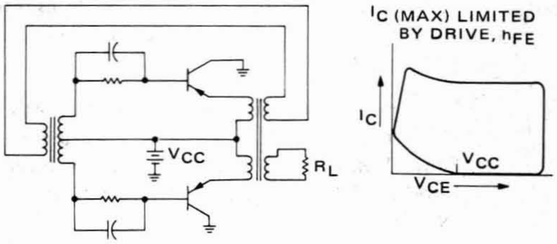
(B) SOLENOID DRIVER WITH RECTIFIER DIODE TO SUPPRESS INDUCTIVE KICK


L
R_L
D_1
V_{BB}
V_{CC}
$I_{MAX} = V_{CC} / R_L$
A
B
I_C
V_F of D_1
V_{CC}
C
V_{CE}

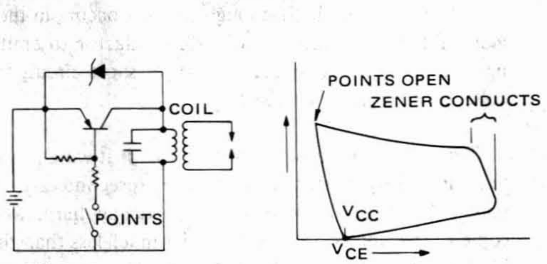
(C) SOLENOID DRIVER WITH ZENER DIODE SUPPRESSION


L
R_L
V_{BB}
V_{CC}
$I_{C\ (MAX)} = V_{CC} / R_L$
A
B
I_C
V_{CC}
C
V_{CE}

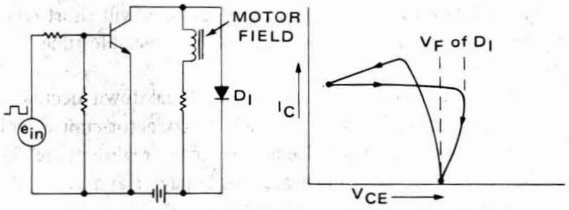
(D) POWER INVERTER


V_{CC}
R_L
$I_{C\ (MAX)}$ LIMITED BY DRIVE, h_{FE}
I_C
V_{CC}
V_{CE}

(E) IGNITION SYSTEM


COIL
POINTS
POINTS OPEN
ZENER CONDUCTS
V_{CC}
V_{CE}

(F) SWITCHING TYPE MOTOR CONTROL


MOTOR FIELD
D_I
e_{in}
V_F of D_I
I_C
V_{CE}

(G) SWITCHING TYPE SERIES REGULATOR

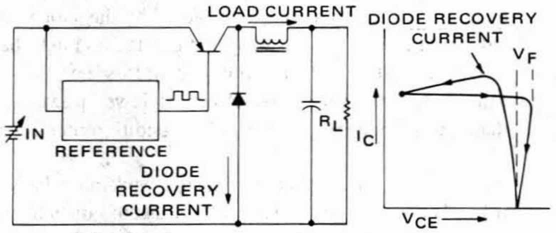

LOAD CURRENT
IN
REFERENCE
DIODE RECOVERY CURRENT
R_L
DIODE RECOVERY CURRENT
V_F
I_C
V_{CE}

FIGURE 6 – Examples of circuits and their typical load lines

in the resistivity profiles will occur. At normal operating temperatures the gradual diffusion of dopants in the semiconductor would take many many years to produce any noticeable change in device characteristics. However, prolonged operation at temperatures on the order of those at which the material becomes an intrinsic conductor–would cause noticeable changes in device performance in a much shorter time.

Second breakdown in transistors is triggered when the temperature of some part of the material achieves an extremely high value, causing the material to go into intrinsic conduction, thereby becoming a very low resistance material. While in second breakdown, if the current is removed or held to very low values, no particular harm comes and the semiconductor will act normally when it cools.

However, in most circuits, when the transistor enters second breakdown, a collector-emitter short results. The reason for this is that it is difficult to prevent the junction temperature from exceeding the melting point of the material. High pin-point temperatures in the transistor are produced because certain biasing conditions have caused current to concentrate into a few very small areas.[3] These small areas sustain the full collector current which normally, under ideal conditions, would be distributed evenly along the entire semiconductor active region. Now, should the temperature at one of these hot spots become sufficiently high, second breakdown will occur. The resulting decrease in voltage across the device normally will result in an increase of current through the transistor because of the action of the other circuit elements. One small area now has to sustain even more current than before, so the temperature can go extremely high. Extreme temperatures can rapidly change the characteristics of the device or melt the material. If enough melting occurs in the region of the high current path from collector to emitter, upon cooling a low resistance path or short circuit from collector to emitter will exist.

There is good reason to believe that if it were possible to remove the current within a few microseconds after the onset of second breakdown, no particular harm would come to the transistor. Indeed, under much less than these ideal conditions, it has been possible to observe devices being switched in and out of second breakdown, and in Thornton's and Simmon's original paper, it was proposed that second breakdown might be used as a possible mode of operation for generation of very fast pulses. This application, however, proves to be not practical because it is difficult to control, and most devices will short when held in second breakdown for any appreciable time.

The current at which second breakdown occurs decreases markedly with increases in collector-emitter voltage when operating in the normal active region mode. The curves of Figure 3 illustrate this behavior and are typical for most types of semiconductors.

The reason for collector voltage being an important variable is that as collector voltage is increased the base width is reduced, thereby accentuating current crowding effects because the higher electric field caused by the shorter path reduces the current spreading or fan out. As might be inferred, transistors with narrow base widths (i.e., higher f_t) will encounter second breakdown at lower power levels than lower frequency devices, other conditions being equal.

Note: 1966 August/September and November Issues of IEEE Transaction on Electron Devices contain numerous excellent papers on the subject of second breakdown.

Notice that the curves for various pulse widths are parallel to each other and for shorter pulse widths, greater power is required to trigger secondary breakdown. This behavior is understandable because it naturally takes some time to develop a hot spot temperature; the difference between the curves of various pulse widths are evidence of the effect of the thermal response of the hot spot.

Far less work has been done in the avalanche mode regarding safe area, that is, under biasing conditions such that the collector emitter voltage exceeds the V_{CEO} rating of the device. However, it is reported that in this mode considerably less power is required to destroy the device than in the normal operating mode. The usual explanation is that under reverse base current the IR drops in the base are such that severe current concentration occurs near the center of the emitter. The current is thus restricted to a much smaller area than would be the case when operating in the normal active region where current tends to concentrate near the emitter periphery. It has also been observed that avalanche operation produces a wide variation in second breakdown capability among devices of the same type.

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2. Takashi Agatsuma, "Turnover Phenomena in N ν N Si Devices and Second Breakdown in Transistors" IEEE Transactions on Electron Devices, vol ED-13, pp 748-753 November 1966.
3. F. Bergmann and D. Gerstner, "Some New Aspects of Thermal Instability of Current Distribution in Power Transistors," IEEE Transactions on Electron Devices, vol. ED-13, pp. 630-634, August/September 1966.

APPENDIX 1 – TESTING

Testing at Motorola is done by destroying a number of units under conditions of various voltages, currents, and pulse widths. Generally, five transistors are destroyed at each test point. For example, in a one millisecond test for a 60-volt transistor, voltages such as 10, 30, and 60 volts would be selected and five transistors would be destroyed at each point. The average failure points would be connected by a curve. (Normally the average failure points will be on a straight line on log-log paper.) Then the line is derated so that it is lower than the lowest point observed by some safety factor.

Since second breakdown is a temperature phenomena, it is expected and observed that, as junction temperature or case temperature is increased, second breakdown would occur at lower levels. To provide worst case design data, the case temperature is chosen for second breakdown testing such that the average junction temperature at the point of failure will be approximately that of the junction temperature rating of the device. At high voltages near the BV_{CEO} limit, it is found that junction temperatures to within 20 or 30°C of $T_{J(max)}$ are required. However, at the lower voltage points of the curve, cooling of the case is necessary because of the high power levels required to cause destruction. That is, for almost all transistors, a power dissipation curve based on a 25°C case temperature and the second breakdown curve based on dc conditions will cross at some point in the voltage-current plot. (See Figure 3.) It becomes very difficult when testing at low voltages to prevent T_J from exceeding $T_{J(max)}$. Under pulsed conditions, second breakdown generally limits power even at low case temperatures (25°C and below) regardless of voltage. By using thermal response data, the case temperature can be computed which will place the junction temperature at $T_{J(max)}$ for safe area testing. In practice, second breakdown is not very sensitive to case temperature; a ∆T of 100°C degrades safe area by about 20% for most transistors.

To provide maximum thermal and current stability when testing, a common-base test circuit is used. The complete circuit is shown in Figure 1. All tests are pulse tests; a one second pulse is usually sufficiently long to be considered equivalent to dc.

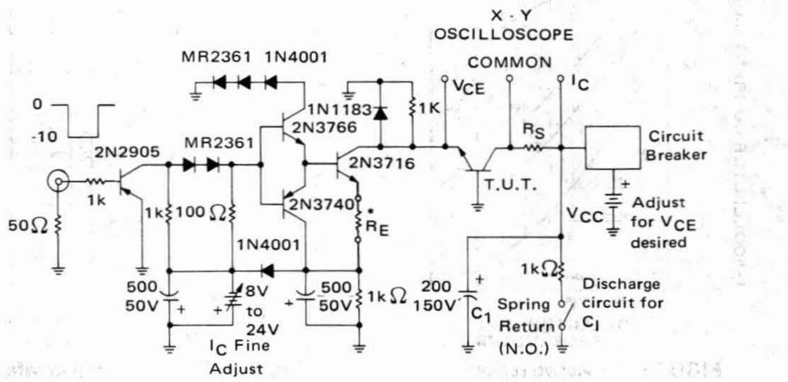
The transistor voltage-current product is monitored on an X-Y oscilloscope. A resistor (R_S on the schematic) made from Canthol type A-1 flat ribbon is used to sense current. A 0.1-ohm sensing resistor is used for collector currents below five amperes, and a 0.01-ohm sensing resistor is used at higher collector currents.

To keep the voltage drop in the interconnecting wiring to a negligible value, number 10 wire is used for circuit connections, and number 4 stranded cable is employed for connecting to the voltage source.

The 500 µF capacitor bypasses voltage transients resulting from the rapid change of current through the inductance of the connecting leads. The fuse or circuit breaker is necessary to prevent burning out the sensing resistor or other components when the transistor shorts.

Non-destructive testing should be feasible by employing circuitry to quickly remove the current when second breakdown occurs, but so far no generally successful schemes have been published.

NPN SAFE OPERATING AREA PULSE CIRCUIT


X - Y
OSCILLOSCOPE
COMMON
VCE
IC
MR2361 1N4001
0
-10
2N2905
MR2361
1N1183
2N3766
1K
RS
2N3716
Circuit Breaker
T.U.T.
2N3740
RE
VCC
Adjust for VCE desired
1k
1k
100 Ω
50Ω
1N4001
1kΩ
Discharge circuit for CI
500 50V
8V to 24V
IC Fine Adjust
500 50V
1kΩ
200 150V
C1
Spring Return (N.O.)

NOTES:

1. TRANSISTORS USED DEPEND UPON DEVICE BEING TESTED; ONES SHOWN WILL TEST TO 5 Adc
2. FOR PNP TEST CIRCUIT, CHANGE POLARITY OF ALL TRANSISTORS' AND REVERSE ALL DIODES, CAPACITORS, AND POWER SUPPLIES.
3. CAPACITOR VALUES IN µF.

* SELECTED TO GIVE APPROXIMATE I_C DESIRED.

(APPENDIX 1) FIGURE 1 - Typical circuit used to establish DC safe operating areas

APPENDIX 2 – SAFE AREA CURVES

Safe operating areas for several low level silicon transistors can be obtained by referring to the figure indicated opposite the 2N type number given in Figure 1.

FIGURE 1

Type	Figure	Type	Figure	Type	Figure
2N2192	2	2N3467	7	2N3506	4
2N2193	2	2N3468	7	2N3507	4
2N2194	2	2N3494	8	2N3634	10
2N2195	2	2N3495	8	2N3635	10
2N3244	7	2N3498	6	2N3636	10
2N3245	7	2N3499	6	2N3637	10
2N3252	3	2N3500	6	2N3742	5
2N3253	3	2N3501	6	2N3743	9
2N3444	3				

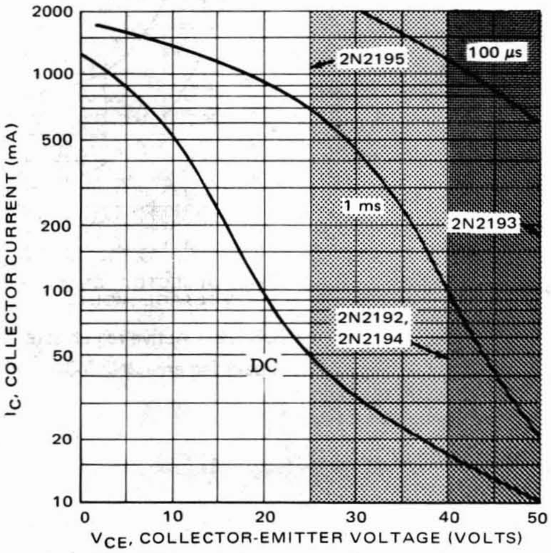


FIGURE 2 - Active region safe operating areas 2N2192, 2N2193, 2N2194, 2N2195

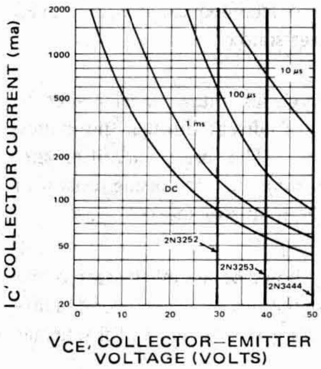


FIGURE 3 – Active region safe operating areas 2N3252, 2N3253, 2N3444

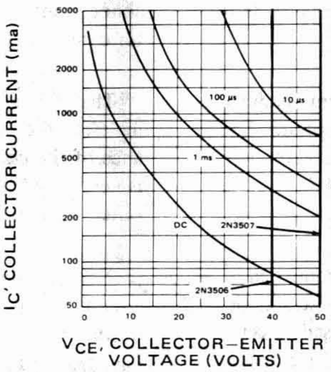


FIGURE 4 – Active region safe operating areas 2N3506, 2N3507

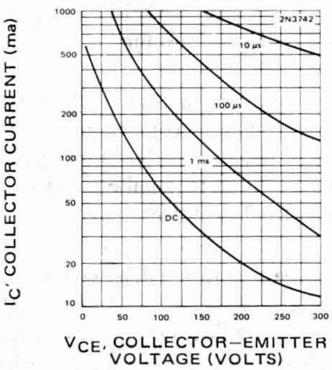


FIGURE 5 – Active region safe operating area 2N3742

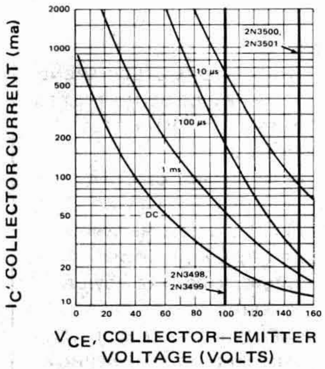


FIGURE 6 – Active region safe operating areas 2N3498, 2N3499, 2N3500, 2N3501

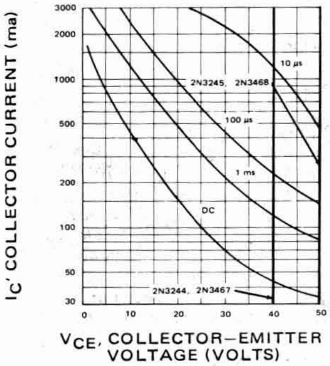


FIGURE 7 – Active region safe operating areas 2N3467, 2N3468, 2N3244, 2N3245

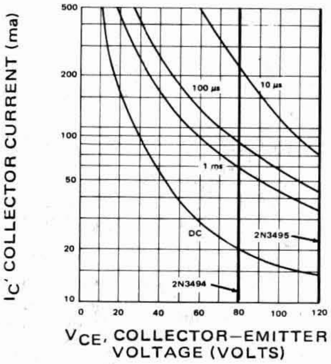


FIGURE 8 – Active region safe operating areas 2N3494, 2N3495

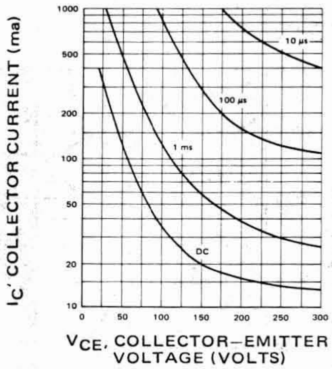


FIGURE 9 - Active region safe operating area 2N3743

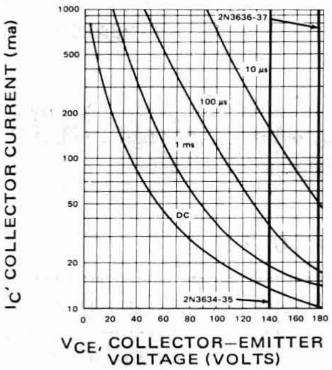


FIGURE 10 – Active region safe operating areas 2N3634, 2N3635 2N3636, 2N3637

$$T_J = r(t,D)\,\theta_{JC}\,P_D + T_C$$

$D = t/\tau_p = 5/20 = 0.25$. A curve for $D = 0.25$ is not on the graph; however, values for this duty cycle can be interpolated between the $D = 0.2$ and $D = 0.3$ curves. At 5 ms, read $r(t,D) = 0.45$.

$$T_J = 0.45 \times 35 \times 5 + 75 = 79 + 75 = 154^\circ C$$

The average junction temperature increase above ambient is:

$$\begin{aligned} T_{J(average)} - T_C &= \theta_{JC}\,P_D\,D \\ &= (35)\,(5)\,(0.25) \qquad (3) \\ &= 43.75^\circ C \end{aligned}$$

Note that T_J at the end of any power pulse does not equal the sum of the average temperature rise (43.75°C in the example) and that due to one pulse (57.8°C in example), because cooling occurs between the power pulses.

If the temperatures calculated are lower than $T_{J(max)}$, the device should operate satisfactorily providing the load line of operation is within the safe area. Safe area should always be checked. As a rule of thumb for pulses of power shorter than 1 ms, second breakdown limits power at low reference temperatures while thermal resistance limits power at high temperatures.

While junction temperature can be easily calculated for a steady pulse train where all pulses are of the same amplitude and pulse duration as shown in the previous example, a simple equation for arbitrary pulse trains with random variations is impossible to derive. However, since the heating and cooling response of a semiconductor is essentially the same, the superposition principle may be used to solve problems which otherwise defy solution.

Using the principle of superposition each power interval is considered positive in value, and each cooling interval negative, lasting from time of application to infinity. By multiplying the thermal resistance at a particular time by the magnitude of the power pulse applied, the magnitude of the junction temperature change at a particular time can be obtained. The net junction temperature is the algebraic sum of the terms.

The application of the superposition principle is most easily seen by studying Figure 3.

Figure 3a illustrates the applied power pulses. Figure 3b shows these pulses transformed into pulses lasting from time of application and extending to infinity; at t_o, P_1 starts and extends to infinity; at t_1, a pulse $(-P_1)$ is considered to be present and thereby cancels P_1 from time t_1, and so forth with the other pulses. The junction temperature changes due to these imagined positive and negative pulses are shown in Figure 3c. The actual junction temperature is the algebraic sum as shown in Figure 3d.

Problems may be solved by applying the superposition principle exactly as described; the technique is referred to as Method 1, the pulse-by-pulse method. It yields satisfactory results when the total time of interest is much less than the time required to achieve steady state conditions, and must be used when an uncertainty exists in a random pulse train as to which pulse will cause the highest temperature. Examples using this method are given in Appendix 1 under Method 1.

For uniform trains of repetitive pulses, better answers and less work is required by averaging the power pulses to achieve an average power pulse and then calculating the temperature at the end of the n or n+1 pulse. The essence of this method is shown in Figure 6. The duty cycle family of curves shown on Figure 2 and used to solve the example problem is based on this method; however, the curves may only be used for a uniform train after steady state conditions are achieved. Method 2 in Appendix 1 shows equations for calculating the temperature at the end of the n_{th} or n+1 pulse in a uniform train. Where a duty cycle family of curves is available, of course, there is no need to use this method.

Temperature rise at the end of a pulse in a uniform train before steady state conditions are achieved is handled by Method 3 (a or b) in the Appendix. The method is basically the same as for Method 2, except the average power is modified by the transient thermal resistance factor at the time when the average power pulse ends.

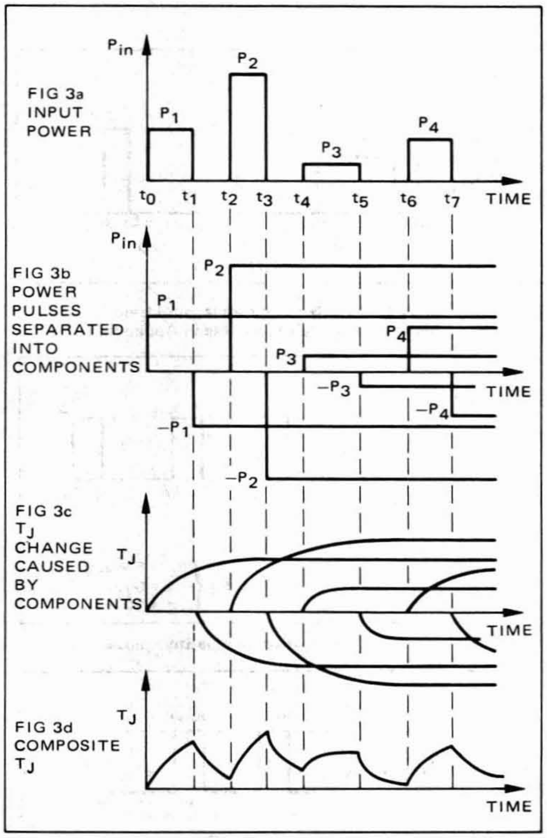


FIGURE 3 – Application of superposition principle

A random pulse train is handled by averaging the pulses applied prior to situations suspected of causing high peak temperatures and then calculating junction temperature at the end of the n_{th} or n+1 pulse. Part c of Method 3 shows an example of solving for temperature at the end of the 3rd pulse in a three pulse burst.

HANDLING NON-RECTANGULAR PULSES

The thermal response curves, Figure 1, are based on a step change of power; the response will not be the same for other waveforms. Thus far in this treatment we have assumed a rectangular shaped pulse. It would be desirable to be able to obtain the response for any arbitrary waveform, but the mathematical solution is extremely unwieldy. The simplest approach is to make a suitable equivalent rectangular model of the actual power pulse and use the given thermal response curves; the primary rule to observe is that the energy of the actual power pulse and the model are equal.

For a power pulse that is nearly rectangular, a pulse model having an amplitude equal to the peak of the actual pulse, with the width adjusted so the energies are equal, can be proven to be a conservative model (see Figure 7a). For a triangular or sine-wave power pulse, as shown in Figure 7b, a model with an amplitude equal to 70% of the peak and a width of 70% of the actual width has been found to yield results close to the actual case. Power pulses having more complex waveforms could be modeled by using two or more pulses as shown in Figure 7c.

As an example, the case of a transistor used in a dc to ac power converter will be analyzed. The idealized waveforms of collector current, I_C, collector to emitter voltage, V_{CE}, and power dissipation, P_D, are shown in Figure 8.

A model of the power dissipation is shown in Figure 8d. This switching transient of the model is made, as was suggested, for a triangular pulse.

For example, T_J at the end of the rise, on, and fall times, T_1, T_2 and T_3 respectively, will be found.

Conditions:

Device = 2N3716

$\theta_{JC} = 1.2^{\circ}C/W$, $I_C = 10$ A, $V_{CE} = 80$ V

$t_f = t_r = 1\ \mu s$, $t_{off} = t_{on} = 4\ \mu s$, $\therefore \tau = 10\ \mu s$

$P_{on} = 20$ W, $P_{fp} = P_{rp} = 200$ W

(Curve 2, Figure 1 applies to the 2N3716)

Procedure: Average each pulse over the period using equation 1-3 (Appendix 1), i.e.,

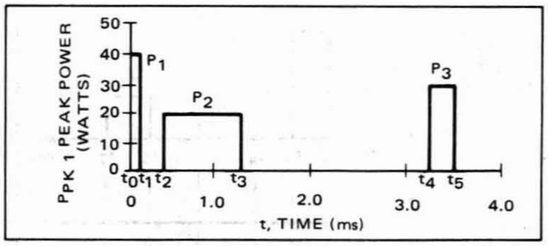


FIGURE 4 — Non-repetitive pulse train (Values shown apply to example in Appendix I)

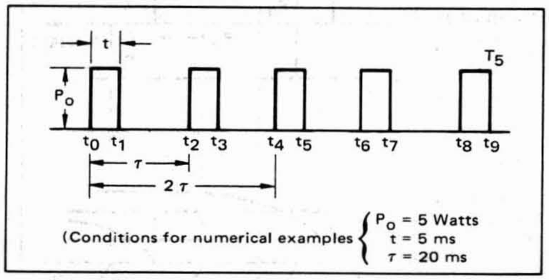


FIGURE 5 — A train of equal repetitive pulses

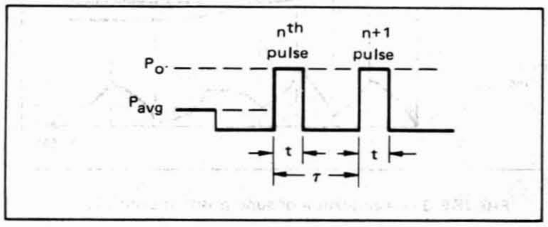


FIGURE 6 — Model for a repetitive equal pulse train

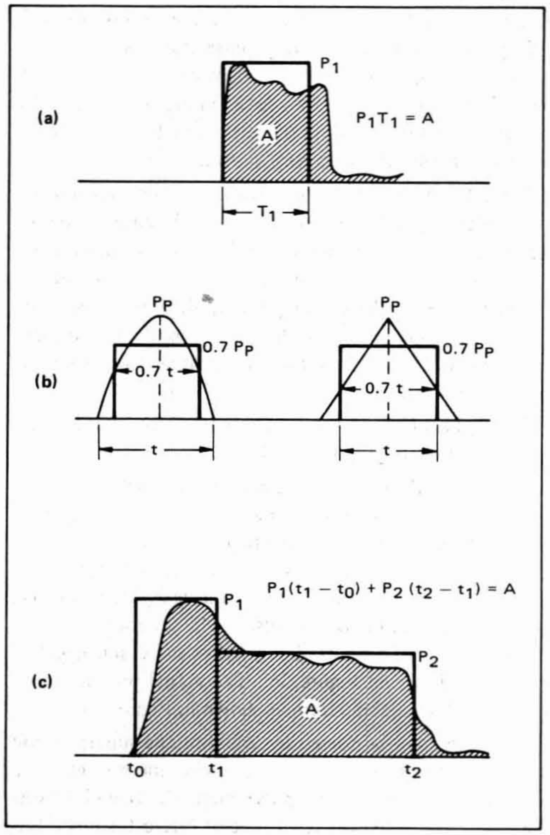


FIGURE 7 — Modeling of power pulses

THERMAL RESPONSE OF SEMICONDUCTORS

INTRODUCTION

For a certain amount of dc power dissipated in a semiconductor, the junction temperature reaches a value which is determined by the thermal conductivity from the junction (where the power is dissipated) to the air or heat sink. When the amount of heat generated in the junction equals the heat conducted away, a steady-state condition is reached and the junction temperature can be calculated by the simple equation:

$$T_J = P_D \theta_{JR} + T_R \tag{1a}$$

where T_J = junction temperature
T_R = temperature at reference point
P_D = power dissipated in the junction
θ_{JR} = steady-state thermal resistance from junction to a temperature reference.

Power ratings of semiconductors are based upon steady-state conditions, and are determined from equation (1a) under worst case conditions, i.e.:

$$P_{D(max)} = \frac{T_{J(max)} - T_R}{\theta_{JR(max)}} \tag{1b}$$

$T_{J(max)}$ is normally based upon results of an operating life test or serious degradation with temperature of an important device characteristic. T_R is usually taken as 25°C, and θ_{JR} can be measured using various techniques. The reference point may be the semiconductor case, a lead, or the ambient air, whichever is most appropriate. Should the reference temperature in a given application exceed the reference temperature of the specification, P_D must be correspondingly reduced.

Equation (1b) does not exclusively define the maximum power that a transistor may handle. At high power levels, particularly at high voltages, secondary breakdown* may occur at power levels less than that given by equation (1b). Secondary breakdown can be prevented by operating within the Safe Area given on a manufacturer's data sheet. Needless to say, abiding by the Safe Area is most important in avoiding a catastrophic failure.

DC Safe Area and thermal resistance allow the designer to determine power dissipation under steady state conditions. Steady state conditions between junction and case are generally achieved in one to ten seconds while minutes may be required for junction to ambient temperature to become stable. However, for pulses in the microsecond and millisecond region, the use of steady-state values will not yield true power capability because the thermal capacity of the system has not been taken into account.

To account for thermal capacity, a time dependent factor r(t) is applied to the steady-state thermal resistance. Thermal resistance, at a given time, is called transient thermal resistance and is given by:

$$\theta_{JR}(t) = r(t) \cdot \theta_{JR} \tag{2}$$

The mathematical expression for the transient thermal resistance has been determined to be extremely complex. The response is, therefore, plotted from empirical data. Curves, typical of the results obtained, are shown in Figure 1. These curves show the relative thermal response of the junction, referenced to the case, resulting from a step function change in power. Observe that during the fast part of the response, the slope is 1/2; (i.e., $T_J \propto \sqrt{t}$) a fact found true of all devices measured. The curves shown are for a variety of transistor types ranging from rather small devices in TO-5 glass header package (curve 6) to a large 10 ampere transistor in a TO-3 package (curve 2). Observe that the total percentage difference is less than 4:1 in the short pulse ($\sqrt{t}$) region. The values of thermal resistance vary over 50:1, however. Therefore, the curves could be applied with judgement to any semiconductor type. The package is the most important single variable which affects thermal response.

Recent Motorola data sheets have a graph similar to that of Figure 2. It shows not only the thermal response to a step change in power (the D = O curve), but also has other curves which may be used to obtain an effective r(t) value for a train of repetitive pulses with different duty cycles. The mechanics of using the curves to find T_J at the end of the first pulse in the train, or to find $T_{J(pk)}$ once steady state conditions have been achieved, are quite simple and require no background in the subject. However, problems where the applied power pulses are either not identical in amplitude or width, or the duty cycle is not constant, require a more thorough understanding of the principles illustrated in the body of this report.

USE OF TRANSIENT THERMAL RESISTANCE DATA

Part of the problem stems from the fact that power pulses are seldom rectangular, therefore to use the r(t) curves, an equivalent rectangular model of the actual power pulse must be determined. Methods of doing this are described near the end of this note.

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*Secondary breakdown is a result of current concentrating to a small area which causes the transistor to lose its ability to sustain a collector-emitter voltage. The voltage drops to a low value generally causing the circuit to deliver a very high current to the transistor resulting in a collector to emitter short. See AN-415.

Circuit diagrams external to Motorola products are included as a means of illustrating typical semiconductor applications; consequently, complete information sufficient for construction purposes is not necessarily given. The information in this Application Note has been carefully checked and is believed to be entirely reliable. However, no responsibility is assumed for inaccuracies. Furthermore, such information does not convey to the purchaser of the semiconductor devices described any license under the patent rights of Motorola Inc. or others.

Before considering the subject matter in detail, an example will be given to show the use of the thermal response data sheet curves. Figure 2 is a representative graph which applies to a 2N3467 transistor.

Pulse power $P_D = 5$ Watts
Duration $t = 5$ milliseconds
Period $\tau_p = 20$ milliseconds
Case temperature, $T_C = 75^{o}C$
Junction to case thermal resistance,
$\theta_{JC} = 35^{o}C/W$

The temperature is desired, a) at the end of the first pulse b) at the end of a pulse under steady state conditions.

For part a use:

$$T_J = r(5\ ms)\,\theta_{JC}\,P_D + T_C$$

The term r(5 ms) is read directly from the graph of Figure 2 using the D = O curve,

$$\therefore T_J = 0.33 x 35 x 5 + 75 = 57.8^{o}\ C + 75 = 132.8^{o}C$$

The peak junction temperature rise under steady conditions is found by:

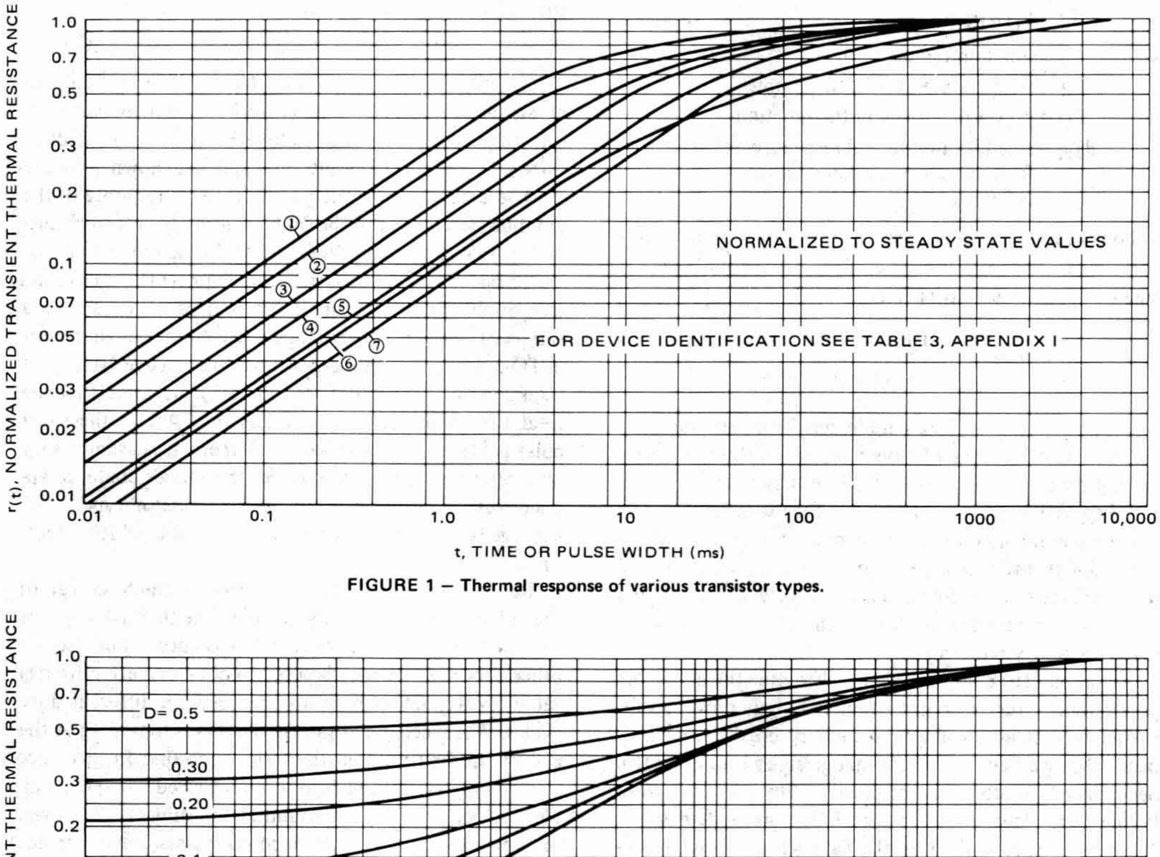

FIGURE 1 — Thermal response of various transistor types.

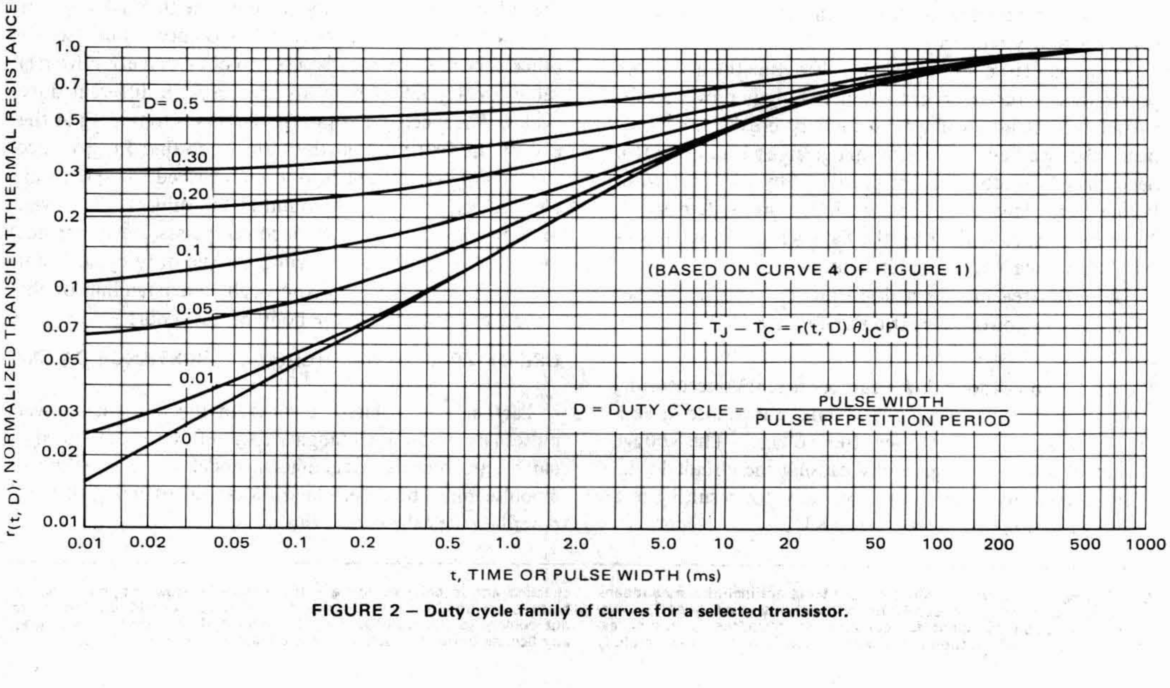

FIGURE 2 — Duty cycle family of curves for a selected transistor.

$$P_{avg} = 0.7\,P_{rp}\,\frac{t_r}{\tau} + 0.7\,P_{fp}\,\frac{t_r}{\tau} + P_{on}\,\frac{t_{on}}{\tau}$$

$$= 140\,\frac{0.7}{10} + 140\,\frac{0.7}{10} + 20\,\frac{4}{10} = 27.6\ \mathrm{W}$$

From equation 1-4, Appendix 1,

$$T_1 = [P_{avg} + (0.7\,P_{rp} - P_{avg}) \cdot r(t_1 - t_0)]\theta_{JC}$$

$r(t_1 - t_0)$ is found from Curve 2, Figure 1

At this point it is observed that the thermal response curves of Figure 1 do not extend to a shorter time than 10 μs because of measurement difficulty. However, indications are that the response curve follows the $\sqrt{t}$ law in this region.

The value for $r(t_1 - t_0)$ or $r(0.7\ \mu s)$ is 0.0085.

We then have:

$$T_1 = [27.6 + (140 - 27.6)\ 0.0085]\ 1.2$$
$$T_1 = [27.6 + 0.955]\ 1.2 = 34.3^{o}C$$

For T_2 we have by using superposition:

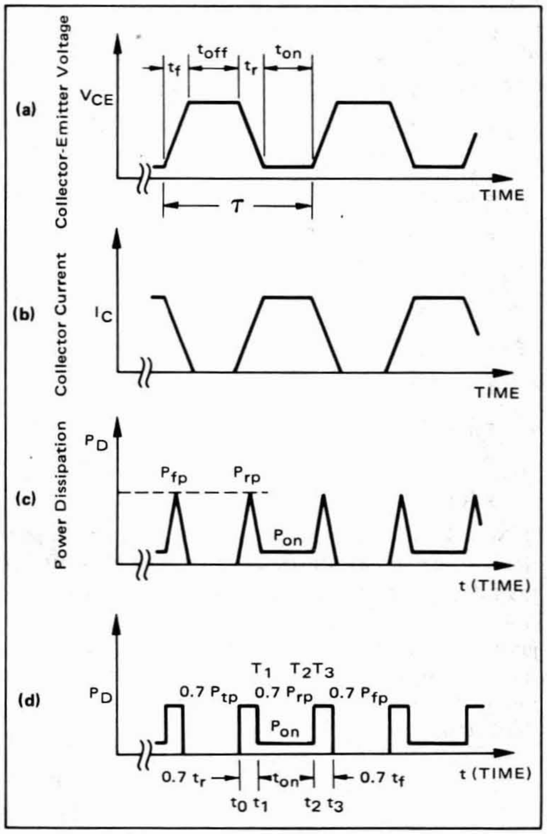

FIGURE 8 – Idealized waveforms of I_C, V_{CE} and P_D in a dc to ac inverter

$$T_2 = [P_{avg} - P_{avg}\,r(t_2 - t_0) + 0.7\,P_{rp}\,r(t_2 + t_0)$$
$$-0.7\,P_{rp}\,r(t_2 - t_1) + P_{on}\,r(t_2 - t_1)]\,\theta_{JC}$$
$$= [P_{avg} + 0.7\,P_{rp} = P_{avg}\quad r(t_2 - t_0)$$
$$+ P_{on}\,r(t_2 - t_1) - 0.7\,P_{rp}\,r(t_2 - t_1)]\theta_{JC}$$
$$= [27.6 + (140 - 27.6)\ 0.18 + 20 \cdot 0.017$$
$$- 140 \cdot 0.017]\ 1.2$$
$$= [27.6 + 2.03 + 0.24 - 2.38]\ 1.2 = 33^{o}C$$

For the final point T_3 we have

$$T_3 = [P_{avg} - P_{avg}\,r(t_3 - t_0) + 0.7\,P_{rp}\,r(t_3 - t_0)$$
$$- 0.7\,P_{rp}\,r(t_3 - t_1) + P_{on}\,r(t_3 - t_1)$$
$$- P_{on}\,r(t_3 - t_2) + 0.7\,P_{rf}\,r(t_3 - t_2)]\,\theta_{JC}$$
$$= [27.6 - 27.6 \cdot 0.0195 + 140 \cdot 0.0195$$
$$- 140 \cdot 0.0180 + 20 \cdot 0.0180 - 20 \cdot 0.0085$$
$$+ 140 \cdot 0.0085]\ 1.2$$

$$T_3 = [27.6 - 0.538 + 2.73 - 2.52 + 0.36 - 0.170$$
$$+ 1.19]\ 1.2 = 28.65 \cdot 1.2 = 34.4^{o}C$$

Inspection of the results of the calculations T_1, T_2, and T_3 reveals that the term of significance is the average power. One might conclude that when a combination of high duty cycle and short pulse widths are present, the product of average power and the steady state thermal resistance is the determining factor for junction temperature rise.

At low duty cycles, the switching losses may produce high peak temperature while the average temperature could be quite low. Slow-speed transistors should be checked for this condition.

SUMMARY

This report has explained the concept of transient thermal resistance and its use. Methods using various degrees of approximations have been presented to determine the junction temperature rise of a device. Since the thermal response data shown is a step function response, modeling of different wave shapes to an equivalent rectangular pulse of pulses has been discussed.

The concept of a duty cycle family of curves has also been covered; a concept that can be used to simplify calculation of the junction temperature rise under a repetitive pulse train.

Safe area ratings must also be observed. It is possible to have T_J well below $T_{J(max)}$ as calculated from the thermal response curves, yet have a hot-spot in the semiconductor which is hot enough to trigger second breakdown.

APPENDIX 1 METHODS OF SOLUTION

In the examples, a type 2N3467 transistor will be used; its steady state thermal resistance, θ_{JC}, is 35°C/W and its value for r(t) is shown by curve 4 in Figure 1.

Definitions:

$P_1, P_2, P_3 \ldots P_n$ = power pulses (Watts)

$T_1, T_2, T_3 \ldots T_n$ = junction to case temperature at end of $P_1, P_2, P_3 \ldots P_n$

$t_0, t_1, t_2, \ldots t_n$ = times at which a power pulse begins or ends

$r(t_n - t_k)$ = transient thermal resistance factor at end of time interval $(t_n - t_k)$.

TABLE 1 – SEVERAL POSSIBLE METHODS OF SOLUTIONS

1. Junction Temperature Rise Using Pulse-By-Pulse Method
    - A. Temperature rise at the end of the n_{th} pulse for pulses with unequal amplitude, spacing, and duration.
    - B. Temperature rise at the end of the n_{th} pulse for pulses with equal amplitude, spacing, and duration.
2. Temperature Rise Using Average Power Concept Under Steady State Conditions For Pulses Of Equal Amplitude, Spacing, And Duration
    - A. At the end of the n_{th} pulse.
    - B. At the end of the (n+1) pulse.
3. Temperature Rise Using Average Power Concept Under Transient Conditions
    - A. At the end of the n_{th} pulse for pulses of equal amplitude, spacing and duration.
    - B. At the end of the n+1 pulse for pulses of equal amplitude, spacing and duration.
    - C. At the end of the n_{th} pulse for pulses of unequal amplitude, spacing and duration.
    - D. At the end of the n+1 pulse for pulses of unequal amplitude, spacing and duration.

METHOD 1A – FINDING T_J AT THE END OF THE Nth PULSE IN A TRAIN OF UNEQUAL AMPLITUDE, SPACING, AND DURATION

General Equation:

$$T_n = \sum_{i=1}^{n} P_i \left[r(t_{2n-1} - t_{2i-2}) - r(t_{2n-1} - t_{2i-1}) \right] \theta_{JC} \quad (1\text{-}1)$$

where n is the number of pulses and P_i is the peak value of the ith pulse.

To find temperature at the end of the first three pulses, Equation 1-1 becomes:

$$T_1 = P_1\, r(t_1)\, \theta_{JC} \quad (1\text{-}1A)$$

$$T_2 = [P_1\, r(t_3) - P_1\, r(t_3 - t_1) + P_2\, r(t_3 - t_2)]\, \theta_{JC} \quad (1\text{-}1B)$$

$$T_3 = [P_1\, r(t_5) - P_1\, r(t_5 - t_1) + P_2\, r(t_5 - t_2) - P_2\, r(t_5 - t_3) + P_3\, r(t_5 - t_4)]\, \theta_{JC} \quad (1\text{-}1C)$$

Example:

Conditions are shown on Figure 4 as:

P_1 = 40 W	$t_0 = 0$	t_3 = 1.3 ms
P_2 = 20 W	t_1 = 0.1 ms	t_4 = 3.3 ms
P_3 = 30 W	t_2 = 0.3 ms	t_5 = 3.5 ms

Therefore,

$t_1 - t_0$ = 0.1 ms

$t_2 - t_1$ = 0.2 ms

$t_3 - t_2$ = 1 ms

$t_4 - t_3$ = 2 ms

$t_5 - t_4$ = 0.2 ms

$t_3 - t_1$ = 1.2 ms

$t_5 - t_1$ = 3.4 ms

$t_5 - t_2$ = 3.2 ms

$t_5 - t_3$ = 2.2 ms

Procedure:

Find $r(t_n - t_k)$ for preceeding time intervals from Figure 2, then substitute into Equations 1-1A, B, and C.

$$T_1 = P_1\, r(t_1)\, \theta_{JC} = 40 \cdot 0.05 \cdot 35 = 70^{\circ}C$$

$$\begin{aligned} T_2 &= [P_1\, r(t_3) - P_1\, r(t_3 - t_1) + P_2\, r(t_3 - t_2)]\, \theta_{JC} \\ &= [40\,(0.175) - 40\,(0.170) + 20\,(0.155)]\ 35 \\ &= [40\,(0.175 - 0.170) + 20\,(0.155)]\ 35 \\ &= [0.2 + 3.1]\ 35 = 115.5^{\circ}C \end{aligned}$$

$$T_3 = [P_1\, r(t_5) - P_1\, r(t_5 - t_1) + P_2\, r(t_5 - t_2) - P_2\, r(t_5 - t_3) + P_3\, r(t_5 - t_4)]\, \theta_{JC}$$

$$\begin{aligned} T_3 &= [40\,(0.28) - 40\,(0.277) + 20\,(0.275) - 20\,(0.227) + 30\,(0.07)]\ 35 \\ &= [40\,(0.28 - 0.277) + 20\,(0.275 - 0.227) + 30\,(0.07)]\ 35 \\ &= [0.12 + 0.96 + 2.1]^{\dagger}\ 35 = 3.18 \cdot 35 = 111.3^{\circ}C \end{aligned}$$

Note, by inspecting the last bracketed term in the equations above that very little residual temperature is left from the first pulse at the end of the second and third pulse. Also note that the second pulse gave the highest value of junction temperature, a fact not so obvious from inspection of the figure. However, considerable residual temperature from the second pulse was present at the end of the third pulse.

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† Relative amounts of temperature residual from P_1, P_2, and P_3 respectively are indicated by the terms in brackets.

METHOD 1B – FINDING T_J AT THE END OF THE Nth PULSE IN A TRAIN OF EQUAL AMPLITUDE, SPACING, AND DURATION

The general equation for a train of equal repetitive pulses can be derived from Equation 1-1. $P_i = P_D$, $t_i = t$, and the spacing between leading edges or trailing edges of adjacent pulses is τ.

General Equation:

$$T_n = P_D\,\theta_{JC} \sum_{i=1}^{n} r\,[(n-i)\,\tau + t] - r\,[(n-i)\,\tau] \qquad (1\text{-}2)$$

Expanding:

$$\begin{aligned} T_n = P_D\,\theta_{JC}\ & r\,[(n-1)\,\tau + t] - r\,[(n-1)\,\tau] \\ & + r\,[(n-2)\,\tau + t] - r\,[(n-2)\,\tau] + r\,[(n-3)\,\tau + t] \\ & - r\,[(n-3)\,\tau] + \ldots + r\,[(n-i)\,\tau + t] \\ & - r\,[(n-i)\,\tau]\ \ldots\ldots + r(t)] \end{aligned} \qquad (1\text{-}2A)$$

For 5 pulses, equation 1-2A is written:

$$\begin{aligned} T_5 = P_D\,\theta_{JC}\ & [r(4\,\tau + t) - r(4\tau) + r(3\tau + t)] \\ & - r(3\tau) + r(2\tau + t) - r(2\tau) + r(\tau + t) \\ & - r(\tau) + r(t)] \end{aligned}$$

Example:

Conditions are shown on Figure 5 substituting values into the preceeding expression:

$$\begin{aligned} T_5 = (5)\,(35)\ & [r\,(4{\cdot}20 + 5) - r(4{\cdot}20) + r(3.20 + 5) \\ & + r(3{\cdot}20) + r(2.20 + 5) - r(2{\cdot}20) + r(20 + 5) \\ & - r(20) + r(5)] \end{aligned}$$

$$\begin{aligned} T_5 = (5)(35)\ & [0{\cdot}6 - 0.76 + 0.73 - 0.72 + 0.68 \\ & - 0.66 + 0.59 - 0.55 + 0.33] = (5)(35)(0.40) \end{aligned}$$

$$T_5 = 70.0^{\circ}\mathrm{C}$$

Note that the solution involves the difference between terms nearly identical in value. Greater accuracy will be obtained with long or repetitive pulse trains using the technique of an average power pulse as used in Methods 2 and 3.

METHOD 2 – AVERAGE POWER METHOD, STEADY STATE CONDITION

The essence of this method is shown in Figure 6. Pulses previous to the n_{th} pulse are averaged. Temperature due to the n_{th} or n+1 pulse is then calculated and combined properly with the average temperature.

Assuming the pulse train has been applied for a period of time (long enough for steady state conditions to be established), we can average the power applied as:

$$P_{avg} = P_D\,\frac{t}{\tau} \qquad (1\text{-}3)$$

METHOD 2A – FINDING TEMPERATURE AT THE END OF THE N_{th} PULSE

Applicable Equation:

$$T_n = [\,P_{avg} + (P_D - P_{avg})\ r(t)]\ \theta_{JC} \qquad (1\text{-}4)$$

or, by substituting Equation 1-3 into 1-4,

$$T_n = \left[\frac{t}{\tau} + \left(1 - \frac{t}{\tau}\right) r(t)\right] P_D\ \theta_{JC} \qquad (1\text{-}5)$$

The result of this equation will be conservative as it adds a temperature increase due to the pulse $(P_D - P_{avg})$ to the average temperature. The cooling between pulses has not been accurately accounted for; i.e., T_J must actually be less than $T_{J(avg)}$ when the nth pulse is applied.

Example: Find T_n for conditions of Figure 5.

Procedure: Find P_{avg} from equation (1-3) and substitute values in equation (1-4) or (1-5).

$$\begin{aligned} T_n &= [(1.25) + (5.0 - 1.25)\,(0.33)]\ (35) \\ &= 43.7 + 43.2 = 86.9^{\circ}\mathrm{C} \end{aligned}$$

METHOD 2B – FINDING TEMPERATURE AT THE END OF THE N + 1 PULSE

Applicable Equation:

$$\begin{aligned} T_{n+1} = [\,P_{avg} + (P_D - P_{avg})\ r(t + \tau) \\ + P_D\,r(t) - P_D\,r(\tau)]\ \theta_{JC} \end{aligned} \qquad (1\text{-}6)$$

or, by substituting equation 1-3 into 1-6,

$$T_{n+1} = \left[\frac{t}{\tau} + \left(1 - \frac{t}{\tau}\right) r(t + \tau) + r(t) - r(\tau)\right] P_D\,\theta_{JC} \qquad (1\text{-}7)$$

Example: Find T_n for conditions of Figure 5.

Procedure: Find P_{avg} from equation (1-3) and substitute into equation (1-6) or (1-7).

$$\begin{aligned} T_{n+1} = [(1.25) + (5 - 1.25)\,(0.59) + (5)\,(0.33) \\ - (5)\,(0.56)]\ (35) = 80.9^{\circ}\mathrm{C} \end{aligned}$$

continued

METHOD 2B continued

Equation (1-6) gives a lower and more accurate value for temperature than equation (1-4). However, it too gives a higher value than the true T_J at the end of the n+1th pulse. The error occurs because the implied value for T_J at the end of the nth pulse, as was pointed out, is somewhat high. Adding additional pulses will improve the accuracy of the calculation up to the point where terms of nearly equal value are being subtracted, as shown in the examples using the pulse by pulse method. In practice, however, use of this method has been found to yield reasonable design values and is the method used to determine the duty cycle of family of curves – e.g., Figure 2.

Note that the calculated temperature of 80.9°C is 10.9°C higher than the result of example 1B, where the temperature was found at the end of the 5th pulse. Since the thermal response curve indicates thermal equillibrium in 1 second, 50 pulses occurring 20 milliseconds apart will be required to achieve stable average and peak temperatures; therefore, steady state conditions were not achieved at the end of the 5th pulse.

METHOD 3 – AVERAGE POWER METHOD, TRANSIENT CONDITIONS

The idea of using average power can also be used in the transient condition for a train of repetitive pulses. The previously developed equations are used but P_{avg} must be modified by the thermal response factor at time $t_{(2n-1)}$.

METHOD 3A – FINDING TEMPERATURE AT THE END OF THE N_{th} PULSE FOR PULSES OF EQUAL AMPLITUDE, SPACING AND DURATION

Applicable Equation:

$$T_n = \left[\frac{t}{\tau}\, r\, t_{(2n-1)} + \left(1 - \frac{t}{\tau}\right) r(t)\right] P_D\, \theta_{JC} \qquad (1\text{-}8)$$

Conditions: (See Figure 5)

Procedure: At the end of the 5th pulse (See Figure 7 . . .

$$T_5 = [5/20 \cdot r(85) + (1 - 5/20)\, r(5)]\ (5)\ (35)$$

$$= [(0.25)\ (0.765) + (0.75)\ (0.33)]\ (175)$$

$$= 77^{\circ}\mathrm{C}$$

This value is a little higher than the one calculated by summing the results of all pulses; indeed it should be, because no cooling time was allowed between P_{avg} and the nth pulse. The method whereby temperature was calculated at the n+1 pulse could be used for greater accuracy.

METHOD 3B – FINDING TEMPERATURE AT THE END OF THE n+1 PULSE FOR PULSES OF EQUAL AMPLITUDE, SPACING AND DURATION

Applicable Equation:

$$T_{n+1} = \left[\frac{t}{\tau}\, r\,(t_{2n-1}) + \left(1 - \frac{t}{\tau}\right) r(t+\tau) + r(t) - r(\tau)\right] P_D\, \theta_{JC} \qquad (1\text{-}9)$$

Example: Conditions as shown on Figure 5. Find temperature at the end of the 5th pulse.

For n+1 = 5, n = 4, $t_{2n-1} = t_7$ = 65 ms,

$$T_5 = \left[\frac{5}{20}\ r(65\text{ ms}) + \left(1 - \frac{5}{20}\right) r(25\text{ ms}) + r(5\text{ ms}) - r(20\text{ ms})\right] (5)\ (35)$$

$$T_5 = [(0.25)(0.73) + (0.75)(0.59) + 0.33 - 0.55](5)(35)$$

$$T_5 = 70.8^{\circ}\mathrm{C}$$

The answer agrees quite well with the answer of Method 1B where the pulse-by-pulse method was used for a repetitive train.

METHOD 3C – FINDING T_J AT THE END OF THE N_{th} PULSE IN A RANDOM TRAIN

The technique of using average power does not limit itself to a train of repetitive pulses. It can be used also where the pulses are of unequal magnitude and duration. Since the method yields a conservative value of junction temperature rise it is a relatively simple way to achieve a first approximation. For random pulses, equations 1-4 through 1-7 can be modified. It is necessary to multiply P_{avg} by the thermal response factor at time $t_{(2n-1)}$. P_{avg} is determined by averaging the power pulses from time of application to the time when the last pulse starts.

Applicable Equations:

General: $$P_{avg} = \sum_{i=1}^{n} P_i\, \frac{t_{(2i-1)} - t_{(2i-2)}}{t_{(2n)} - t_{(2i-2)}} \qquad (1\text{-}10)$$

For 3 Pulses:

$$P_{avg} = P_1\, \frac{t_1 - t_0}{t_4 - t_0} + P_2\, \frac{t_3 - t_2}{t_4 - t_2} \qquad (1\text{-}11)$$

continued

METHOD 3C continued

Example: Conditions are shown on Figure 4 (refer to Method 1A).

Procedure: Find P_{avg} from equation 1-3 and the junction temperature rise from equation 1-4.

Conditions: Figure 4

$$P_{avg} = 40 \cdot \frac{0.1}{3.3} + 20\,\frac{1}{3} = 1.21 + 6.67$$

$$= 7.88 \text{ Watts}$$

$$T_3 = [P_{avg}\, r(t_5) + (P_3 - P_{avg})\, r(t_5 - t_4)]\, \theta_{JC}$$

$$T_3 = [7.88\,(0.28) + (30 - 7.88) \cdot 0.07]\ 35$$

$$= [2.21 + 1.56]\ 35 = 132^{o}C$$

This result is high because in the actual case considerable cooling time occurred between P_2 and P_3 which allowed T_J to become very close to T_C. Better accuracy is obtained when several pulses are present by using equation 1-10 in order to calculate $T_J - t_C$ at the end of the $n^{th} + 1$ pulse. This technique provides a conservative quick answer if it is easy to determine which pulse in the train will cause maximum junction temperature.

METHOD 3D – FINDING TEMPERATURE AT THE END OF THE N+1 PULSE IN A RANDOM TRAIN

The method is similar to 3C and the procedure is identical. P_{avg} is calculated from Equation 1-10 modified by $r(t_{2n-1})$ and substituted into equation 1-6, i.e.,

$$T_{n+1} = [\,P_{avg}\, r(t_{2n-1}) + (P_D - P_{ave})\, r(t_{2n-1} - t_{2n-2}) + P_D\, r(t_{2n+1} - t_{2n}) - P_D\, r(t_{2n+1} - t_{2n-1})]\, \theta_{JC}$$

The previous example can not be worked out for the n+1 pulse because only 3 pulses are present.

TABLE 2 – Summary Of Numerical Solutions For The Repetitive Pulse Train Of Figure 5

Temperature Desired	Temperature Obtained, °C (Method Used)		
	Pulse by Pulse	Average Power, N_{th} Pulse	Average Power, N+1 Pulse
At end of 5th pulse	70.0 (1B)	77 (3A)	70.8 (3B)
Steady state peak	—	86.9 (2A)	80.9 (2B)

Note: Number in parenthesis is method used.

TABLE 3 – Curve Identification, Die Size, And Package (See Figure 1 of Text)

2N Number	Curve Number	Die Size (Mils)	Package
2N1724	3	150 x 150	TO-61
25	3		
2N2192	4	35 x 35	TO-39
93	4		
94	4		
95	4		
2N2217	6	20 x 20	TO-5
18,A	6		
19,A	6		
2N2904,A	6	25 x 25	TO-5
05,A	6		
2N3021	1	60 x 60	TO-3
22	1		
23	1		
24	1		
25	1		
26	1		
2N3055	2	120 x 140	TO-3
2N3232	2		
2N3235	2		
2N3244	4	40 x 40	TO-39
45	4		
2N3252	4	35 x 35	TO-39
53	4		
2N3444	4	35 x 35	TO-39
2N3445	3	150 x 150	TO-3
46	3		
47	3		
48	3		
2N3467	4	40 x 40	TO-39
68	4		
2N3487	3	150 x 150	TO-61
88	3		
89	3		
90	3		
91	3		
92	3		
2N3498	4	35 x 35	TO-39
99	4		
2N3500	4		
3501	4		
2N3506	5	60 x 60	TO-39
07	5		
2N3634	4	40 x 40	TO-39
35	4		
36	4		
37	4		
2N3713	2	120 x 140	TO-3
14	2		
15	2		
16	2		
2N3719	7	60 x 60	TO-39
20	7		
2N3743	5	25 x 25	TO-39
2N3789	2	150 x 150	TO-3
90	2		
91	2		
92	2		
2N4907	2	150 x 150	TO-3
08	2		
09	2		
MJ2255	2	120 x 140	TO-3
56	2		
57	2		
MJ2267	2	150 x 150	TO-3
68	2		
MJ2801	2	120 x 140	TO-3
02	2		
MJ2901	2	150 x 150	TO-3

APPENDIX 2 THERMAL RESPONSE MEASUREMENTS

To measure the thermal response of a transistor, a temperature sensitive parameter of the device is the best indicator of device temperature. Other methods are impractical on a completely assembled device. If the parameter varies linearly with temperature, finding thermal response is greatly simplified since the measured parameter value will be directly proportional to temperature.

The forward voltage drop of the collector-base junction, when operated at low currents, has a linear voltage change with temperature and is a good choice for the temperature sensitive parameter. Since the collector-base junction of a transistor is reversed biased when power is dissipated, a measurement using the forward V_{CB} must be made during the cooling interval. A suitable measurement procedure is to dissipate power long enough to achieve thermal equilibrium while periodically switching the circuit to shut-off the power, forward-bias the collector-base junction, and monitor its change in voltage as the device cools off. The switching must be performed rapidly or the initial part of the response will not be seen.

A circuit suitable for finding the response is shown in Figure 1. With the transistor under test in the circuit, the power-sense switch (SW2) is set in the sense position which removes the emitter current supply and the base return from the transistor. With the collector supply set at a suitable value, the sense supply is adjusted so that a sense current through the base collector junction, just sufficient to bring the forward drop into a fairly linear position of its V-I characteristic, is obtained. The switch is then set to the power position, and the emitter supply is connected. The power can now be applied by opening SW1, which turns on Q1, permitting Q2 and Q3 to turn on, thereby completing the power circuit for the transistor under test.

Power is increased by increasing emitter current until the voltage change of the collector-base junction, when SW1 is thrown to the measure position, is sufficient for accurate readings. Usually about 100 mV is adequate, and several pictures, using different sweep rates, are taken of the response display on an oscilloscope. The thermal response curve is plotted from the photographs.

Power must be supplied to the transistor under test for a sufficient amount of time to insure that the collector-base junction temperature has stabilized. Also, care should be taken that the transistor is mounted on a heat sink in such a way that the case is at a nearly constant temperature. In other words, the thermal resistance from the transistor case to the heat sink should be negligible compared to the junction-to-case thermal resistance. If this precaution is not taken, results will be influenced by the response of the heatsink.

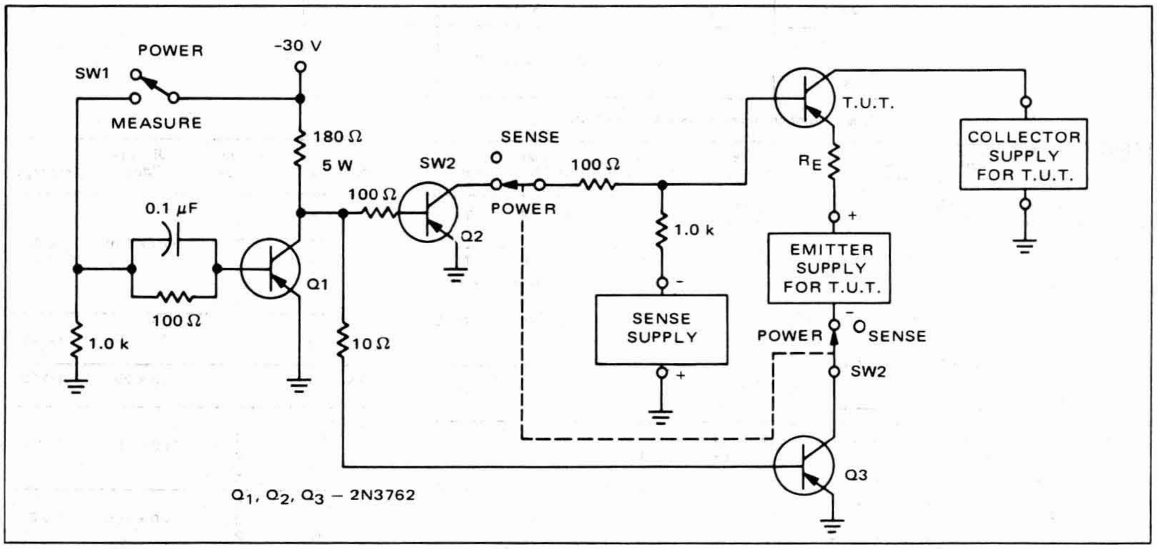

FIGURE 1 – Thermal response test fixture for PNP transistors up to 1 Ampere I_C. A fixture for NPN transistors is built using NPN compliments of the transistors shown and reversing all power supply polarities. The circuit can be scaled up to handle higher currents.

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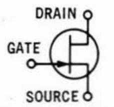
2. Lockett, R. A., Bell, H. A., Priston, R. "Thermal Resistance of Low Power Semiconductor Devices Under Pulse Conditions," Mullard Technical Communications No. 76, July, 1965.

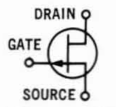
FIELD-EFFECT TRANSISTORS IN THEORY AND PRACTICE

INTRODUCTION

There are two types of field-effect transistors, the Junction Field-Effect Transistor (JFET) and the "Metal-Oxide Semiconductor" Field-Effect Transistor (MOSFET), or Insulated-Gate Field-Effect Transistor (IGFET). The principles on which these devices operate (current controlled by an electric field) are very similar – the primary difference being in the methods by which the control element is made. This difference, however, results in a considerable difference in device characteristics and necessitates variances in circuit design, which are discussed in this note.



N-Channel JFET



P-Channel JFET

JUNCTION FIELD-EFFECT TRANSISTOR (JFET)

In its simplest form the junction field-effect transistor starts with nothing more than a bar of doped silicon that behaves as a resistor (Figure 1a). By convention, the terminal into which current is injected is called the source terminal, since, as far as the FET is concerned, current originates from this terminal. The other terminal is called the drain terminal. Current flow between source and drain is related to the drain-source voltage by the resistance of the intervening material. In Figure 1b, p-type regions have been diffused into the n-type substrate of Figure 1a leaving an n-type channel between the source and drain. (A complementary p-type device is made by reversing all of the material types.) These p-type regions will be used to control the current flow between the source and the drain and are thus called gate regions.

As with any p-n junction, a depletion region surrounds the p-n junctions when the junctions are reverse biased (Figure 1c). As the reverse voltage is increased, the depletion regions spread into the channel until they meet, creating an almost infinite resistance between the source and the drain.

If an external voltage is applied between source and drain (Figure 1d) with zero gate voltage, drain current flow in the channel sets up a reverse bias along the surface of the gate, parallel to the channel. As the drain-source voltage increases, the depletion regions again spread into the channel because of the voltage drop in the channel which reverse biases the junctions. As V_{DS} is increased, the depletion regions grow until they meet, whereby any further increase in voltage is counterbalanced by an increase in the depletion region toward the drain. There is an effective increase in channel resistance that prevents any further increase in drain current. The drain-source voltage that causes this current limiting condition is called the "pinch-off" voltage (V_P). A further increase in drain-source voltage produces only a slight increase in drain current.

The variation in drain current (I_D) with drain-source voltage (V_{DS}) at zero gate-source voltage (V_{GS}) is shown in Figure 2a. In the low-current region, the drain current is linearly related to V_{DS}. As I_D increases, the "channel" begins to deplete and the slope of the I_D curve decreases. When the V_{DS} is equal to V_P, I_D "saturates" and stays relatively constant until drain-to-gate avalanche, $V_{BR(DSS)}$ is reached. If a reverse voltage is applied to the gates, channel pinch-off occurs at a lower I_D level (Figure 2b) because the depletion region spread caused by the reverse-

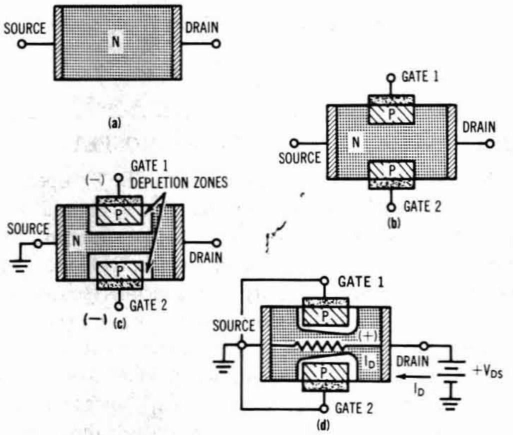


FIGURE 1 – Development of Junction Field-Effect Transistors

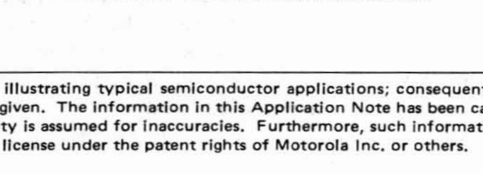


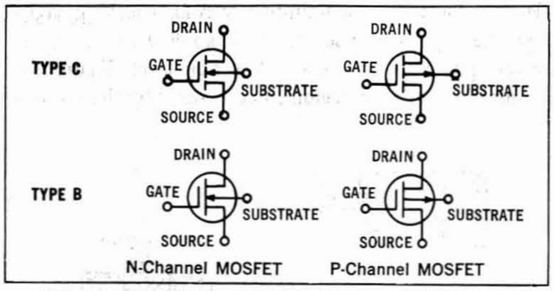
FIGURE 2 – Drain Current Characteristics

Circuit diagrams external to Motorola products are included as a means of illustrating typical semiconductor applications; consequently, complete information sufficient for construction purposes is not necessarily given. The information in this Application Note has been carefully checked and is believed to be entirely reliable. However, no responsibility is assumed for inaccuracies. Furthermore, such information does not convey to the purchaser of the semiconductor devices described any license under the patent rights of Motorola Inc. or others.

biased gates adds to that produced by V_{DS}. Thus reducing the maximum current for any value of V_{DS}.

Due to the difficulty of diffusing impurities into both sides of a semiconductor wafer, a single ended geometry is normally used instead of the two-sided structure discussed above. Diffusion for this geometry (Figure 3) is from one side only. The substrate is of p-type material onto which an n-type channel is grown epitaxially. A p-type gate is then diffused into the n-type epitaxial channel. Contact metalization completes the structure.

The substrate, which functions as Gate 2 of Figure 1, is of relatively low resistivity material to maximize gain. For the same purpose, Gate 1 is of very low resistivity material, allowing the depletion region to spread mostly into the n-type channel. In most cases the gates are internally connected together. A tetrode device can be realized by not making this internal connection.



MOS FIELD-EFFECT TRANSISTORS (MOSFET)

The metal-oxide-semiconductor (MOSFET) operates with a slightly different control mechanism than the JFET. Figure 4 shows the development. The substrate may be high resistivity p-type material, as for the 2N4351. This time two separate low-resistivity n-type regions (source and drain) are diffused into the substrate as shown in Figure 4b. Next, the surface of the structure is covered with an insulating oxide layer and a nitride layer. The oxide layer serves as a protective coating for the FET surface and to insulate the channel from the gate. However the oxide is subject to contamination by sodium ions which are found in varying quantities in all environments. Such contamination results in long term instability and changes in device characteristics. Silicon nitride is impervious to sodium ions and thus is used to shield the oxide layer from contamination. Holes are cut into the oxide and nitride layers allowing metallic contact to the source and drain. Then, the gate metal area is overlayed on the insulation, covering the entire channel region and, simultaneously, metal contacts to the drain and source are made as shown in Figure 4d. The contact to the metal area covering the channel is the gate terminal. Note that there is no physical penetration of the metal through the oxide and nitride into the substrate. Since the drain and source are isolated by the substrate, any drain-to-source current in the absence of gate voltage is extremely low because the structure is analogous to two diodes connected back to back.

The metal area of the gate forms a capacitor with the insulating layers and the semiconductor channel. The metal area is the top plate; the substrate material and channel are the bottom plate.

For the structure of Figure 4, consider a positive gate potential (see Figure 5). Positive charges at the metal side of the metal-oxide capacitor induce a corresponding negative charge at the semiconductor side. As the positive charge at the gate is increased, the negative charge "induced" in the semiconductor increases until the region beneath the oxide effectively becomes an n-type semiconductor region, and current can flow between drain and source through the "induced" channel. In other words, drain current flow is "enhanced" by the gate potential. Thus drain current flow can be modulated by the gate voltage; i.e. the channel resistance is directly related to the gate voltage. The n-channel structure may be changed to a p-channel device by reversing the material types.

An equivalent circuit for the MOSFET is shown in Figure 6. Here, $C_{g(ch)}$ is the distributed gate-to-channel

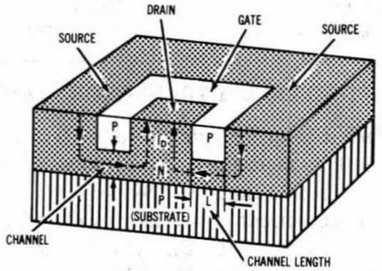


FIGURE 3 – Junction FET with Single-Ended Geometry

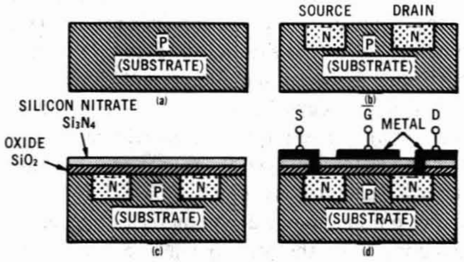


FIGURE 4 – Development of Enhancement-Mode N-Channel MOSFET

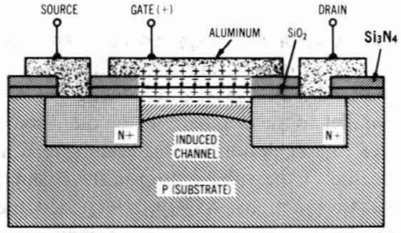


FIGURE 5 – Channel Enhancement. Application of Positive Gate Voltage Causes Redistribution of Minority Carriers in the Substrate and Results in the Formation of a Conductive Channel Between Source and Drain

capacitance representing the nitride-oxide capacitance. C_{gs} is the gate-source capacitance of the metal gate area overlapping the source, while C_{gd} is the gate-drain capacitance of the metal gate area overlapping the drain. $C_{d(sub)}$ and $C_{s(sub)}$ are junction capacitances from drain to substrate and source to substrate. Y_{fs} is the transadmittance between drain current and gate-source voltage. The modulated channel resistance is r_{ds}. R_D and R_S are the bulk resistances of the drain and source.

The input resistance of the MOSFET is exceptionally high because the gate behaves as a capacitor with very low leakage ($r_{in} \approx 10^{14}\ \Omega$). The output impedance is a function of r_{ds} (which is related to the gate voltage) and the drain and source bulk resistances (R_D and R_S).

To turn the MOSFET "on", the gate-channel capacitance, $C_{g(ch)}$, and the Miller capacitance, C_{gd}, must be charged. In turning "on", the drain-substrate capacitance, $C_{d(sub)}$, must be discharged. The resistance of the substrate determines the peak discharge current for this capacitance.

The FET just described is called an enhancement-type MOSFET. A depletion-type MOSFET can be made in the following manner: Starting with the basic structure of Figure 4, a moderate resistivity n-channel is diffused between the source and drain so that drain current can flow when the gate potential is at zero volts (Figure 7). In this manner, the MOSFET can be made to exhibit depletion characteristics. For positive gate voltages, the structure enhances in the same manner as the device of Figure 4. With negative gate voltage, the enhancement process is reversed and the channel begins to deplete of carriers as seen in Figure 8. As with the JFET, drain-current flow depletes the channel area nearest the drain first.

The structure of Figure 7, therefore, is both a depletion-mode and an enhancement-mode device.

MODES OF OPERATION

There are two basic modes of operation of FET's – depletion and enhancement. Depletion mode, as previously mentioned, refers to the decrease of carriers in the channel due to variation in gate voltage. Enhancement mode refers to the increase of carriers in the channel due to application of gate voltage. A third type of FET that can operate in both the depletion and the enhancement modes has also been described.

The basic differences between these modes can most easily be understood by examining the transfer characteristics of Figure 9. The depletion-mode device has considerable drain-current flow for zero gate voltage. Drain current is reduced by applying a reverse voltage to the gate terminal. The depletion-type FET is classified by the industry as a "Type A" FET. The "Type A" FET is not characterized with forward gate voltage.

The depletion/enhancement mode type device also has considerable drain current with zero gate voltage. This type device is classified as a "Type B" device. The "Type B" FET is defined in the forward region and may have usable forward characteristics for quite large gate voltages. Notice that for the junction FET, drain current may be enhanced by forward gate voltage only until the gate-source p-n junction becomes forward biased.

The third type of FET operates only in the enhancement mode. This is referred to as a "Type C" FET. The "Type C" FET has extremely low drain current flow for zero gate-source voltage. Drain current conduction occurs for a V_{GS} greater than some threshold value, $V_{GS(th)}$. For gate voltages greater than the threshold, the transfer characteristics are similar to the "Type B" FET.

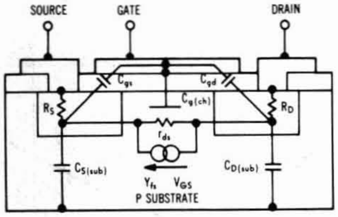


FIGURE 6 – Equivalent Circuit of Enhancement-Mode MOSFET

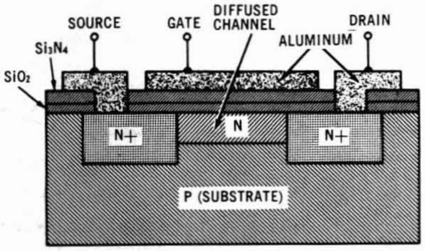


FIGURE 7 – Depletion Mode MOSFET Structure. This Type of Device may be Designed to Operate in Both the Enhancement and Depletion Modes

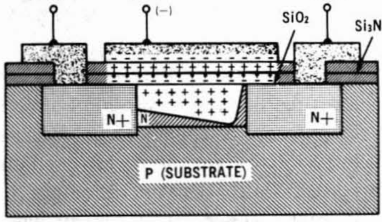


FIGURE 8 – Channel Depletion Phenomenon. Application of Negative Gate Voltage Causes Redistribution of Minority Carriers in Diffused Channel and Reduces Effective Channel Thickness. This Results in Increased Channel Resistance

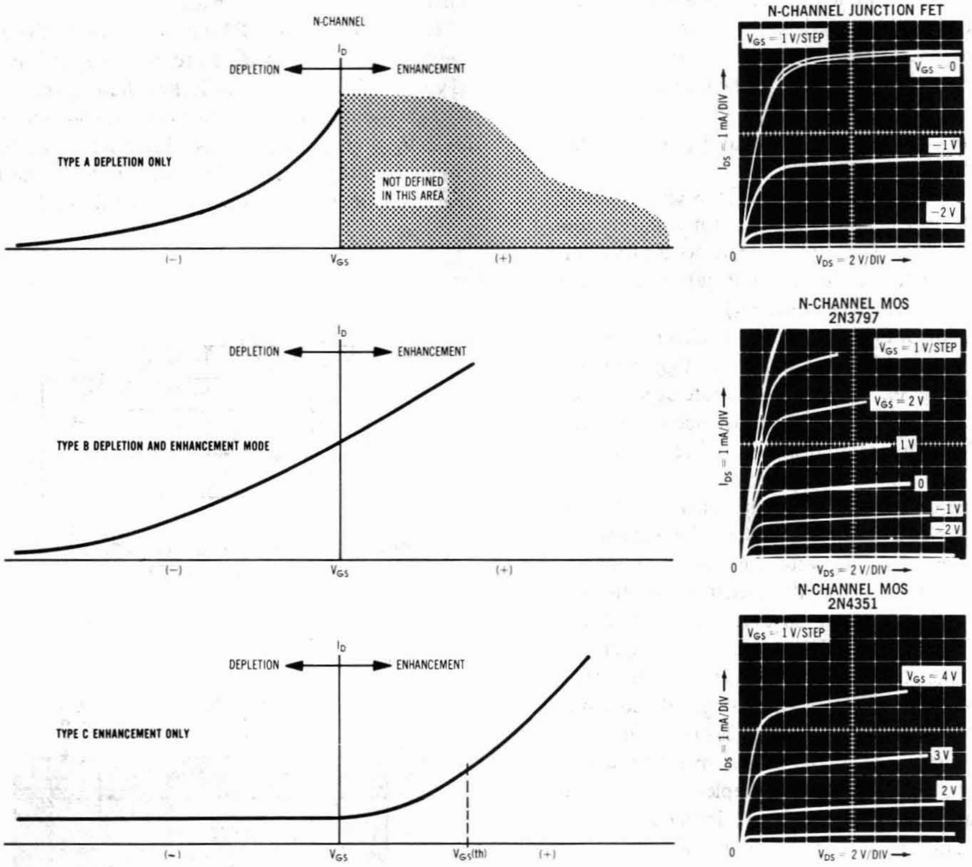


FIGURE 9 — Transfer Characteristics and Associated Scope Traces for Types A, B and C FETs

ELECTRICAL CHARACTERISTICS

Because the basic mode of operation for field-effect devices differs greatly from that of conventional junction transistors, the terminology and specifications are necessarily different. An understanding of FET terminology and characteristics are necessary to evaluate their comparative merits from data-sheet specifications.

Static Characteristics

Static characteristics define the operation of an active device under the influence of applied dc operating conditions. Of primary interest are those specifications that indicate the effect of a control signal on the output current. The V_{GS}–I_D transfer characteristics curves are illustrated in Figure 9 for the three types of FETs. Figure 10 lists the data-sheet specifications normally employed to describe these curves, as well as the test circuits that yield the indicated specifications.

Of additional interest is the special case of tetrode-connected devices in which the two gates are separately accessible for the application of a control signal. The pertinent specifications for a junction tetrode are those which define drain-current cutoff when one of the gates is connected to the source and the bias voltage is applied to the second gate. These are usually specified as $V_{G1S(off)}$, Gate 1 – source cutoff voltage (with Gate 2 connected to source), and $V_{G2S(off)}$, Gate 2 – source cutoff voltage (with Gate 1 connected to source). The gate voltage required for drain current cutoff with one of the gates connected to the source is always higher than that for the triode-connected case where both gates are tied together.

Reach-through voltage is another specification uniquely applicable to tetrode-connected devices. This defines the amount of difference voltage that may be applied to the two gates before the depletion region of one spreads into the junction of the other – causing an increase in gate current to some small specified value. Obviously, reach-through is an undesirable condition since it causes a decrease in input resistance as a result of an increased gate current, and large amounts of reach-through current can destroy the FET.

Gate Leakage Current

Of interest to circuit designers is the input resistance of an active component. For FETs, this characteristic is specified in the form of I_{GSS} – the reverse-bias gate-to-source current with the drain shorted to the source (Figure 11). As might be expected, because the leakage current across a reverse-biased p-n junction (in the case of a JFET) and across a capacitor (in the case of a MOSFET) is very small, the input resistance is extremely high. At a temperature of 25°C, the JFET input resistance is hundreds of megohms while that of a MOSFET is even greater. For junction devices, however, input resistance may decrease by several orders of magnitude as temperature is raised to 150°C. Such devices, therefore, have gate-leakage current specified at two temperatures. Insulated-gate FETs are not drastically affected by temperature, and their input resistance remains extremely high even at elevated temperatures.

Gate leakage current may also be specified as I_{GDO} (leakage between gate and drain with the source open), or as I_{GSO} (leakage between gate and source with the drain open). These usually result in lower values of leakage current and do not represent worst-case conditions. The I_{GSS} specification, therefore, is usually preferred by the user.

Voltage Breakdown

A variety of specifications can be used to indicate the maximum voltage that may be applied to various elements of a FET. Among those in common use are the following:

$V_{(BR)GSS}$ = Gate-to-source breakdown voltage
$V_{(BR)DGO}$ = Drain-to-gate breakdown voltage
$V_{(BR)DSX}$ = Drain-to-source breakdown voltage (normally used only for MOSFETs)

In addition, there may be ratings and specifications indicating the maximum voltages that may be applied between the individual gates and the drain and source (for tetrode-connected devices). Obviously, not all of these specifications are found on every data sheet since some of them provide the same information in somewhat different form. By understanding the various breakdown mechanisms, however, the reader should be able to interpret the intent of each specification and rating. For example:

In junction FETs, the maximum voltage that may be applied between any two terminals is the lowest voltage that will lead to breakdown or avalanche of the gate junction. To measure $V_{(BR)GSS}$ (Figure 12a), an increasingly higher reverse voltage is applied between the gate and the source. Junction breakdown is indicated by an increase in gate current (beyond I_{GSS}) which signals the beginning of avalanche.

Some reflection will reveal that for junction FETs, the $V_{(BR)DGO}$ specification really provides the same information as $V_{(BR)GSS}$. For this measurement, an increasing voltage is applied between drain and gate. When this applied voltage becomes high enough, the drain-gate junction will go into avalanche, indicated either by a significant increase in drain current or by an increase in gate current (beyond I_{DGO}). For both $V_{(BR)DGO}$ and $V_{(BR)GSS}$ specifications, breakdown should normally occur at the same voltage value.

From Figure 2 it is seen that avalanche occurs at a lower value of V_{DS} when the gate is reverse biased than for the zero-bias condition. This is caused by the fact that the reverse-bias gate voltage adds to the drain voltage, thereby increasing the effective voltage across the junction. The maximum amount of drain-source voltage that may be applied $V_{DS(max)}$ is, therefore, equal to $V_{(BR)DGO}$ minus V_{GS}, which indicates avalanche with reverse bias gate voltage applied.

For MOSFETs, the breakdown mechanism is somewhat different. Consider, for example, the enhancement-mode structure of Figure 5. Here, the gate is completely insulated from the drain, source, and channel by an oxide-nitride layer. The breakdown voltage between the gate and any of the other elements, therefore, is dependent on the thickness and purity of this insulating layer, and represents the voltage that will physically puncture the layer. Consequently, the voltage must be specified separately.

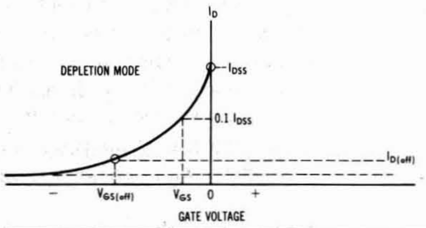
The drain-to-source breakdown is a different matter. For Type C devices, with the gate connected to the source (the cutoff condition) and the substrate floating, there is no effective channel between drain and source and the applied drain-source voltage appears across two opposed series diodes, represented by the source-to-substrate and substrate-to-drain junctions. Drain current remains at a very low level (picoamperes) as drain voltage is increased until the drain voltage reaches a value that causes reverse (avalanche) breakdown of the diodes. This particular condition, represented by $V_{(BR)DSS}$, is indicated by an increase in I_D above the I_{DSS} level, as shown in Figure 12b.

For Type B devices, the $V_{(BR)DSS}$ symbol is sometimes replaced by $V_{(BR)DSX}$. Note that the principal difference between the two symbols is the replacement of the last subscript s with the subscript x. Whereas the s normally indicates that the gate is shorted to the source, the x indicates that the gate is biased to cutoff or beyond. To achieve cutoff in Type B devices, a depleting bias voltage must be applied to the gate, Figure 12b.

An important static characteristic for switching FETs is the "on" drain-source voltage $V_{DS(on)}$. This characteristic for the MOSFETs is a function of V_{GS}, and resembles the $V_{CE(sat)}$ versus I_B characteristics of junction transistors. The curve for these characteristics can be used as a design guide to determine the minimum gate voltage necessary to achieve a specified output logic level.

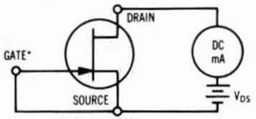
Dynamic Characteristics

Unlike the static characteristics, the dynamic characteristics of field-effect transistors apply equally to Types A, B, and C. The conditions and presentation of the dynamic characteristics, however, depend largely upon the intended application. For example, the following table indicates the dynamic characteristics needed to adequately describe a FET for various applications.

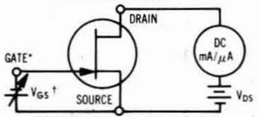


FOR TYPE A FETs (JFETs)

CHARACTERISTIC	DESCRIPTION
I_{DSS} @ $V_{GS} = 0$, $V_P < V_{DS} < V_{(BR)\,DSS}$	Zero-gate-voltage drain current. Represents maximum drain current.
$V_{GS\,(off)}$ @ $I_D = 0.001\ I_{DSS}$, $V_P < V_{DS} < V_{(BR)\,DSS}$	Gate voltage necessary to reduce I_D to some specified negligible value at the recommended V_{DS}, i.e. cutoff.
V_{GS} @ $I_D = 0.1\ I_{DSS}$, $V_P < V_{DS} < V_{(BR)\,DSS}$	Gate voltage for a specified value of I_D between I_{DSS} and I_{DS} at cutoff – normally $0.1\ I_{DSS}$.



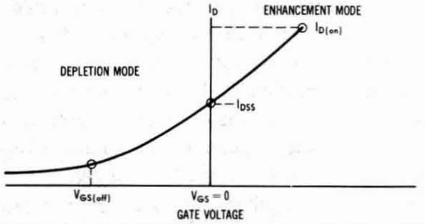
TEST CIRCUIT FOR I_{DSS}



TEST CIRCUIT FOR V_{GS} AND $V_{GS(off)}$

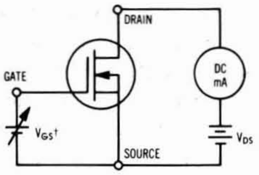
*GATES INTERNALLY CONNECTED

†ADJUST FOR DESIRED I_D



FOR TYPE B FETs (MOSFETs)

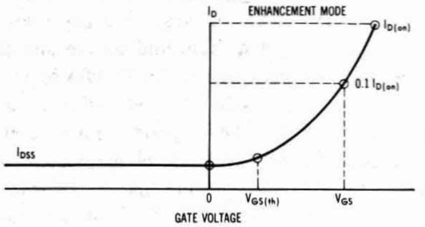
CHARACTERISTIC	DESCRIPTION
$I_{D(on)}$ @ $V_{GS} > 0$, $V_P < V_{DS} < V_{(BR)\,DSS}$	An arbitrary current value (usually near max rated current) that locates a point in the enhancement operating mode.
I_{DSS} @ $V_{GS} = 0$, $V_P < V_{DS} < V_{(BR)\,DSS}$	Zero-gate-voltage drain current.
$V_{GS(off)}$ @ $I_D = 0.001\ I_{DSS}$.	Voltage necessary to reduce I_D to some specified negligible value at the recommended V_{DS}, i.e. cutoff.



TEST CIRCUIT FOR $I_{D(on)}$

†ADJUST FOR DESIRED I_D, NORMALLY NEAR MAX-RATED I_D

TEST CIRCUITS FOR I_{DSS} AND $V_{GS\ (off)}$ SAME AS TYPE A



FOR TYPE C FETs (MOSFETs)

CHARACTERISTIC	DESCRIPTION
$I_{D(on)}$ @ $V_{GS} > 0$, $V_P < V_{DS} < V_{(BR)\,DSS}$	An arbitrary current value (usually near max rated current) that locates a point in the enhancement operating mode.
V_{GS} @ $0.1\ I_{D(on)}$	Gate-source voltage for a specified drain current of $0.1\ I_{D(on)}$.
$V_{GS(th)}$ @ $I_D = 0.001\ I_{D(on)}$ or less	Gate cutoff or turn-on voltage.
I_{DSS} @ $V_{GS} = 0$, $V_P < V_{DS} < V_{(BR)\,DSS}$	Leakage drain current.

$I_{D(on)}$ TEST CIRCUIT
SAME AS FOR TYPE B

V_{GS} TEST CIRCUIT
SAME AS FOR $I_{D(on)}$

$V_{GS(th)}$ TEST CIRCUIT
SAME AS $V_{GS(off)}$ IN TYPE A,
EXCEPT REVERSE V_{GS} BATTERY POLARITY

I_{DSS} TEST CIRCUIT
SAME AS FOR TYPE A

FIGURE 10 – Static Characteristics for the Three FET Types are Defined by the Above Curves, Tables, and Test Circuits

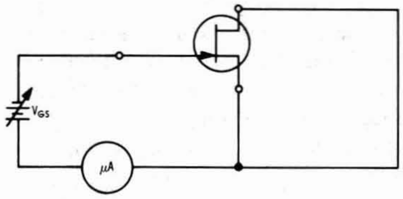


Figure 12a – $V_{(BR)GSS}$ Test Circuit

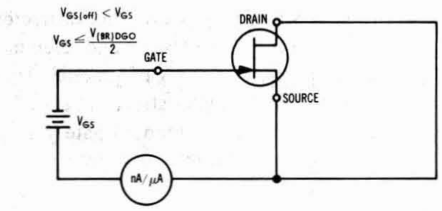
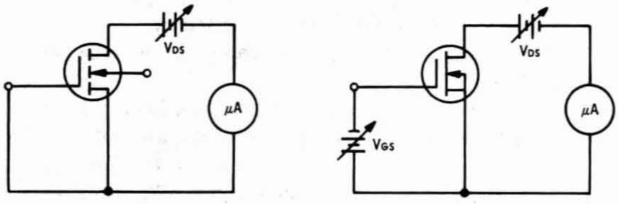


FIGURE 11 – Test Circuit for Leakage Current



TYPE C **TYPE B**

FIGURE 12b – $V_{(BR)DSS}$ and $V_{(BR)DSX}$ Test Circuit (Usually Used for MOSFETs Only).

Audio	RF-IF	Switching	Chopper
y_{fs} (1 kHz)	y_{fs} (1 kHz)		
C_{iss}	C_{iss}	C_{iss}	C_{iss}
C_{rss}	C_{rss}	C_{rss}	C_{rss}
y_{os} (1 kHz)	GP	$Cd_{(sub)}$	$Cd_{(sub)}$
NF	$Re(y_{is})$ (HF)	$r_{ds(on)}$	$r_{ds(on)}$
	$Re(y_{os})$ (HF)	t_{d1}, t_{d2}	
	NF	t_r, t_f	

y_{fs} The forward transadmittance is a key dynamic characteristic for field-effect transistors. It serves as a basic design parameter in audio and rf circuits and is a widely accepted figure of merit for devices.

Because field-effect transistors have many characteristics similar to those of vacuum tubes, and because many engineers still are more comfortable with tube parameters, the symbol g_m used for tube transconductance is often specified instead of y_{fs}. To further confuse things, the "g" school also uses a variety of subscripts. In addition to g_m, some data sheets show g_{fs} while others even show g_{21}.

Regardless of the symbol used, y_{fs} defines the relation between an input signal voltage and an output signal current:

$$y_{fs} = \Delta I_D / \Delta V_{GS} \Big|_{V_{DS} = K}$$

The unit is the mho – current divided by voltage. Figure 13 is a typical y_{fs} test circuit for a junction FET.

As a characteristic of all field-effect devices, y_{fs} is specified at 1 kHz with a V_{DS} the same as that for which $I_{D(on)}$ or I_{DSS} is characterized. Since y_{fs} has both real and imaginary components, but is dominated by the real component at low frequency, the 1 kHz characteristic is given as an absolute magnitude and indicated as $|y_{fs}|$.

It is interesting to note that y_{fs} varies considerably with I_D due to nonlinearity in the $I_D - V_{GS}$ characteristics. This variation, for a typical n-channel, Type A JFET is illustrated in Figure 14. Obviously, the operating point must be carefully selected to provide the desired y_{fs} and signal swing.

For tetrode-connected FETs, three y_{fs} measurements are usually specified on data-sheet tables. One of these, with the two gates tied together, provides a y_{fs} value for the condition where a signal is applied to both gates simultaneously; the others provide the y_{fs} for the two gates individually. Generally, with the two gates tied together, y_{fs} is higher and more gain may be realized in a given circuit. Because of the increased capacitance, however, gain-bandwidth product is much lower.

For rf field-effect transistors, an additional value of y_{fs} is sometimes specified at or near the highest frequency of operation. This value should also be measured at the same voltage conditions as those used for $I_{D(on)}$ or I_{DSS}. Because of the importance of the imaginary component at radio frequencies, the high-frequency y_{fs} specification should be a complex representation, and should be given either in the specifications table or by means of curves showing typical variations, as in Figure 15 for the 2N4223 JFET.

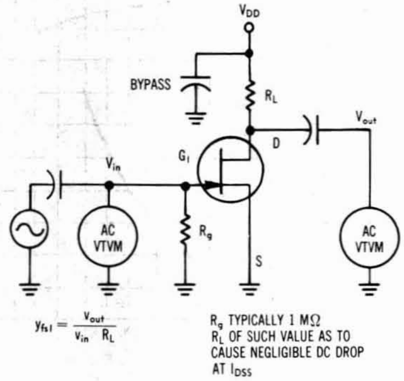
The real portion of this high-frequency y_{fs}, Re (y_{fs}) or G_{21}, is usually considered a significant figure of merit.

y_{os} Another FET parameter that offers a direct vacuum tube analogy is y_{os}, the output admittance:

$$y_{os} = \Delta I_D / \Delta V_{DS} \Big|_{V_{GS} = K}$$

In this case, the analogous tube parameter is r_p – i.e., $y_{os} = 1/r_p$. For Type A and B devices, y_{os} is measured with gate and source grounded (see Figure 16). For Type C units, it is measured at some specified V_{GS} that permits substantial drain-current flow.

As with y_{fs}, many expressions are used for y_{os}. In



$$y_{fs1} = \frac{V_{out}}{V_{in}\ R_L}$$

R_g TYPICALLY 1 MΩ
R_L OF SUCH VALUE AS TO CAUSE NEGLIGIBLE DC DROP AT I_{DSS}

FIGURE 13 – Typical y_{fs} Test Circuit

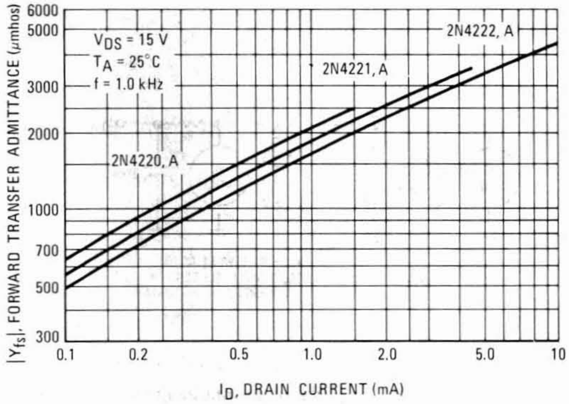


FIGURE 14 – Forward Transfer Admittance versus Drain Current for Typical JFETs

addition to the obvious parallels such as y_{22}, g_{os}, and g_{22}, it is also sometimes specified as r_d, where $r_d = 1/y_{os}$.

Voltages and frequencies for measuring y_{os} should be exactly the same as those for measuring y_{fs}. Like y_{fs}, it is a complex number and should be specified as a magnitude at 1 kHz and in complex form at high frequencies.

μ Closely related to y_{os} and y_{fs} is the amplification factor, μ:

$$\mu = \Delta V_{DS}/\Delta V_{GS} \Big|_{I_D = K}$$

The amplification factor does not appear on the field-effect transistor registration format but can be calculated as y_{fs}/y_{os}. For most small-signal applications, μ has little circuit significance. It does, however, serve as a general indication of the quality of the field-effect manufacturing process.

C_{iss} The common-source-circuit input capacitance, C_{iss}, takes the place of y_{is} in low-frequency field-effect transistors. This is because y_{is} is entirely capacitive at low frequencies. C_{iss} is conveniently measured in the circuit of Figure 17 for the tetrode JFET. As with y_{fs}, two measurements are necessary for tetrode-connected devices.

At very high frequencies, the real component of y_{is} becomes important so that rf field-effect transistors should have y_{is} specified as a complex number at the same conditions as other high-frequency parameters. For tetrode-connected rf FETs, reading of both Gate 2 to source and Gate 1 tied to Gate 2 are necessary.

In switching applications C_{iss} is of major importance since a large voltage swing at the gate must appear across C_{iss}. Thus, C_{iss} must be charged by the input voltage before turn-on effectively begins.

C_{rss} Reverse transfer admittance (y_{rs}) does not appear on FET data sheets. Instead C_{rss}, the reverse transfer capacitance, is specified at low frequency. Since y_{rs} for a field-effect transistor remains almost completely capacitive and relatively constant over the entire usable FET frequency spectrum, the low-frequency capacitance is an adequate specification. C_{rss} is measured by the circuit of Figure 18. For tetrode FETs, values should be specified for Gate 1 and for both gates tied together.

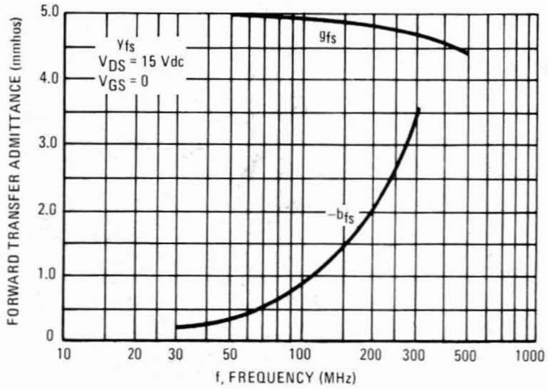


FIGURE 15 – Forward Transfer Admittance versus Frequency

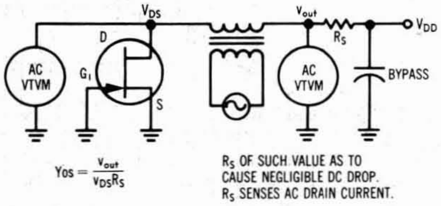

V_{DS}
V_{out}
V_{DD}
D
R_S
AC VTVM
G_1
AC VTVM
BYPASS
S
$Y_{OS} = \frac{V_{out}}{V_{DS}R_S}$
R_S OF SUCH VALUE AS TO CAUSE NEGLIGIBLE DC DROP.
R_S SENSES AC DRAIN CURRENT.

FIGURE 16 – y_{os} Measurement Circuit for Type A and B FETs

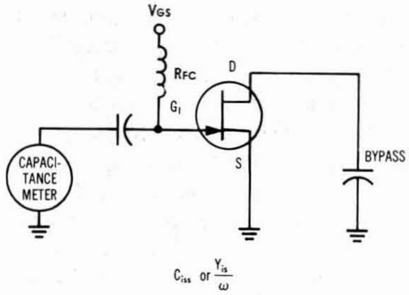


FIGURE 17 – C_{iss} Measurement Circuit

Again, for switching applications C_{rss} is a critical characteristic. Similar to the C_{ob} of a junction transistor, C_{rss} must be charged and discharged during the switching interval. For a chopper application, C_{rss} is the feed-through capacitance for the chopper drive.

$C_{d(sub)}$ For the MOSFET, the drain-substrate junction capacitance becomes an important characteristic affecting the switching behavior. $C_{d(sub)}$ appears in parallel with the load in a switching circuit and must be charged and discharged between the two logic levels during the switching interval.

Noise Figure (NF) Like all other active components, field-effect transistors generate a certain amount of noise. The noise figure for field-effect transistors is normally specified on the data sheet as "spot noise", referring to the noise at a particular frequency. The noise figure will vary with frequency and also with the resistance at the input of the device. Typical graphs of such variations are illustrated in Figure 19 for the 3N126. From graphs of this kind the designer can anticipate the noise level inherent in his design.

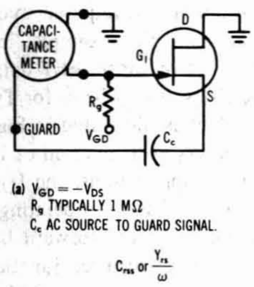
$r_{ds(on)}$ Channel resistance describes the bulk resistance of the channel in series with the drain and source. From an applications standpoint, it is important primarily for switching and chopper circuits since it affects the switching speed and determines the output level. To complete the confusion of multiple symbols for FET parameters, channel resistance is sometimes indicated as $r_{d(on)}$ and also as r_{DS} and r_{ds}. In either case, however, it is measured, for JFETs, by tying the gates to the source, setting all terminals equal to 0 Vdc, and applying an ac voltage from drain to source (see Figure 20). The magnitude of the ac voltage should be kept low so that there will be no pinch-off in the channel. Insulated-gate FETs may be measured with dc gate bias in the enhancement mode.

APPLICATIONS

Device Selection

Obviously, different applications call for special emphasis on specific characteristics so that a simple figure of merit that compares devices for all potential uses would be hard to formulate. Nevertheless, an attempt to pinpoint the characteristics that are most significant for various applications has been made* to permit a rapid, first-order evaluation of competitive devices.

The most important single FET parameter, one that applies for any amplifier application, is y_{fs}. This parameter, or one of its many variations, is specified on most data



(a) $V_{GD} = -V_{DS}$
R_g TYPICALLY 1 MΩ
C_c AC SOURCE TO GUARD SIGNAL.

C_{rss} or $\frac{Y_{rs}}{\omega}$

FIGURE 18 – Recommended C_{rss} Test Circuit

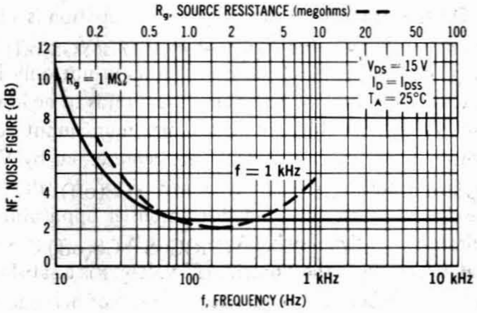


FIGURE 19 – Typical Variations of FET Noise Figure with Frequency and Source Resistance

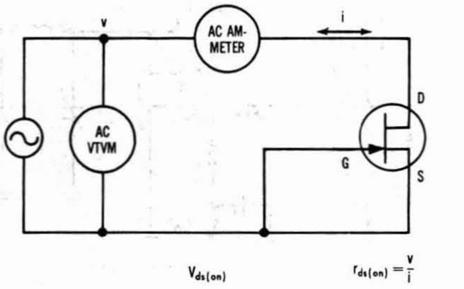


FIGURE 20 – Circuit for Measuring JFET Channel Resistance

sheets, yet some evaluation is required to come up with a reasonable comparison. For example, in the table of electrical characteristics on most JFET data sheets, y_{fs} is specified at I_{DSS} ($V_{GS} = 0$) where, for Type A devices, y_{fs} is maximum. This is illustrated in Figure 14, where typical variations of y_{fs} as a function of I_D are plotted. For some small-signal applications, the I_{DSS} ($V_{GS} = 0$) point can actually be used as a dc operating point because small-signal excursions into the forward bias region will not actually cause the gate-source junction to become forward-biased. However, in most practical uses, some bias is necessary to allow for the anticipated signal swing; and it must be recognized the y_{fs} goes down as the bias is increased.

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*Christiansen, Donald, "Semiconductors: The New Figures of Merit," EEE, October, 1965.

It is seen, also, that maximum y_{fs} increases as I_{DSS} increases so that, where maximum y_{fs} is important, a device with a high I_{DSS} specification is normally desirable.

On the other hand, where power dissipation is a factor to be considered, the figure of merit $y_{fs}/V_{GS(off)}\ I_{DSS}$ has been proposed. This term factors in not only I_{DSS}, which should be low if power dissipation is to be low, but also $V_{GS(off)}$, which indicates maximum input voltage swing. Since the signal peaks are represented by $V_{GS} = V_{GS(off)}$ and $V_{GS} = 0$, the lower $V_{GS(off)}$, the higher the figure of merit. And, for amplifier applications requiring a large signal swing, $V_{(BR)GSS}/V_{GS(off)}$ (assuming that $V_{GS(off)}$ is the "pinch-off" voltage) is a satisfactory merit figure because it indicates the ratio of maximum and minimum drain voltages.

For high-frequency circuits, the input capacitance (C_{iss}) and the Miller-effect capacitance (C_{rss}) become important, so $y_{fs}/(C_{iss} + C_{rss})$ indicates a relative measure of device performance. For switching and chopper circuits, a figure of merit is not often useful. Here the magnitudes of C_{iss}, C_{rss}, $C_{d(sub)}$ and r_{ds} are of primary interest.

Circuits

The types of circuits that can utilize FETs are practically unlimited. In fact, many circuits designed to utilize small-signal pentode tubes can utilize FETs with only minor modifications. For example, the circuit in Figure 21 shows a typical rf stage for a broadcast-band auto radio. In this circuit, a MPF102 n-channel JFET has replaced the 12BL6 pentode normally employed. The specifications for the two devices, including the AGC characteristics, are similar enough to perform adequately in the circuit of Figure 21.

In an audio application, a field-effect transistor such as the MFE4007 can be combined with a high voltage bipolar transistor to make a simple line-operated phonograph amplifier such as that shown in Figure 22. The ceramic pickup is connected through a potentiometer volume control to the field-effect transistor. Collector current of the transistor, in turn, is set by the potentiometer in the source of the FET. With the proper bipolar output transistor, the circuit can be driven directly from the rectified line voltage, while the low voltage for the FET can be derived from a voltage divider in the power supply line.

For switching and logic circuits, complementary enhancement-type field-effect transistors offer two significant advantages: Power is drawn only during switching, not in either stable state; and no coupling elements are required since the input to each FET resembles a capacitor and the coupling is inherent in the device.

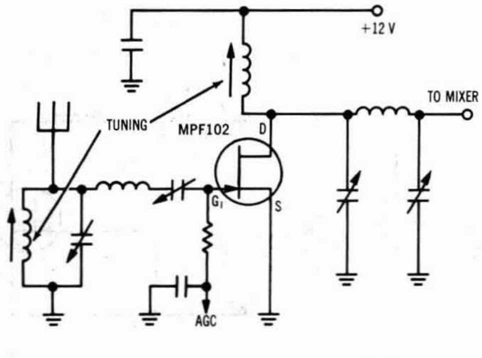


FIGURE 21 – RF Stage of Broadcast Auto Radio

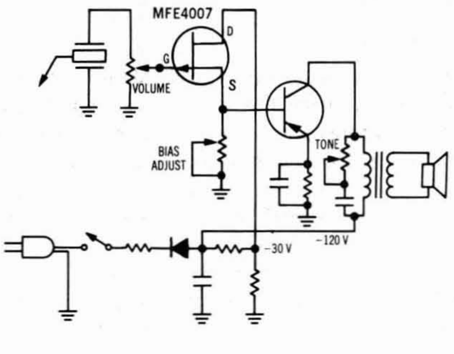


FIGURE 22 – Line Operated Phono Amplifiers

One simple circuit that illustrates these advantages is the complementary inverter of Figure 23. In this circuit, +V is a logical "1" and ground is a logical "0". If the input signal is +V, the p-channel device (upper) is essentially off and conducts only I_{DSS} (picoamperes for a Type C FET). The n-channel FET is forward-biased but since only I_{DSS} is available from the upper stage, V_{DS} is very low. As a result, the potential of the output is near ground – the zero reading. When the input goes to ground, the p-channel FET conducts. The n-channel device, however, is now cutoff and conducts only I_{DSS}. Since the voltage drop across the p-channel device is very low, the drain potential of the p-channel device is approximately +V. This charges capacitor C_L to +V.

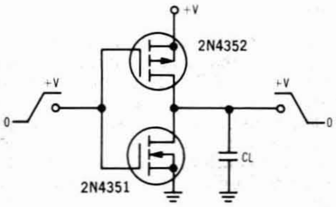
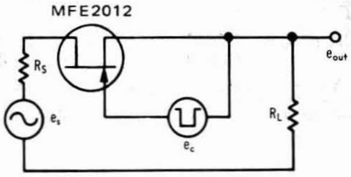


FIGURE 23 – Complementary Inverter Circuit

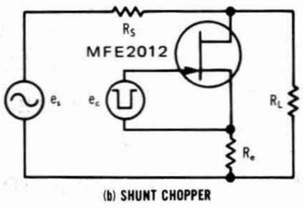
Figure 24 shows three basic chopper circuits. The advantage of the more complex series-shunt circuit (24c) is that it balances out the leakage currents of the FETs in order to reduce voltage error and is used to attain high chopping frequencies. From an applications standpoint, the FET circuit is superior to a junction transistor circuit in that there is no offset voltage with the FET turned on. On the minus side, however, the field-effect-transistor chopper generally has a higher series resistance ($r_{ds(on)}$) than the junction transistor.

As newer and better FETs are introduced and as a larger number of designers learn to use them, the range of applications of FETs should broaden considerably. To date, there has been little activity in the logic area in spite of the advantages of FETs for some logic configurations, but this situation is beginning to change rapidly.

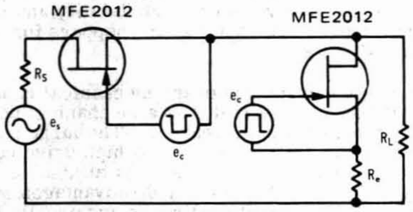
With its high input impedance, the field-effect transistor will play an important role in input circuitry for instrumentation and audio applications where low-impedance junction transistors have generally been least successful.



(a) SERIES CHOPPER CIRCUIT



(b) SHUNT CHOPPER



(c) SERIES-SHUNT CHOPPER

Figure 24 – FET Chopper Circuits

FIELD-EFFECT TRANSISTORS IN CHOPPER AND ANALOG SWITCHING CIRCUITS

INTRODUCTION

Two characteristics of the field-effect transistor make it an excellent device for chopping and analog switching applications. The most important characteristic is that the FET does not have an inherent offset voltage between the input and output terminals. Secondly, since the input impedance of the FET is extremely high, the FET circuit does not require a floating drive circuit (i. e. a transformer drive).

In this paper the FET chopper is first compared with a mechanical chopper and a junction-transistor chopper, and the advantages of the FET are pointed out.

The FET characteristics pertinent to chopper and analog switch design are then discussed in some detail.

The circuit portion of this paper is divided into three parts. First, three basic chopper circuits are examined, and the sources of error-voltages and circuit limitations of each are pointed out.

Secondly, some practical chopper circuits are introduced with the limitations of chopping frequency and input voltage discussed. Some circuit techniques to overcome these limitations are also given.

Finally, some analog switching circuits employing the FET are discussed together with the limitations of the FET in this area.

A definition of a chopper is first required. A chopper is basically a device that converts a DC voltage (or a low frequency AC) into an AC voltage of the same amplitude. To accomplish this, the device alternately connects and disconnects the source to the load at some periodic frequency. The resulting "chopped" voltage may then be amplified by a conventional AC amplifier, thus avoiding the use of DC amplifiers, which in general are very prone to thermal drift.

FET CHOPPER COMPARED TO MECHANICAL AND TRANSISTOR CHOPPER

Figure 1 shows a simple series chopper using a relay as the chopping element. The relay has a very high series resistance when non-conducting or OFF, and a very low series resistance when conducting or ON. (Typically, 10-50 milliohms for the mercury wetted type.) Mechanical choppers have very good stability and linearity and are superior to solid state choppers for very low levels of DC voltage.

However, the disadvantages of the mechanical chopper are many. First, the fact that it is a mechanical device introduces the possibility of wearout. The large physical size of mechanical choppers, the high drive power required, and the low chopping speeds attainable (approximately 300 Hz max) are other disadvantages of the mechanical chopper. Additionally, relays usually have unsymetrical ON-OFF times, and their performance under environmental extremes is generally poor.

A major advance in the chopper and analog switch field came with the junction transistor. Figure 2 shows a simple series chopper using one transistor. The major drawback of this circuit, however, is the inherent offset voltage of the transistor due to the active P-N junction in the output current path. This offset voltage is present even for zero load current. A transistor series chopper more widely used is shown in Figure 3. The circuit uses two transistors in the inverted configuration, that is, the drive current is from base to collector instead of, as usual, from base to emitter. The offset voltage is minimized by operating in the inverted configuration. Consider the equations for the saturation voltage of a transistor for both forward and inverse configurations for $I_E = 0.0$.

$$V_P^N = V_{CE} = \left(\frac{\lambda KT}{q}\right)\ln\left(\frac{1}{\alpha_I}\right) + r'_e\ I_B$$

$$V_P^I = V_{EC} = \left(\frac{\lambda KT}{q}\right)\ln\left(\frac{1}{\alpha_N}\right) + r'_c\ I_B$$

If $r'_e \simeq r'_c$, then $V_{EC} < V_{CE}$, since α_I is normally less than α_N for most conventional transistors.

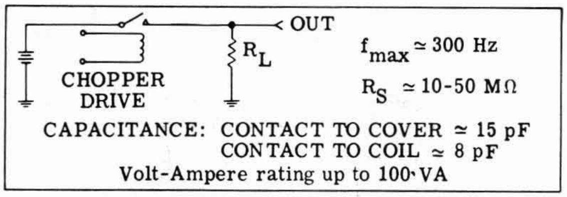

OUT
R_L
$f_{max} \simeq 300$ Hz
$R_S \simeq 10\text{-}50$ MΩ
CHOPPER DRIVE
CAPACITANCE: CONTACT TO COVER ≃ 15 pF
CONTACT TO COIL ≃ 8 pF
Volt-Ampere rating up to 100 VA

FIGURE 1 – MECHANICAL CHOPPER CIRCUIT

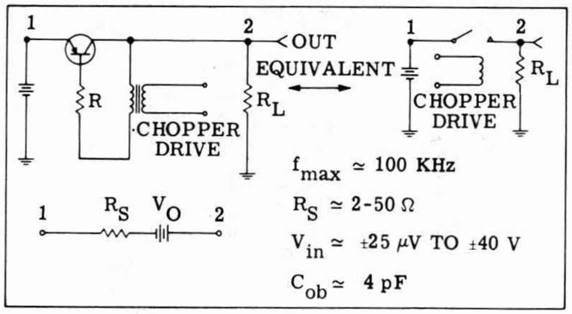

1
2
OUT
EQUIVALENT
1
2
R_L
R
R_L
CHOPPER DRIVE
CHOPPER DRIVE
$f_{max} \simeq 100$ KHz
1 R_S V_O 2
$R_S \simeq 2\text{-}50\ \Omega$
$V_{in} \simeq \pm 25\ \mu V$ TO ± 40 V
$C_{ob} \simeq 4$ pF

FIGURE 2 – TRANSISTOR CHOPPER CIRCUIT

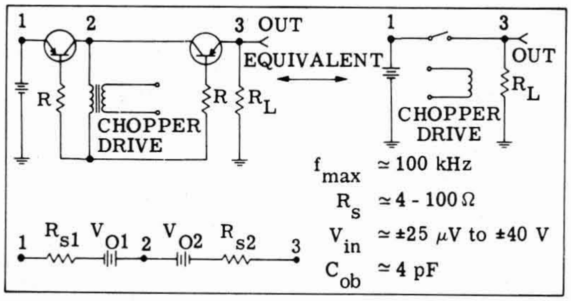

1
2
3 OUT
1
3
EQUIVALENT
OUT
R
R
R_L
R_L
CHOPPER DRIVE
CHOPPER DRIVE
$f_{max} \simeq 100$ kHz
$R_s \simeq 4\text{-}100\ \Omega$
1 R_{s1} V_{O1} 2 V_{O2} R_{s2} 3
$V_{in} \simeq \pm 25\ \mu V$ to ± 40 V
$C_{ob} \simeq 4$ pF

FIGURE 3 – TRANSISTOR CHOPPER CIRCUIT FOR MINIMUM OFFSET VOLTAGE

Furthermore, the transistors are in the circuit in such a way that the offset voltages will be of opposite polarity. By carefully matching the transistors, the offset voltage can be kept to a minimum.

The transistor chopper has several advantages over the mechanical chopper. The transistor chopper requires lower drive power, it can operate at higher frequencies (approximately 100 kHz max.), it is small in size, rugged and performs well under environmental extremes, and finally, it has no moving parts to wear out.

But, unfortunately, the transistor chopper also has some severe disadvantages. The before-mentioned offset voltage can be eliminated at room temperature, for instance, but since it is a function of temperature, the offset voltage will be present at other temperatures.

Floating drives are also required for the two-transistor chopper circuit of Figure 3 in order not to bias the output voltage with the drive signal. To accomplish the floating drive, a transformer is generally used. However, the requirements of both chopper and analog switching circuits frequently dictate fast turn-on and turn-off times and perhaps a long on-time. A transformer capable of meeting these conditions would be difficult to design or select.

The chopper circuit shown in Figure 4 has most of the advantages of both the mechanical and transistor choppers and very few of their disadvantages. The circuit shown uses one N channel junction field-effect transistor (JFET) in a simple series chopper configuration.

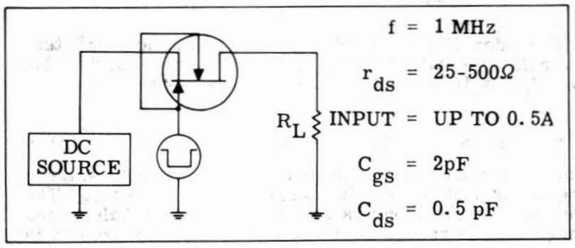


FIGURE 4 – SERIES FET CHOPPER

The N channel JFET consists of a P-type substrate into which an N-type channel is diffused. A P-type gate completes the structure. From gate to source and drain we, therefore, have a P-N junction.

As long as no bias is applied from gate-to-source, current flows freely in the N-type channel. For small drain-to-source voltages, the channel acts like a pure resistance. When a reverse bias is applied from gate to source, however, a depletion region will surround the P-N junction and for large values of V_{GS}, the depletion region will completely encompass the channel, and a very high value of resistance will be seen from drain to source. The JFET is therefore called a depletion-mode device.

Since the gate-to-source P-N junction is always reverse-biased, a very high impedance is seen at the gate. For this reason no transformer is needed for the drive.

There are no offset voltages as in the transistor chopper, because when the FET is turned fully ON, the path from drain to source is a pure resistance. When the FET is turned OFF, the performance approaches that of the mechanical relay with OFF resistance in the order of 10^{12} ohms.

The major disadvantage of the FET chopper appears when chopping a very low-level signal at high frequency. Due to the capacitance from gate to drain, the drive signal is fed through into the output circuit, and causes spikes on the output waveform.

FET CHARACTERISTICS RELEVANT TO CHOPPER AND ANALOG SWITCHING CIRCUIT APPLICATIONS

Figure 5 shows the output characteristics for the MM2103, a P channel insulated gate field-effect transistor (IGFET).

The P channel IGFET consists of an N-type substrate into which two separate P-type regions are diffused. These P-type regions are the source and drain. Next, the whole structure is covered with an oxide layer, and holes are cut through the layer in order to make contact to the drain and source. Finally, a metal contact area is overlayed on the oxide, covering the whole channel region. This metal contact area is the gate terminal.

For zero gate voltage, no current will flow from source to drain. The path from source to drain looks like two P-N junctions back to back. When a negative voltage is applied to the gate of the device, a P-type "channel" is induced in the substrate from drain to source, and current will be able to flow. The flow of current is "enhanced" by the gate potential. The IGFET, therefore, is called an enhancement-mode device. Similarly, a positive potential on the gate of an N-channel IGFET will "enhance" current flow in this device.

The gate is completely isolated from the rest of the device by an oxide layer. Hence, the input impedance at the gate is that of a capacitor and is even higher than the input to the reverse-biased diode in the N-channel JFET.

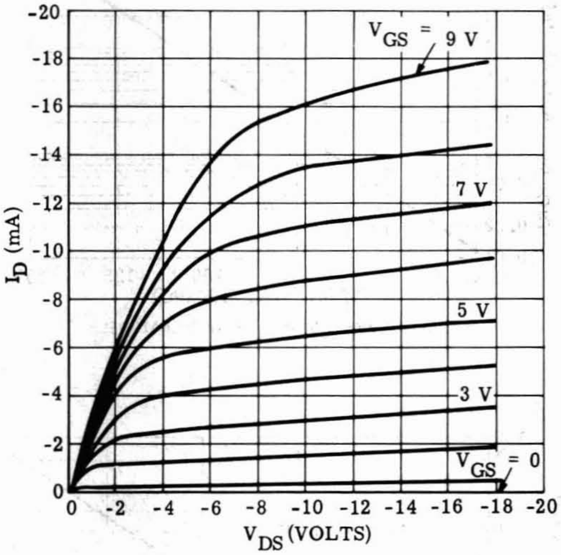


FIGURE 5 – MM2103 DRAIN CHARACTERISTIC

The region in Figure 5 where I_D does not vary appreciably with V_{DS} is called the pinch-off region, while the area within the circle is called the ohmic region. Figure 6 shows this region expanded for both positive and negative values of V_{DS}. In the ohmic region, when the device is turned fully ON, there is a linear relationship between drain current (I_D) and drain-to-source voltage (V_{DS}). The magnitude of this resistance can be changed by varying the gate-to-source voltage (V_{GS}). It is in this ohmic region that the FET is useful for both the chopper and analog switch applications. From Figure 6, it can be seen that to stay in this region the drain current must be kept within narrow limits. In other words, a relatively large value of load resistance (R_L) is required.

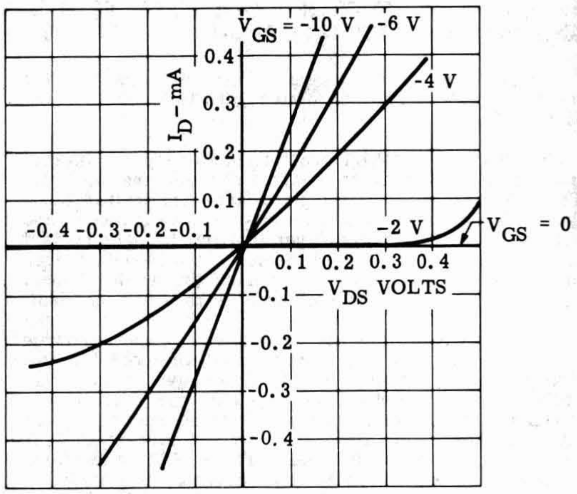


FIGURE 6 — MM2103 LOW LEVEL OUTPUT CHARACTERISTIC

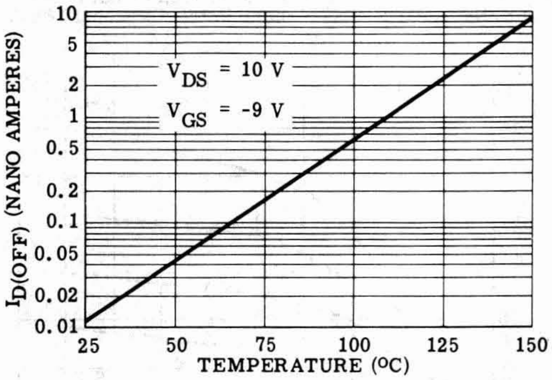


FIGURE 7 — 3N126 I_D (OFF) VS. TEMPERATURE

Leakage current $I_{D(OFF)}$ versus temperature for the 3N126, an N-channel junction FET, is plotted in Figure 7. A very low value of leakage current is important in chopper applications since this leakage current appears in the output circuit and produces an error voltage.

The leakage current of an IGFET is I_{DSS}. I_{DSS} versus temperature for the MM2103 P-channel IGFET is shown in Figure 8. Below 100°C the leakage is so low that accurate readings are more dependent upon available equipment and measurement techniques than on the magnitude of the leakage current. As a point of interest, however, the curve of Figure 8 can be projected back to room temperature (shown with dotted lines) and an I_{DSS} of $\simeq 0.003$ pA is read. At room temperature, of course, surface and package leakage account for considerably more than I_{DSS} with a resulting room temperature leakage of about 0.5 pA. This low leakage current, however, indicates that the OFF voltage error caused by this leakage current will be negligible for most chopper and analog switching circuits.

Drain-to-source resistance (r_{ds}), when the device is turned ON, is a very important characteristic in both chopper and analog switching circuits. Figure 9 shows r_{ds} versus V_{GS} for three values of temperature for the MM2103. On a static basis there is interest in only two states of the device — fully ON or fully OFF. The MM2103, a P-channel IGFET, needs a negative potential of 10-20 V to achieve an r_{ds} minimum. From Figure 9 at V_{GS} = -10 V and T = 25°C, find $r_{ds} \simeq 300\ \Omega$.

Consider Figure 10 which shows the same characteristic for the MM2102 N-channel IGFET; observe that for V_{GS} = 10 V and T = 25°C, $r_{ds} \simeq 100\ \Omega$.

One reason for this 3:1 improvement in r_{ds} is that in the P-channel device the carriers are holes, while in the N-channel device the carriers are electrons. The mobility of electrons is greater than that of holes, and therefore, is responsible for part of the improvement in r_{ds}. Since a low r_{ds} is needed in the ON condition, the N-channel IGFET is preferable for chopper and analog switching applications.

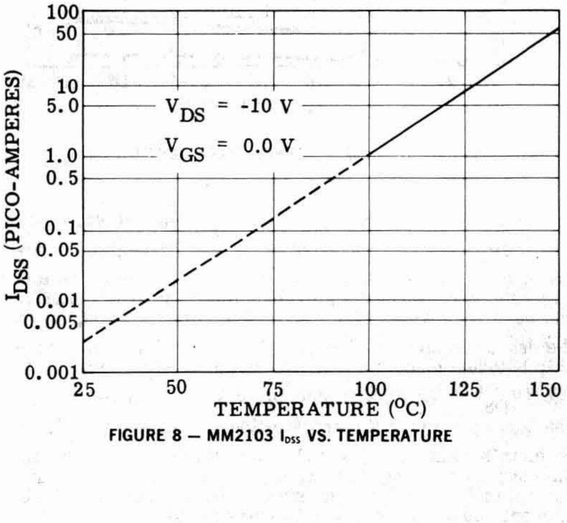


FIGURE 8 — MM2103 I_{DSS} VS. TEMPERATURE

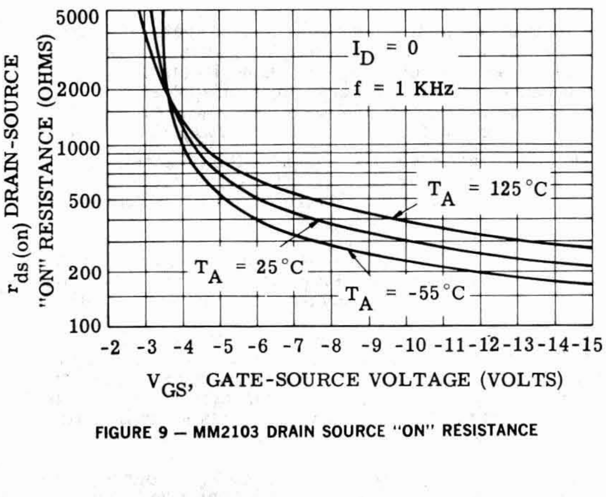


FIGURE 9 — MM2103 DRAIN SOURCE "ON" RESISTANCE

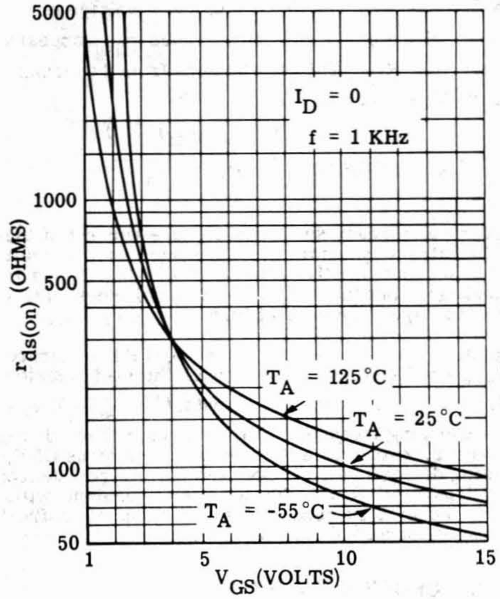


FIGURE 10 — DRAIN SOURCE "ON" RESISTANCE

It is important to know how much capacitance must be charged and discharged during transition times. Figure 11 shows a plot of the small-signal, common-source, short-circuit input capacitance C_{iss}, and reverse transfer capacitance, C_{rss} versus voltage of the N-channel and P-channel IGFET's. There is no appreciable change in either capacitance with voltage.

As shown in Figure 12, the capacitance of the JFET does vary with voltage (approximately the square root of the voltage). Figure 12 is a valuable design aid in determining the capacitance at a particular operating point.

C_{rss} is actually the capacitance from gate to drain, and it is this capacitance that causes the feedthrough of the control signal into the load. C_{iss} is the parallel combination of the gate-to-drain and gate-to-source capacitance, C_{gd} and C_{gs}.

C_{gd} and C_{gs} will together form a series capacitance in parallel with r_{ds}. When the FET is used as an analog switch, this capacitance will bypass r_{ds} at high input frequencies and this bypass-capacitance will therefore limit the frequency at which the FET can be used as an analog switch.

BASIC CHOPPER CIRCUITS

There are three basic chopper configurations: the series chopper, the shunt chopper and the series-shunt chopper.

The series chopper is the most commonly used. It is shown in Figure 13 with equivalent circuits for both the ON and OFF conditions. It was previously noted that in order to operate in the ohmic region when the device is turned ON, the drain current must be limited to a low value. Ordinarily, a large value of load resistance is used to limit the current. In the case of the series chopper, a high value of load resistance also minimizes the ON voltage error due to r_{ds}. The ON voltage error is given by:

$$V_{(ON)\ ERROR} = \frac{E_{in}\ (R_s + r_{ds})}{R_s + r_{ds} + R_L}$$

When the device is OFF, a small error due to the leakage of the FET is present. This OFF error is given by the formula:

$$V_{(OFF)\ ERROR} = I_{DG}\ R_L \quad \text{Where } (I_{DG} = I_{D(OFF)})$$

But as established earlier, the leakage of the FET (and in particular of the IGFET) is low, and this OFF voltage error will be very small. Typically, for an IGFET chopper with R_L = 100K, the (OFF) ERROR will be less than a microvolt at room temperature.

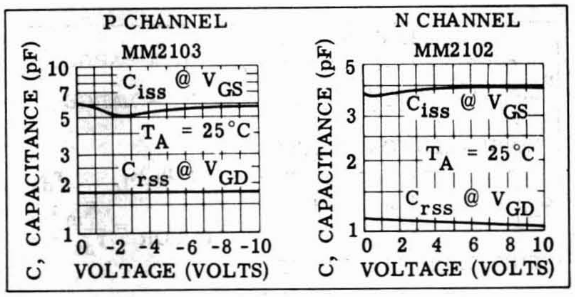


FIGURE 11 — CAPACITANCE

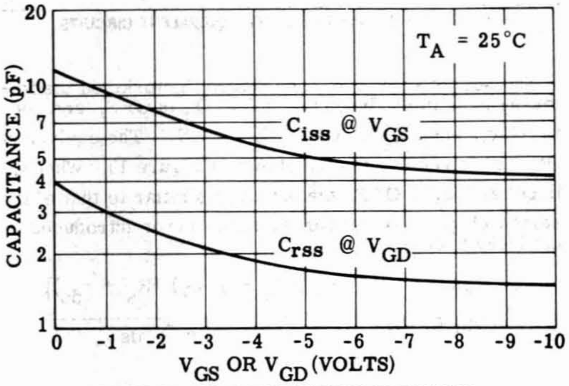


FIGURE 12 — 3N126 CAPACITANCE VS. VOLTAGE

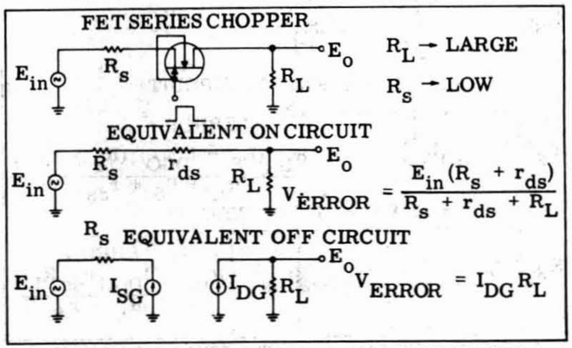


FIGURE 13 — FET SERIES CHOPPER EQUIVALENT CIRCUITS

The simple shunt chopper shown in Figure 14 performs the chopping function by periodically shorting the input to ground. From the ON equivalent circuit, Figure 14b, note that this is a circuit that will be advantageous to use if a large source resistance (R_s) is encountered. The formula for ON voltage error is:

$$V_{(ON)\ ERROR} = \frac{E_{in}\, r_{ds}}{r_{ds} + R_s} \quad \text{Where } R_L \gg r_{ds}$$

When the FET is turned OFF, the leakage current again produces an error voltage as shown by this formula:

$$V_{(OFF)\ ERROR} = \frac{I_{DG}\, R_s\, R_L}{R_L + R_s}$$

However, this error will usually be small compared to the drop across R_s.

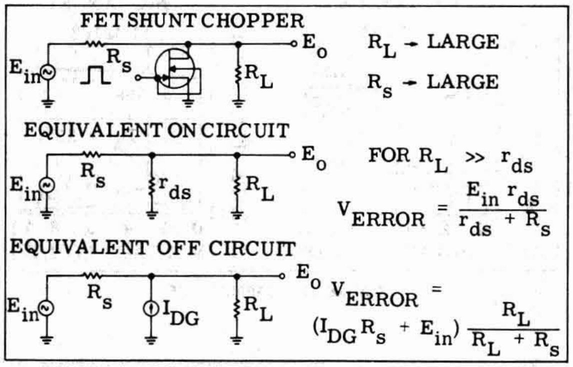

FET SHUNT CHOPPER
E_{in}
R_s
R_L
E_o
$R_L \rightarrow$ LARGE
$R_s \rightarrow$ LARGE
EQUIVALENT ON CIRCUIT
r_{ds}
FOR $R_L \gg r_{ds}$
$V_{ERROR} = \frac{E_{in} r_{ds}}{r_{ds} + R_s}$
EQUIVALENT OFF CIRCUIT
I_{DG}
$V_{ERROR} = (I_{DG} R_s + E_{in}) \frac{R_L}{R_L + R_s}$

FIGURE 14 – FET SHUNT CHOPPER EQUIVALENT CIRCUITS

The series shunt chopper, Figure 15, works on the following principle: When Q_1 is ON, Q_2 is OFF, and conversely, when Q_1 is OFF, Q_2 is ON. The equivalent ON-OFF circuits are also shown in Figure 15. When Q_1 is ON and Q_2 is OFF, the output is similar to that of the series chopper except for the small error introduced by the leakage of Q_2.

$$V_{(ON)\ ERROR} = \frac{R_L\left[(E_s + I_{DGO})\,(R_s + r_{ds})\right]}{R_L + R_s + r_{ds}}$$

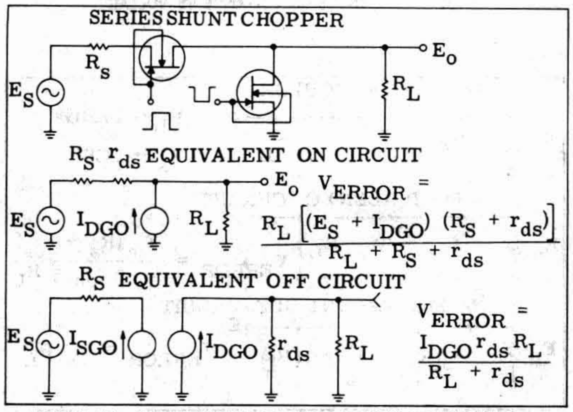

SERIES SHUNT CHOPPER
R_s
E_S
E_o
R_L
R_S r_{ds} EQUIVALENT ON CIRCUIT
E_o
I_{DGO}
$V_{ERROR} = \frac{R_L[(E_S + I_{DGO})(R_S + r_{ds})]}{R_L + R_S + r_{ds}}$
R_S EQUIVALENT OFF CIRCUIT
I_{SGO}
I_{DGO}
r_{ds}
$V_{ERROR} = \frac{I_{DGO} r_{ds} R_L}{R_L + r_{ds}}$

FIGURE 15 – SERIES-SHUNT CHOPPER EQUIVALENT CIRCUITS

When Q_1 is OFF and Q_2 is ON, the OFF voltage error due to the leakage of Q_1 is reduced since r_{ds2} appears in parallel with R_L. This can be seen from the formula for OFF voltage error.

$$V_{(OFF)\ ERROR} = \frac{(I_{DG_O})\,(r_{ds})\,(R_L)}{R_L + r_{ds}}$$

However, as already seen, the leakage current of the IGFET is extremely small, so the series shunt circuit cannot be justified for the sake of minimizing the error due to leakage. But the series shunt circuit does have a definite advantage in the area of high-frequency chopping.

In the simple series chopper when the FET is turned OFF, C_{rss} must be discharged through the load resistor R_L. The relatively long time constant ($C_{rss}R_L$) will limit the chopping frequency. In the series shunt chopper, however, every time the series device turns OFF, the shunting device is turned ON, and the low resistance of Q_2 will parallel R_L. The RC time constant will, therefore, be greatly reduced, and the chopping frequency can be increased significantly.

PRACTICAL CHOPPER CIRCUITS

In this section some actual chopping circuits are examined to determine the limitations of input voltage and chopping frequency.

SERIES CHOPPER

Figure 16 shows a simple series chopper. The maximum chopping frequency for this particular circuit was found to be approximately 200 kHz. This limitation is primarily due to the long RC time constant for discharging C_{rss} (C_{gd}) through the 10K load resistor. The maximum allowable input voltages were +2 V and -0.4V. The reason for these voltage limitations is the ON-OFF requirement of the JFET. For this particular N-channel JFET (3N126) the ON condition is $V_{GS} = 0.0V$, and the OFF condition is $V_{GS} \geq 4$ V. The ON condition is obtained by grounding the gate. When the source starts to go positive (i.e. the input voltage) there is actually a negative potential from gate to source. The negative gate-source voltage will cause r_{ds} to increase, and the device will start to turn OFF.

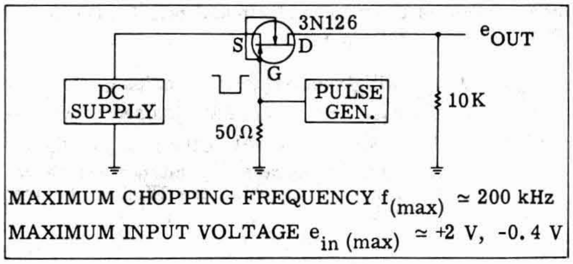

3N126
S
D
G
e_{OUT}
DC SUPPLY
PULSE GEN.
50Ω
10K
MAXIMUM CHOPPING FREQUENCY $f_{(max)} \simeq 200$ kHz
MAXIMUM INPUT VOLTAGE $e_{in\ (max)} \simeq +2$ V, -0.4 V

FIGURE 16 – PRACTICAL SERIES CHOPPER USING N CHANNEL JFET

The negative voltage limitation follows from this reasoning: When the input (source) goes more negative than -0.4 V, the P-N diode from gate to source becomes forward biased. Hence, the limitation of -0.4 V maximum.

In addition, there is a minimum input-voltage limitation, due to the feedthrough spikes in the output circuit. For inputs $< +10$ mV, the feedthrough spikes at high chopping frequencies become an appreciable part of the output waveform.

There are several circuit techniques useful for minimizing these spikes: (1) the control signal could be a "sloppy" square wave; i.e. dv/dt should be kept at as low a value as possible. Sharp corners on the waveform should be avoided. (A sine wave could be used.) (2) A capacitor could be applied at the output. (3) For fixed amplitude, a clipper circuit could be applied at the output.

When the FET is OFF, it can be seen that large negative input voltages will tend to turn the device ON again. The circuit of Figure 16 can be modified to get around some of these limitations. For instance, in order to overcome the limitation of maximum input voltage when the device is ON, the circuit in Figure 17 can be used. The operation of this circuit is as follows: When the FET is ON the driver transistor is OFF and a potential of +10 V appears at diode D_1. The diode is now reverse biased. When the input (source) goes positive, the 100K resistor from source to gate will make the gate follow in potential as long as the diode does not become forward biased. If the diode D_1 starts to conduct, a negative potential appears from gate to source and the FET will begin to turn OFF. For negative input-voltages there is no problem as before since the gate will follow the source until D_1 avalanches. The circuit of Figure 17 also improves the performance when the FET is OFF. When the FET is OFF, the driver transistor is turned ON, and when the gate of the FET is at -15 V, the FET will remain OFF for inputs up to -10 V.

The maximum input voltage of ±10 V, as outlined above, is here a function of the biasing voltage. The real limitation for the input voltage to this circuit is the source-to-gate breakdown voltage. This breakdown voltage is 50V for the JFET and 75 V for the IGFET. Hence, the maximum input voltage for this circuit with the proper bias would be ±22 volts or in the case of only positive inputs, the maximum would be +44 volts. (Roughly -6 volts are required to keep the 3N126 OFF.)

SERIES-SHUNT CHOPPER

In the previous discussion of basic chopper circuits, it was indicated that a series shunt chopper would be capable of high chopping frequencies. Such a circuit is shown in Figure 18. Chopping at a rate of 5 MHz was successfully accomplished with this circuit. An N-channel and a P-channel IGFET were used as the series and shunting device respectively. This allows one drive circuit for both devices. Now when the series device is turned OFF, the r_{ds} of the shunting device (≈ 200Ω) is parallelling R_L to ground and the RC time constant is reduced to 2% of its original value for an R_L of 10K.

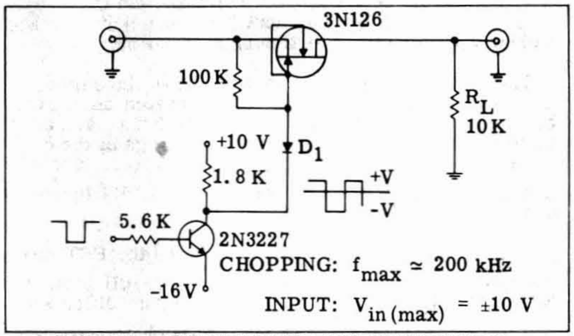
This circuit can also be modified to accept large ± values of input voltage as will be seen later in the discussion of analog circuits.

A series shunt chopper capable of low-level chopping is shown in Figure 19. Two N-channel IGFET's with matched C_{rss} are used in the circuit. The gate drives for the pair are produced by a current-mode astable multivibrator, similar to the one given in the Motorola Switching Transistor Handbook. The major reason for using a current-mode circuit is that the complementary outputs are not delayed in time with respect to each other. When one output is turning OFF, the other output must be concurrently turning ON. By matching C_{rss}, the feedthrough spikes in the output of the chopper can be nearly eliminated. Complete elimination of feedthrough spikes is difficult to achieve since the TURN-ON and TURN-OFF characteristics of IGFET's are not symmetrical.

ANALOG SWITCHING CIRCUITS

Most of what has already been said about choppers also applies to analog switches.

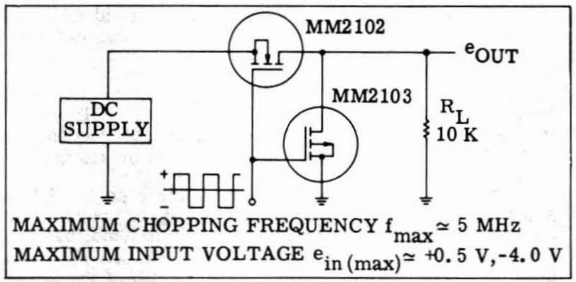
By definition the analog switch is a device that either transmits an analog signal without distortion, or completely blocks it.



CHOPPING: f_{max} ≈ 200 kHz

INPUT: $V_{in\,(max)}$ = ±10 V

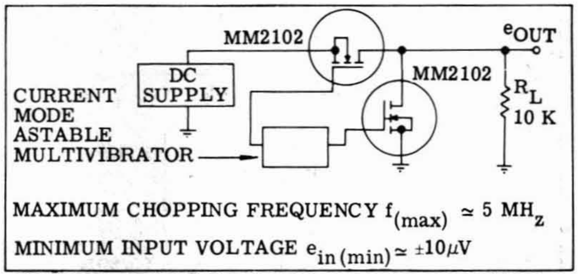
FIGURE 17 — JFET CIRCUIT FOR LARGE INPUT VOLTAGES



MAXIMUM CHOPPING FREQUENCY f_{max} ≈ 5 MHz

MAXIMUM INPUT VOLTAGE $e_{in\,(max)}$ ≈ +0.5 V, -4.0 V

FIGURE 18 — SERIES-SHUNT CHOPPER FOR HIGH FREQUENCY APPLICATIONS USING COMPLEMENTARY ENHANCEMENT MODE IGFET'S



MAXIMUM CHOPPING FREQUENCY $f_{(max)}$ ≈ 5 MHz

MINIMUM INPUT VOLTAGE $e_{in\,(min)}$ ≈ ±10μV

FIGURE 19 — SERIES-SHUNT CHOPPER FOR LOW INPUT VOLTAGES

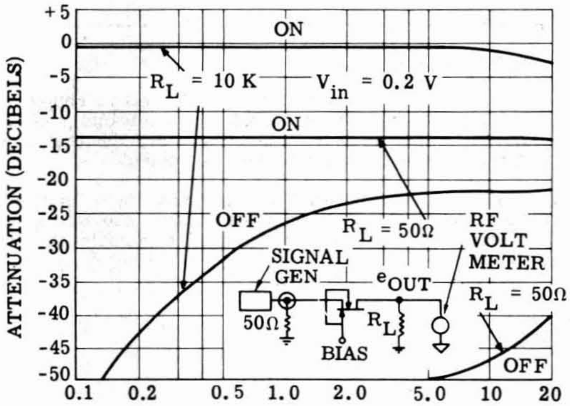


FIGURE 20 — FREQUENCY RESPONSE OF 3N126

Tests run on the N-channel JFET showed that the device is capable of passing input frequencies up to 20 MHz without appreciable distortion or attenuation.

The results of these tests are shown in Figure 20. The 3N126 N-channel JFET was operated as a switch between a sinusoidal input voltage of 0.2 V, and an RF voltmeter monitoring the output. Readings of the output voltage were taken for two values of load resistance R_L. The output was measured both with the FET turned ON and with the FET turned OFF.

For a load resistance R_L = 10K and the FET turned ON the curve shows the output to be 2.5 dB down at 20 MHz. The R_L = 10K curve for the OFF condition shows the output to be 22 dB down at 20 MHz or approximately 20 dB of separation between ON and OFF.

With a 50 Ω load considerable loss is experienced due to the r_{ds} (approximately 500 Ω) of the FET. The output is 14 dB down at 20 MHz for the FET turned ON, and 40 dB down for the FET turned OFF resulting in a separation of 26 dB.

The circuit in Figure 17 can be used as an analog switch as well as a chopper. This switch would be able to pass an input signal of ±10 volts with a frequency up to 20 MHz without appreciable distortion or attenuation.

Another analog switching circuit using an IGFET is shown in Figure 21. (The circuit could, of course, also be used as a chopper.) The problem of handling large ± values of input voltage is solved here in a somewhat different fashion than for the JFET circuit of Figure 17. There is no P-N junction from gate to source or drain to worry about since the gate is insulated from the rest of the device and thus diode D_1 is not required. There are, however, P-N junctions from substrate to source and substrate to drain. These junctions must not be allowed to become forward biased. One way to accomplish this is to cut off the substrate lead and leave it floating; however, since the substrate is connected to the can, this results in quite a bit of pick-up.

Another solution, as shown in Figure 21, is to diode couple the substrate to source, and then tie the substrate back to ground through a 100K ohm resistor.

This same modification can, of course, be done to the series shunt high-frequency chopper and enable this circuit to operate with large ± voltages at the input.

The analog switch might be used in a commutator circuitry as shown in Figure 22. Each switch has a three input AND gate in series with the gate drive. In order to turn a switch ON, a positive potential is required at the gate. To accomplish this the three inputs of the AND gate must be true or at a positive potential.

Assume that A_n is to be sampled. Suppose the logic common is a clock signal, D_{1n} is an order from the control system to sample A_n, and D_{2n} is ready signal from the device to be sampled. When all these conditions are true at the same time, switch Q_n will be turned ON and A_n will be sampled. The circuit of Figure 20 can, of course, be modified to accept large values of input voltage.

Since in this kind of commutating circuitry only one channel will be turned on at a time, an error will be introduced due to the leakages of the other switches. This error is equal to $(n - 1) \cdot I_{DSS} \cdot R_L$, if we assume the leakage to be the same for all the devices.

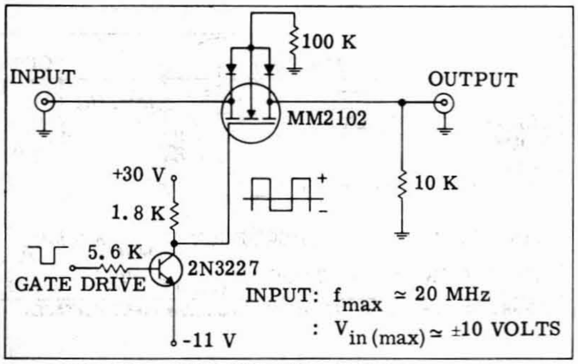

100 K
INPUT
OUTPUT
MM2102
+30 V
1.8 K
10 K
5.6 K
GATE DRIVE
2N3227
INPUT: $f_{max} \simeq 20$ MHz
: $V_{in\,(max)} \simeq \pm 10$ VOLTS
-11 V

FIGURE 21 – IGFET CIRCUIT FOR LARGE INPUT VOLTAGES

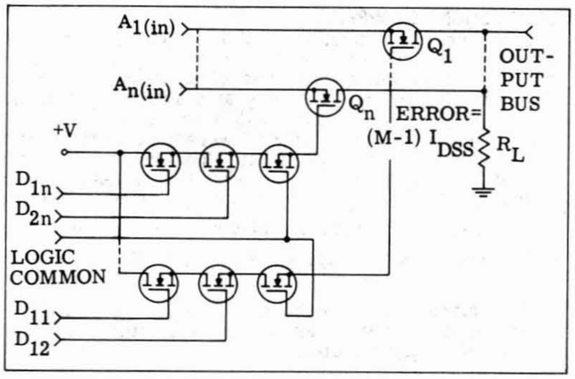


FIGURE 22 – COMMUTATOR NETWORK USING N CHANNEL IGFET

SUMMARY

It has been found that the FET used in chopper and analog switching circuits offers the advantage of no inherent offset voltage, also, another advantage, most circuits do not require an isolated drive.

From examining FET characteristics, it is seen that the extremely low leakage current of insulated gate devices results in extremely small errors in the output circuits.

The chopping frequency obtainable far surpasses that of the transistor chopper with 5 MHz for the series shunt chopper.

As an analog switch, the FET is able to pass input signals varying from DC to 20 MHz. In the OFF condition, the IGFET's offer a resistance of 10^{12} Ω.

In all, chopper and analog switching circuit applications seem like an area tailor-made for the FET.

FET CURRENT REGULATORS – CIRCUITS AND DIODES

INTRODUCTION

With the present rapid advancement of semiconductor technology, it was inevitable that a two terminal current regulator be developed. The present state of the art in current regulator diodes is merely the beginning of a wide range of current and power handling capabilities. Herein we touch upon the early development of current regulating devices; first the bipolar transistor circuits, then the original diode, and the potted circuits. Finally, field effect transistor circuits and the field effect diode are extensively treated. Included are numerous applications to spark the imagination.

HISTORICAL SKETCH OF CURRENT SOURCES

The constant current device in its original form was simply a high resistance in series with a power supply. A variation of the original sources was the vacuum tube. The most popular tube for this application was the pentode because of its large plate resistance and high voltage capability.

In the early 1950's, with the development of the transistor, current sources were reduced in physical size and improved in power efficiency. The number of terminal connections for the pentode, seven maximum, was reduced to three and even two. Primarily, the reduction in size allowed the encapsulation or potting of circuit assemblies which permitted their use as a unit circuit component.

The constant-current-diode was first introduced at the British Physical Society Exhibition in 1960.[1] As far as this author has been able to find out, it was only a working hypothesis. As a laboratory substitute the reverse leakage of a large germanium junction was used. This was a poor substitute; however, it did allow circuits to be constructed, thereby proving design concepts. Since these diodes were of a lesser quality than desired, they did not become popular.

Field-effect transistors, being analogous to the vacuum tube in many ways, gave rise to a variety of circuits which were quite acceptable as current sources, regulators, and limiters. One of the more important parameters of the junction field-effect transistor, I_{DSS}, is a measure of the drain current flowing with the gate-source shorted. Under this test condition the drain current remains significantly constant over a wide range of drain-source voltages. Coupled with the low output conductance, these devices make good current sources. Consequently, the natural evolution produced a constant current, two-terminal device, simply a junction field-effect transistor with an internal gate to source connection, the "constant-current diode".

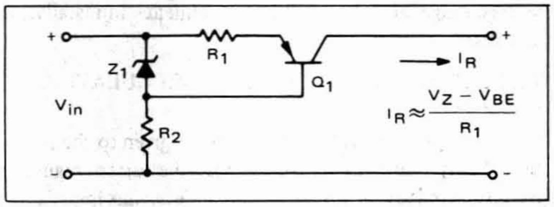


FIGURE 1 – Simple Series Regulator

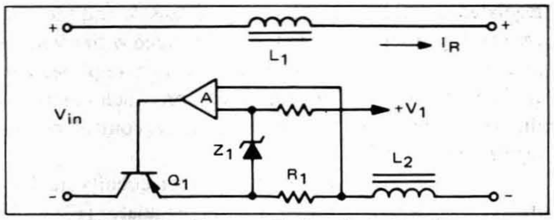


FIGURE 2 – Common-Emitter Series Regulator

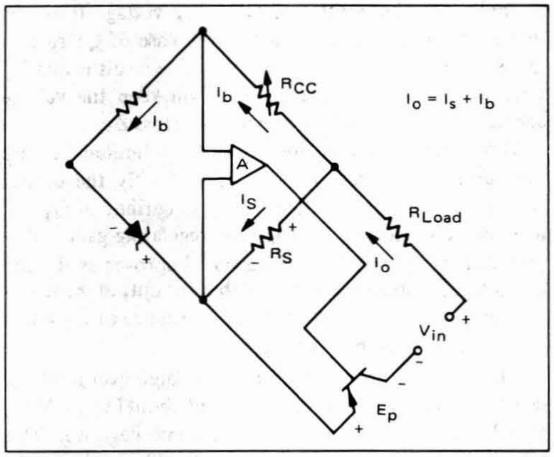


FIGURE 3 – Bridge-Balancing Regulator

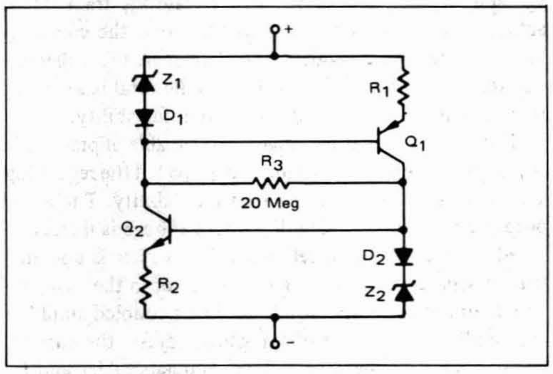


FIGURE 4 – 2-Terminal Constant-Current Device

Circuit diagrams external to Motorola products are included as a means of illustrating typical semiconductor applications; consequently, complete information sufficient for construction purposes is not necessarily given. The information in this Application Note has been carefully checked and is believed to be entirely reliable. However, no responsibility is assumed for inaccuracies. Furthermore, such information does not convey to the purchaser of the semiconductor devices described any license under the patent rights of Motorola Inc. or others.

Although field-effect transistors exhibit degrees of current limiting, these diodes have been especially designed for maximum impedance over the operating range, broad voltage range, and packaged for convenience in installation and space saving.

BIPOLAR TRANSISTOR CURRENT-REGULATING CIRCUITS

The emphasis in voltage regulators is given to the reduction of output impedance. In contrast, the current regulator is constructed to have the highest possible output impedance. Instead of sensing the voltage at the output terminals, the regulated current is passed through a resistor and the voltage developed across the resistor is compared with a voltage reference. Any voltage difference is then amplified and applied to a series regulating transistor which completes the regulating feedback connection by controlling the regulated current flow.

Three representative current-regulator circuits are illustrated in Figures 1, 2 and 3. The first regulator (Figure 1) utilizes R_1 as the current measuring resistor whose voltage is applied to the emitter of Q_1. The voltage from the reference diode, Z_1, is applied to the base of Q_1 so that Q_1 is itself the comparison element. The result is that Q_1 attempts to pass a current which will keep the voltage across R_1 closely equal to the voltage across Z_1.

Performance of this simple circuit is limited because the current measured by R_1 is not exactly the output current, since it also contains the base current of Q_1 and does not contain I_{CBO}. The only regulating gain is that provided by Q_1 itself. Performance improves as R_1 and the voltage across Z_1 are increased, but the output resistance can never surpass the collector-base resistance of Q_1 which is effectively shunting the output.

The output current, I_R, will be regulated over a voltage range extending from a positive limit of about $(V_{IN} - V_{Z1})$ to a lower limit which can even become negative. This assumes, of course, that Q_1 has suitable collector-base voltage and dissipation ratings. In this case the transistor is acting as a common-base amplifier so that the collector-base voltage rating, which is higher than the collector-emitter rating, may be used as long as the total base circuit resistance is held low enough to prevent instability.

The current regulator in Figure 2 is capable of practically any degree of performance required, provided the regulating amplifier is given the necessary gain and stability. The actual output current is sensed by R_1 whose voltage is then compared with that of the reference, Z_1, which is operated from a separate voltage source. Any error in the two voltages is amplified by the high-gain, direct coupled amplifier and applied to the base of Q_1 which adjusts the current, I_R, to minimize the error. The inductances L_1 and L_2 help to maintain a high output impedance at high frequencies where the regulating gain inevitably decreases and the transistors are unable to maintain a high impedance themselves. The use of inductances here is a direct dual of the use of a shunting capacitor to lower output impedance at high frequencies in a voltage regulator.

The bridge-balancing regulator[2] in Figure 3 is the refinement of the series-sensing type. Here the voltage to be regulated is the drop caused by the load current flowing through R_S, the sensing resistor. The feedback resistor is R_{CC}, a current control. The only current flowing through the current control is the bridge current. When the voltage drop in R_{CC} (due to I_b) equals the drop in R_S (due to I_S), the conditions for bridge balance are met, and a null exists across the input terminals of the error amplifier.

The output current of this circuit can be programmed by varying R_{CC} or changing I_b, either event causing the voltage drop across R_{CC} to change. In order to restore the balance condition, the voltage drop across R_S must change. This happens when the feedback to the "pass" element alters its conduction, so as to permit a change in load current in the proper direction and amount as to restore the balance.

The refinement then, is the capability of varying the output current, without changing the sensing resistance.

A novel variation of Figure 1 is shown in Figure 4. This circuit can readily be used as a component due to its two terminal configuration. The circuit consists of a pnp and an npn current source connected so that each regulates the other's reference. The current through the compensating diodes D_1 and D_2 is the same as the current through the transistor base-emitter junctions, which improves the tracking with temperature. The circuit requires a minimum voltage of $2\ (V_Z + V_D)$ for operation, the maximum is determined by transistor ratings. The value of R_3 is shown as a very high resistance, since its purpose is merely voltage neutralization.

FIELD-EFFECT TRANSISTOR CIRCUITS

Field-effect transistor circuits are very appealing as constant-current sources. Output impedances can range anywhere from the kilohm region to the tens of megohms, depending on the device and configuration used. FETs are available with values of g_{os} ranging from one-half to several hundred micromhos. Saturation voltages, or the minimum operating voltages, are in the region of one volt. The maximum voltage before breakdown occurs presently approaches the one hundred volt level. A nearly zero temperature coefficient is practical if the device is biased properly. Best of all, the FET constant-current source is usually a very simple, easy-to-design circuit. Either a fixed or an adjustable current source can be constructed with nothing more than a FET, a resistor (fixed or variable), and a battery.

Obviously, the simplest constant-current circuit is that of Figure 5, an FET with the gate and source shorted. In this case, the FET operates at I_{DSS}, the zero-bias drain current. The circuit output conductance is equal to the g_{os} of the FET. g_{os} at low frequencies is equal to y_{os}. For higher frequencies, depending on the value of the device output capacitance, series inductance could be added. I_o will change if V_{DS} changes according to the relationship,

$$\Delta I_o = \Delta V_{DS}\, g_{os}. \qquad (1)$$

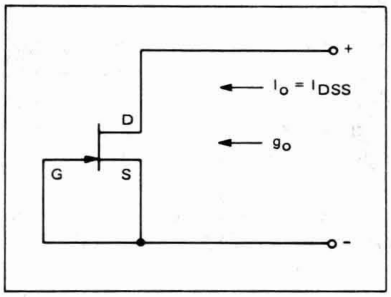


FIGURE 5 – Constant-Current Source Without a Source Resistor

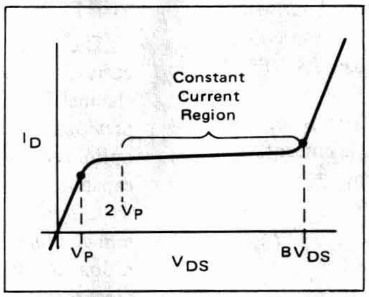


FIGURE 6 – FET Output Characteristic

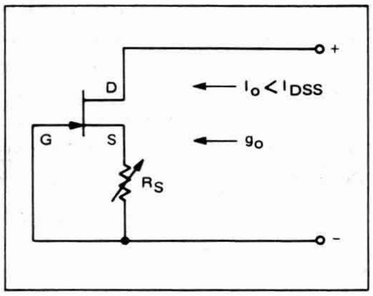


FIGURE 7 – Constant-Current Source With a Source Resistor

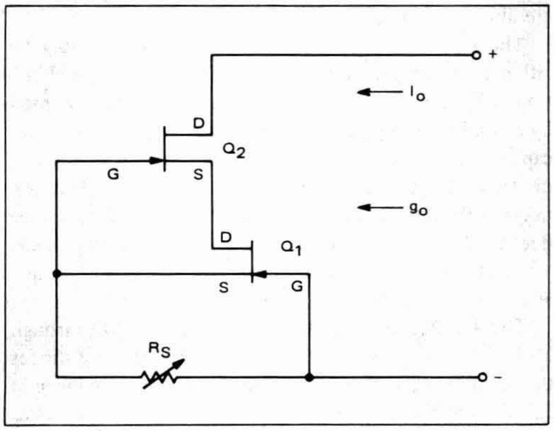


FIGURE 8 – Cascaded FET Contant-Current Source

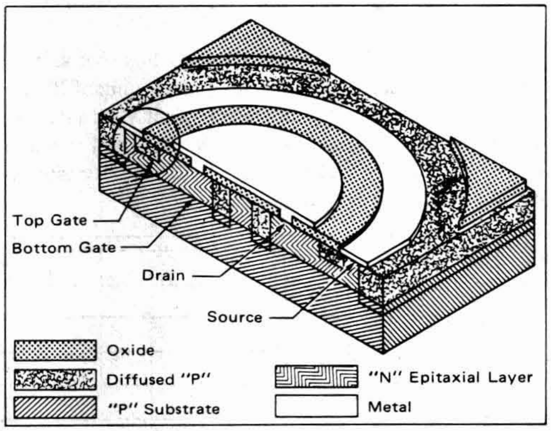


FIGURE 9 – Field Effect Diode

This simple circuit will deliver a relatively constant current from about 2 V_P (the pinch-off or threshold voltage) to BV_{DS} (the breakdown voltage drain to source), as shown in Figure 6.

With the addition of a source resistor shown in Figure 7, the previous circuit becomes capable of supplying any current below I_{DSS}.[3] The approximate value of gate-source voltage, V_{GS}, required for a given operating current, I_o, is:

$$V_{GS} = V_P \left[1 - \sqrt{\frac{I_o}{I_{DSS}}} \right] \qquad (2)$$

The source resistor, R_S, required is then:

$$R_S = \frac{V_{GS}}{I_o} \, . \qquad (3)$$

Resistor R_S may be variable to provide an adjustable current source. As R_S is increased and I_o decreased, the FET g_{os} decreases. The circuit output conductance decreases more rapidly than the FET g_{os} because of the feedback action produced across R_S. The circuit output conductance is:

$$g_o = \frac{g_{os}}{1 + R_S\,(g_{os} + g_{fs})} \approx \frac{g_{os}}{1 + R_S\, g_{fs}} \, , \qquad (4)$$

where g_{fs} is the real part of y_{fs}, the forward transfer admittance.

If two FETs are cascaded as shown in Figure 8, a much lower g_o value for a particular I_o can be obtained. Here I_o is regulated by Q_1 and $V_{DS1} = -V_{GS2}$. The dc value of I_o is controlled by R_S and Q_1. However, Q_1 and Q_2 both affect current stability.

Where $R_S = 0$

$$I_o = \frac{V_{DS2}\, g_{os1}\, g_{os2}}{g_{os1} + g_{fs2}} \, , \qquad (5)$$

and

$$g_o = \frac{g_{os1}\, g_{os2}}{g_{os1} + g_{os2} + g_{fs2}} \, , \qquad (6)$$

if $R_S = 0$ and $g_{os1} \approx g_{os2}$,

$$g_o = \frac{g_{os}}{2g_{os} + g_{fs} + R_S\,(g_{fs2} + g_{os}\, g_{fs} + g_{os2})} \, ,$$

$$\approx \frac{(g_{os})^2}{g_{fs}\,(1 + R_S\, g_{fs})} \, . \qquad (7)$$

When designing cascaded FET current sources, care must be exercised to ensure that both FETs are operating with adequate drain-source voltage, preferably $V_{DS} > 2\,V_P$, and that Q_2 has a significantly higher I_{DSS} than Q_1.

Notes worth mentioning—all FET circuits described are two terminal devices and can be easily used as circuit elements; all devices shown are N-channel JFETS. For P-channel devices reverse all polarities.

If a zero temperature coefficient (OTC) is required, each transistor must be operated at a specific current, I_{DZ}, the drain current for OTC, which is given by: [4]

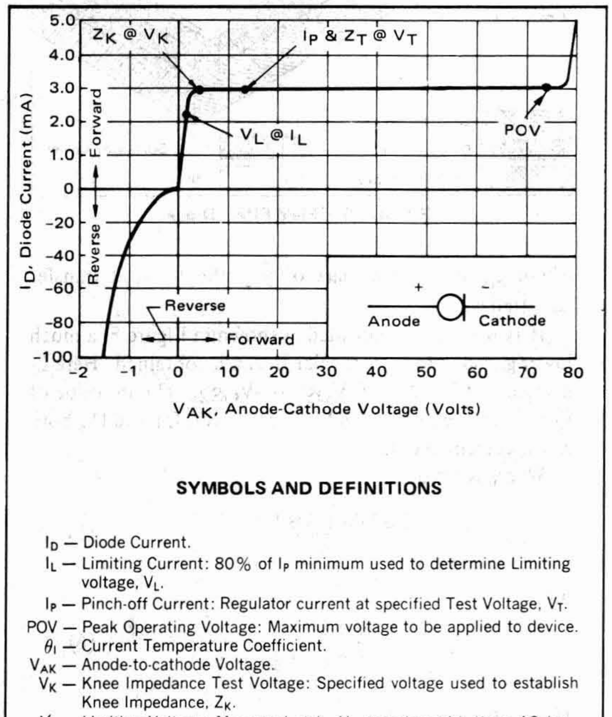
$$I_{DZ} \approx I_{DSS} \left(\frac{0.63}{V_P} \right)^2 . \qquad (8)$$

The gate-source bias voltage required is:

$$V_{GSZ} \approx V_P - 0.63 . \qquad (9)$$

By analyzing equation 8 we find that I_{DZ} increases as I_{DSS} increases. I_{DZ} can be as high as 1 mA for I_{DSS} units of 20 mA.

Operation at $I_D < I_{DZ}$, but near I_{DZ} will yield a positive TC if desired. Conversely, negative TCs will result if $I_D > I_{DZ}$. Negative TCs of 1.2 μA/°C are obtainable at 4 mA currents, with the 2N5361.



SYMBOLS AND DEFINITIONS

I_D — Diode Current.
I_L — Limiting Current: 80% of I_P minimum used to determine Limiting voltage, V_L.
I_P — Pinch-off Current: Regulator current at specified Test Voltage, V_T.
POV — Peak Operating Voltage: Maximum voltage to be applied to device.
θ_I — Current Temperature Coefficient.
V_{AK} — Anode-to-cathode Voltage.
V_K — Knee Impedance Test Voltage: Specified voltage used to establish Knee Impedance, Z_K.
V_L — Limiting Voltage: Measured at I_L. V_L, together with Knee AC Impedance, Z_K, indicates the Knee characteristics of the device.
V_T — Test Voltage: Voltage at which I_P and Z_T are specified.
Z_K — Knee AC Impedance at Test Voltage: To test for Z_K, a 90 Hz signal, v_K, with RMS value equal to 10% of test voltage, V_K, is superimposed on V_K:

$$Z_K = v_K / i_K$$

where i_K is the resultant ac current due to v_K
To provide the most constant current from the diode, Z_K should be as high as possible; therefore, a minimum value of Z_K is specified.
Z_T — AC Impedance at Test Voltage: Specified as a minimum value. To test for Z_T, a 90 Hz signal with RMS value equal to 10% of Test Voltage, V_T, is superimposed on V_T.

FIGURE 10 — Typical Current Regulator Characteristics

THE FET CURRENT-REGULATING DIODE

The natural evolvement of the circuit in Figure 5 is the current-regulating "diode", (CRD) which is in essence an N-channel JFET with an internal gate-source short. As stated previously, the design of these diodes has been especially optimized for high impedance and current regulating capability.

A semiconductor diode is defined as a two-electrode semiconductor device. Since the FET device met this definition, it was dubbed a diode. Figure 9 shows a typical cross-section of the diode. The circled area shows that the metal distinctively spans the gate-source areas. Typical current regulator characteristics, symbols, and definitions are illustrated in Figure 10.

The equivalent circuit of the diode would simply be either a current generator in series with a parallel combination of Z_T and a capacitance or the same generator shunted by a conductance g_T and the same capacitance. The shunt capacitance associated with Motorola's current regulating diodes is about 6 to 8 picofarads within the useful voltage range of the devices and is relatively constant. Capacitance does tend to increase and peak as the applied voltage nears V_L, but falls to zero as the voltage goes below V_L. Equivalent circuits are shown in Figure 11.

The 1N5283 through 1N5314, and MCL1300 through MCL1304 are two families of current-regulating diodes that cover a 220 microampere to 4.7 milliampere range in 32 different currents. Performance of several selected diodes is shown in Figure 12. These 10% tolerance units operate over a -55°C to +200°C range and have a moderate temperature coefficient (unless a OTC device is selected) that must be taken into account in precision circuitry which must operate over a significant temperature range. Maximum diode dissipation is a healthy 600 milliwatts derated at 4.8 mW/°C above 75°C T_L, the lead temperature, as explained in Figure 13. The minimum operating voltage, V_L ranges

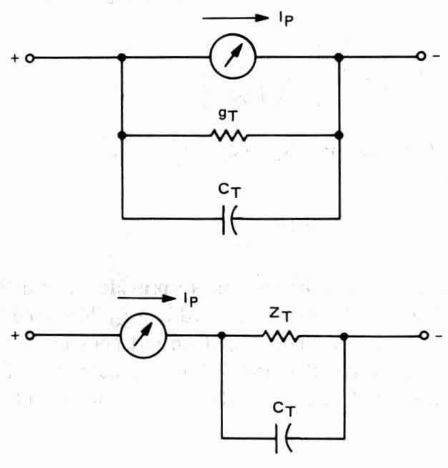


FIGURE 11 — Current-Regulator Diode Equivalent Circuits

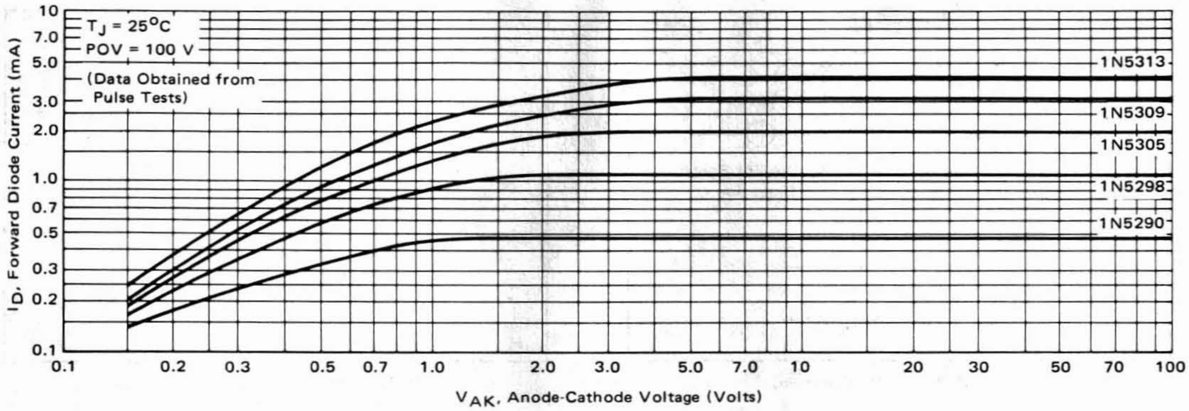
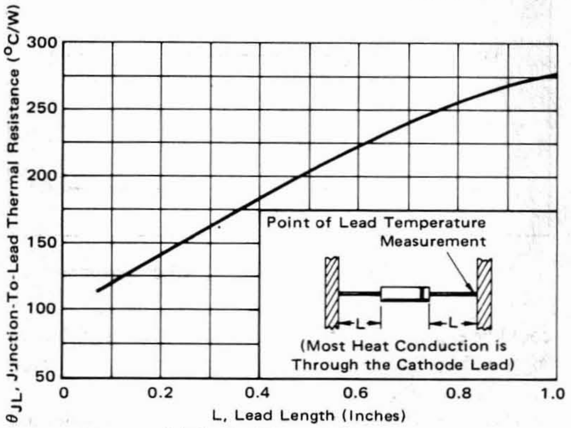


FIGURE 12 — Typical Forward Characteristics



(a) Typical Thermal Resistance

(b) Application Note

As the current available from the diode is temperature dependent, it is necessary to determine junction temperature, T_J, under specific operating conditions to calculate the value of the diode current. The following procedure is recommended:

Lead Temperature, T_L, shall be determined from:

$$T_L = \theta_{LA} P_D + T_A$$

where θ_{LA} is lead-to-ambient thermal resistance, T_A is the ambient temperature

and P_D is power dissipation.

θ_{LA} is generally 30-40°C/W for the various clips and tie points in common use, and for printed circuit-board wiring.

Junction Temperature, T_J, shall be calculated from:

$$T_J = T_L + \theta_{JL} P_D$$

where θ_{JL} is taken from Figure 13(a).

For circuit design limits of V_{AK}, limits of P_D may be estimated and extremes of T_J may be computed. Using data sheet information, changes in current may be found. To improve current regulation, keep V_{AK} low to reduce P_D and keep the leads short, especially the cathode lead, to reduce θ_{JL}.

FIGURE 13 — Thermal Resistance and Power Dissipation Calculations

from 1 to 3 volts, while the forward breakdown voltage is specified at 100 volts for the 1N series, giving a 97 to 99 volt range of constant current operation. Further detailed information is found on the device data sheets.

VARIANCES OF FET DIODE CONFIGURATIONS

Various diode configurations can be implemented to extend their maximum operating voltage and current ranges.

An extension of the dynamic voltage range is achieved by placing the devices in series as shown in Figure 14(a). Here it is necessary to introduce voltage-balancing resistances. The resistive values should be high since they shunt the output resistance. This technique is synonymous to the current-balancing required when paralleling zener diodes.

The current range of the diodes can be extended by the simple expedient of paralleling these devices as Figure 14(b) indicates. No special precautions are required. The resultant current is merely the summation of the individual currents.

There are instances where a bipolar device, one which regulates or limits in both directions, is of use. In this case, the diodes can be connected in series-opposing fashion as shown in Figure 14(c). During the cycle when one is limiting, the other is a forward-biased junction, producing a diode voltage drop.

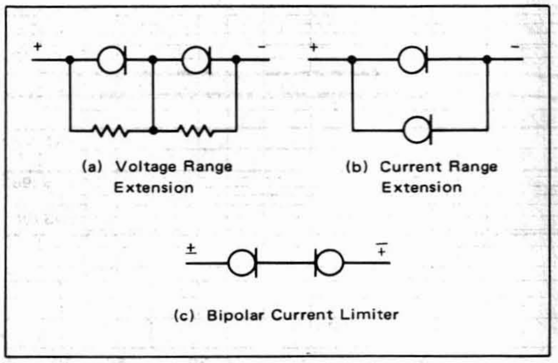
GENERAL APPLICATIONS

(a) Low voltage references, those below normal zener voltages of about 2.5 volts, or voltage references with good characteristics below about 6 volts can be easily attained using the current-regulator diode in series with a resistor. These diodes serve well as a precision millivolt reference source, where required. The diode simply drives a known resistor, producing an output reference voltage the value of which is determined by Ohm's law as indicated in Figure 15.

(b) As a zener diode source element the current-regulating diode has several prime advantages. Figure 16(a) and (b) illustrates the unmodified and modified zener regulator circuits, respectively.

Distinct advantages of the zener-CRD combination are that the maximum permissible V_{in} is determined by the maximum current-regulating diode voltage (100 volts), rather than maximum zener dissipation, and that variations in V_{in} have virtually no effect on V_{out}. In either circuit

$$\Delta V_{out} = \Delta V_{in} \frac{Z_{ZT}}{R_S + Z_{ZT}} \qquad (10)$$



(a) Voltage Range Extension

(b) Current Range Extension

(c) Bipolar Current Limiter

FIGURE 14 – CRD Variations

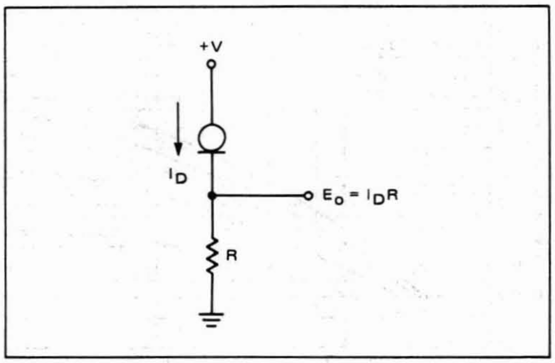


FIGURE 15 – Low Voltage Reference

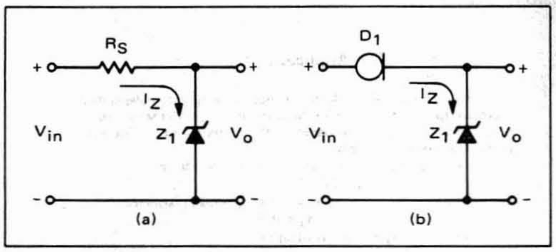


FIGURE 16 – (a) Standard and (b) Modified Zener Voltage Regulator

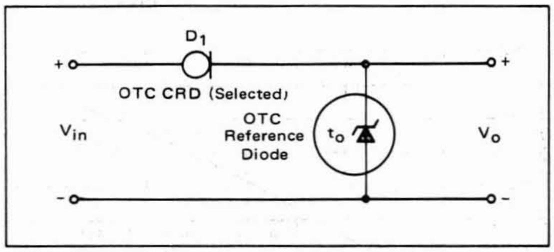


FIGURE 17 – A Most Absolute OTC Voltage Reference

where R_S is the series resistance, either discrete or the dynamic impedance (Z_T) of the CRD, and Z_{ZT} is the zener dynamic impedance.

Since Z_{ZT} is relatively low, it is obvious that as R_S increases in value the regulation, V_{out}/V_{in}, is improved. In practical circuits R_S is normally in the hundreds or thousands of ohms, while the CRD can present megohms. This yields improvements of three to four orders of magnitude.

As V_{in} varies I_Z also varies according to

$$\Delta I_Z = \frac{\Delta V_{in}}{R_S + Z_{ZT}} . \qquad (11)$$

From the relationship given it is obvious that as V_{in} increases, the current through, and consequently, the power dissipated in the zener increases. V_{in} is thus limited by the power rating of the zener. Using a CRD alleviates this problem entirely.

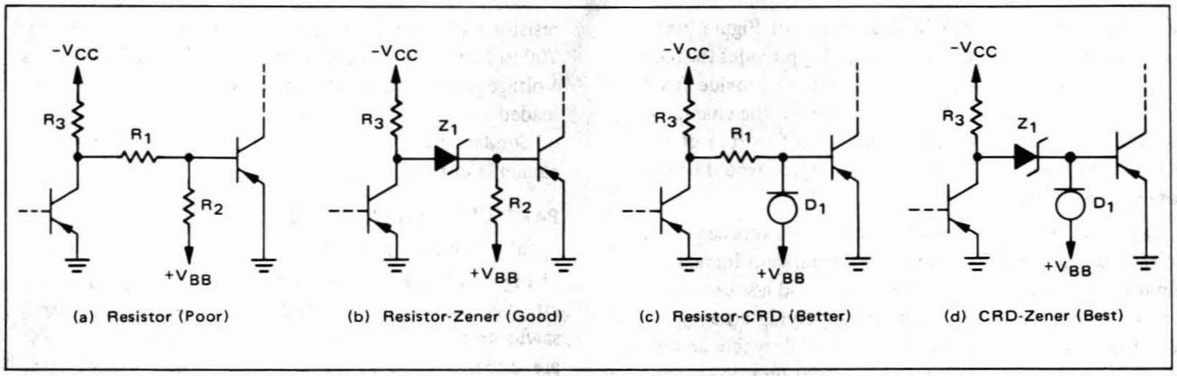
A most absolute voltage reference can be implemented using a zener-CRD combination as Figure 17 suggests. The CRD exhibits a zero temperature coefficient characteristic at currents around 0.5 mA. A Motorola family of OTC reference diodes also operates on zener currents of 0.5 mA. A combination of the two with OTC characteristics, would yield a constant reference voltage between the input voltage limits of 2 $V_L + V_Z$ to POV + V_Z (practically, about 8.4 to 106.4 volts with a 6.4 V zener), and the temperature range of 0°C to 100°C. A change in V_{out} of about 10 mV could be expected over the V_{in} range. A TC of 0.001%/°C could be expected over the temperature range. The devices suggested are the 1N4569A reference diode and a selected 1N5290 current-regulator diode.

When voltages lower than system power supplies are required and a zener is used to provide same, another advantage of the CRD is one of tremendous decoupling of either ripple or noise on the supply lines. Due to the high ratio of the dynamic impedance of the CRD as compared to the zener, an attenuation of about 100 dB can be realized at frequencies up to several hundred kilohertz.

(c) A standard form of dc coupling, as shown in Figure 18(a), is much improved by the substitution of a zener diode for resistor R_1, as illustrated in Figure 18(b). This modification substantially reduces the loss of gain introduced by the coupling circuit. A similar increase in gain is achieved by the substitution of a CRD for R_2, as Figure 18(c) indicates. Furthermore, as might be expected, a coupling circuit with very desirable characteristics results from a combination of these methods. Figure 18(d) shows an amplifier stage incorporating this approach.

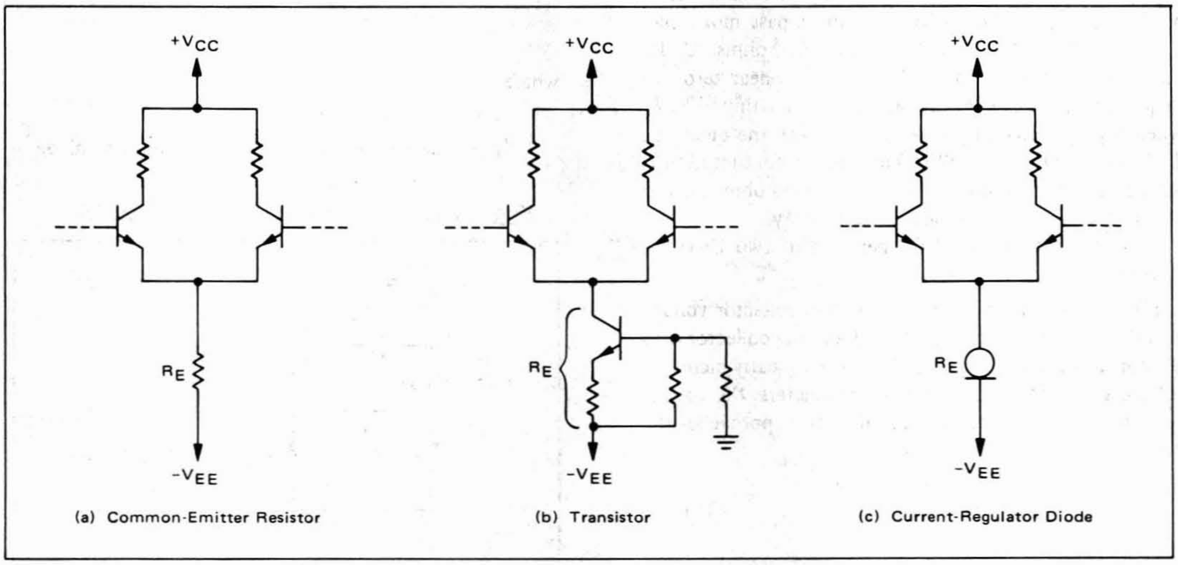
(d) The common mode rejection ratio of emitter-coupled differential amplifiers is directly proportional to the common-emitter impedance. For this reason current sourcing in the emitter is commonly used.[5] Figure 19(a) illustrates the use of a resistor voltage combination, while Figure 19(b) is the biased-transistor version. An improvement over both of these methods is attained by the use of a CRD as shown in Figure 19(c).

When high input impedance is required, the differential amplifier incorporates the Darlington input configuration


-VCC
R3
R1
R2
+VBB
Z1
D1

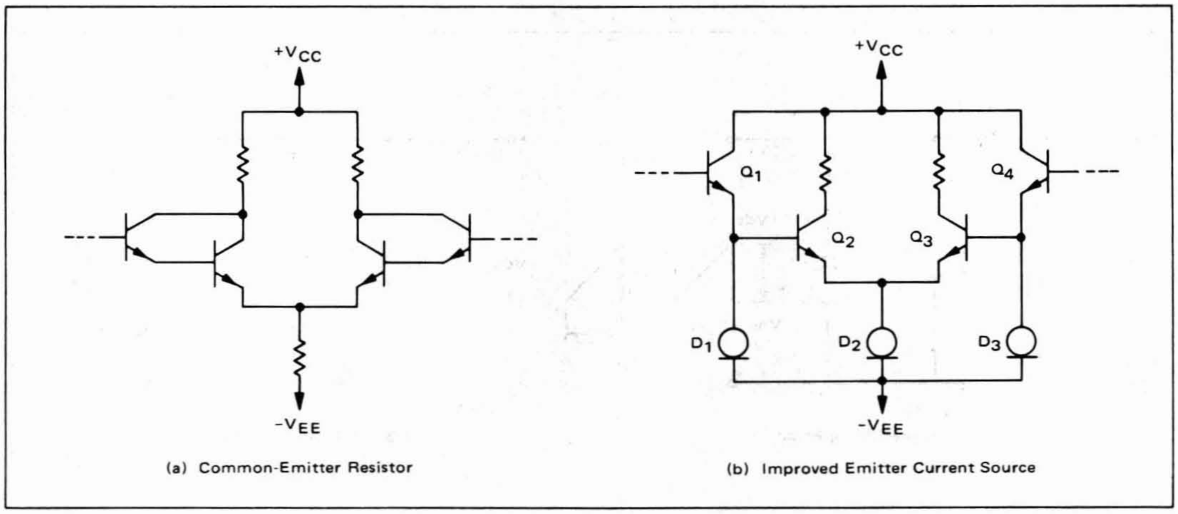
(a) Resistor (Poor) (b) Resistor-Zener (Good) (c) Resistor-CRD (Better) (d) CRD-Zener (Best)

FIGURE 18 – DC Coupling Methods



(a) Common-Emitter Resistor (b) Transistor (c) Current-Regulator Diode

FIGURE 19 – Current Sources in Differential Amplifiers


+VCC
-VEE
Q1
Q2
Q3
Q4
D1
D2
D3

(a) Common-Emitter Resistor (b) Improved Emitter Current Source

FIGURE 20 – Common-Emitter Current Sourcing for Darlington-Input Differential Amplifier

of Figure 20(a). The modified amplifier of Figure 20(b) has 3 current sources. Current source D_2 provides the high common mode rejection, while D_1 and D_3 provide fixed currents in Q_1 and Q_4. Using this method, the characteristics of transistors Q_1 and Q_4 are not a function of the betas of the input transistors Q_2 and Q_3, as would be the case with a standard Darlington circuit.[6]

(e) The emitter resistor of emitter-followers can often be replaced by a CRD, resulting in a significant increase in input impedance, a gain closer to unity, and less obvious is a lower transistor dissipation when supplying a heavy external load. Figure 21 illustrates an example where an output of 5 volts peak is required in a 600 ohm load, with ± 10 volt supplies. When the input peak is +5 V the load current is 8.33 mA. The drop across R_1 is now 5 V and in order that Q_1 is not cut off, R_1 must pass more than 8.33 mA. Thus R_1 should be less than 600 ohms. Under quiescent conditions, the emitter of Q_1 is near zero and so quiescent current is 16.7 mA and Q_1 is dissipating 167 mW. When R_1 is replaced by an 8.33 mA CRD, the quiescent dissipation will be 83 mW. Thus power consumption is halved, and since the transistor load is 600 ohms instead of 300 ohms, the voltage gain is nearer unity.

Observe that the parallel operation of two CRD's is used to obtain the 8.33 mA.

(f) In amplifier circuits where the collector voltage is defined by an external feedback loop, the collector load resistor can be replaced by a CRD to give a greatly increased voltage gain. Using T equivalent parameters, the voltage gain, Av, of a grounded-emitter amplifier approaches the value given by:

$$Av = \frac{r_c}{r_e}. \qquad (12)$$

In order to realize this gain a large collector load is required. This can be attained by replacing the collector resistor with a CRD, resulting in actual voltage gains from 700 to 1000 with currently available small-signal transistors. Voltage gain will be reduced if the amplifier is substantially loaded.

Similar results can be obtained using the CRD as drain elements in FET circuits.

PARTICULAR APPLICATIONS

(a) Simple Sawtooth Generators[7]. The two circuits of Figure 22 make use of the Motorola four-layer and field effect diodes to provide exceedingly simple, fixed-frequency sawtooth generators with linear output waveforms. Shown are circuits for both positive and negative going ramps. The principal design equation for these circuits is:

$$T = \frac{CV_{BR}}{I_P}, \qquad (13)$$

where

T = period of one cycle

I_P = pinch-off current of the current limiting diode

C = timing capacitor in μF

V_{BR} = breakover voltage of the four layer diode

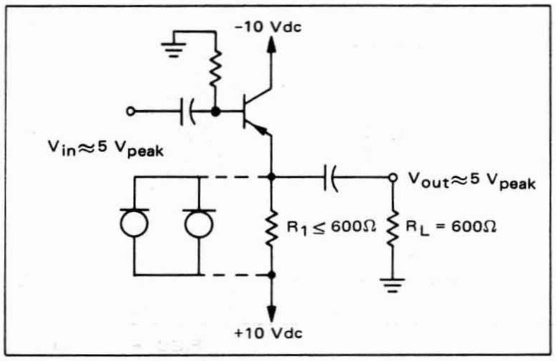
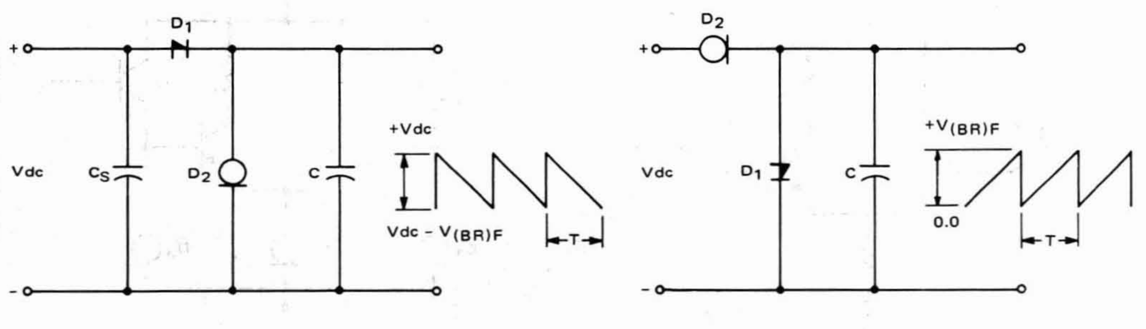


FIGURE 21 – Improved Emitter-Follower



(a) Negative-Going Ramp

(b) Positive-Going Ramp

FIGURE 22 – Sawtooth Generator Circuits

(b) Triangular-Wave Generator. The use of the CRD in series–opposing fashion makes possible the generation of a high-quality triangular wave from a sine or square wave source as Figure 23 illustrates. Square wave drive results in a better waveform at the zero crossings. Here the output frequency is identical to the input frequency. The peak to peak amplitude is given by:

$$V_{o\ p\text{-}p} = \frac{It}{C} \qquad (14)$$

where $V_{o\ p\text{-}p}$ is in volts, C is in microfarads, I is in milliamperes and t is in milliseconds.

and $V_{o\ p\text{-}p} < V_{in\ p\text{-}p}$.

(c) Square Wave Generator or an Improved Clipper. A popular circuit and the improved version is shown in Figure 24(a) and (b) respectively. Note the vast improvement in the output waveform as illustrated. The output frequency is naturally the same as the input frequency. The peak value of the output waveform is:

$$V_{o\ pk} \approx (0.7 + V_Z)\ \text{volts} \qquad (15)$$

where V_Z is the zener voltage in volts.

The improved circuit also has the additional advantages of increased efficiency and reduced power dissipation in the zener.

(d) Stairstep Generator. This circuit operates on the same principle as the triangular wave generator. A single CRD is used and the ratio of I to C is much greater. The circuit would appear as shown in Figure 25. The height of each step is defined by Equation 14. The time between steps is governed by the period of the input pulse. In this application $V_{CC} - V_{CE(sat)}$ of Q_1 must exceed the level of the highest step by the least 2 V_L of the CRD.

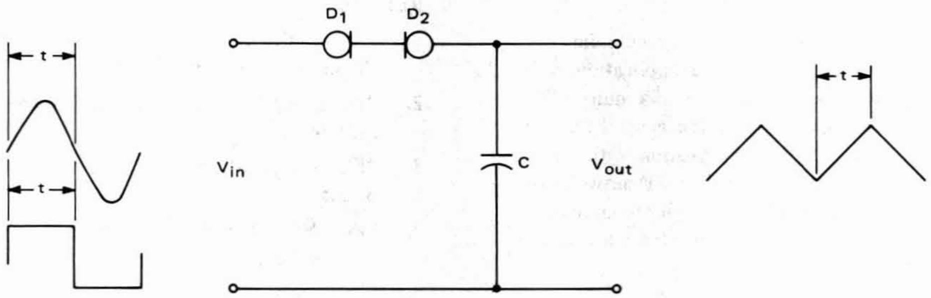
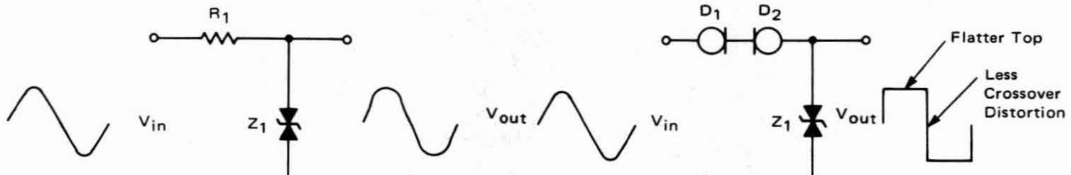


FIGURE 23 — Triangular-Wave Generator or Integrator



(a) Resistor-Zener

(b) CRD-Zener

FIGURE 24 — Square-Wave Generator or Clipper

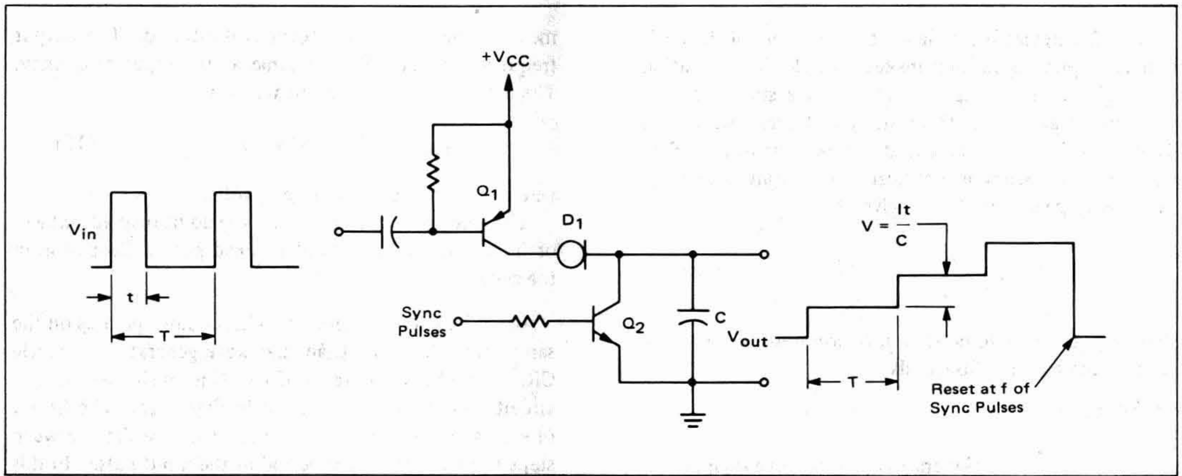


FIGURE 25 – Stairstep Generator

CONCLUSION

In the course of this paper, the current-regulating diode has been shown, by theory and practical application, to be a most versatile component in the design of a multitude of basic circuits. Their application to the general fields of electronics is only limited by the imagination of the user.

If the advantages gained by using the CRD outweigh the disadvantage of added cost, the CRD is highly recommended. An inexpensive plastic FET can also serve the purpose, but with poorer overall characteristics.

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8. Hemingway, Op. Cit.

SELECTING VARACTOR DIODES

THE ENGINEER has a valuable tool in the varactor diode. This device combines all the advantages of solid-state operation with high-power output in the uhf region and beyond. The engineer, however, faces a bewildering task in specifying varactors for harmonic generator applications. New varactors are introduced at an accelerating rate, obsoleting older types. To compound the problem, many new design criteria are proposed and publicly debated.

Solution to this maze of devices and data is a varactor selection procedure based on experience, theory and common sense. This suggested procedure incorporates requirements for performance, cost and delivery.

Varactor diodes are actually a very broad class of semiconductor devices designed for a wide variety of applications including electronic tuning, harmonic generation and parametric amplification. As might be expected, specialized varactor types have been developed for each of these applications. In the case of high-power harmonic generation, the preferred types are abrupt-junction and step-recovery silicon devices. Of these, the step-recovery device typically exhibits a higher power output at any given frequency.

Silicon vs. Gallium Arsenide

Silicon, as a material for varactors, offers the advantages of more advanced technology, proven reliability, better uniformity, lower cost, better thermal resistances and higher breakdown voltages. The other major varactor material, gallium arsenide, has the advantage of higher efficiency and/or higher frequency operation. For most applications at frequencies below the k_u band, silicon varactors are most appropriate.

With silicon, a diffused epitaxial structure is recommended as giving the most uniform, efficient, and reliable device that present technology can produce. Diffused epitaxial means a high resistivity layer is epitaxially grown on a low resistivity substrate. This is followed by a low resistivity gaseous diffusion to form the junction. Usually, the epitaxial layer and the substrate have a donor impurity (N_D) while the diffusion is "doped" with acceptor impurities (N_A).

Packages

The varactor package is a major element in device selection. Basic functions of the package are protection against hostile environments and provisions for electrical and thermal connections. For varactors, the preferred package is a hermetically sealed enclosure with leads at either end. Common packages are the DO-4 stud, the DO-7 glass, the cartridge, the pill with prongs and the pill. These packages are illustrated in Fig. 2.

A DO-4 stud has excellent thermal properties, is easy to mount, has high lead inductance and is limited in its ability to withstand severe shock and vibration. The DO-7 glass package is small, inexpensive, easy to mount, rugged, has high lead inductance and somewhat higher loss at microwave frequencies than ceramic packages. A cartridge, though relatively bulky for small circuits, is rugged, fairly easy to mount and has good thermal properties. On the other hand, both case capacitance and lead inductance are high and the package is costly. The pill with prongs is small, relatively rugged, fairly easy to mount and has low capacitance and inductance. However, it has limited thermal dissipation and is relatively costly. The pill has the same attributes and limitations as the pill with prongs except that it is more difficult to mount.

Good Thermal Path Essential

Since harmonic generation is frequently at high powers, a good thermal path is often essential to varactor operation. Usually, when varactor power

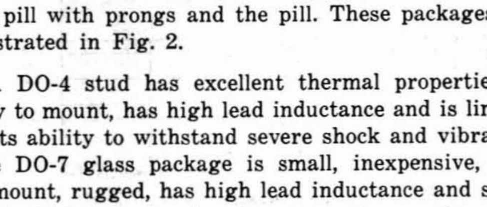


Fig. 1. Cross section of typical diffused epitaxial varactor.

dissipation exceeds 5 watts, an external heat sink, either a metal block or a finned assembly, should be used. These thermal considerations, of course, become even more important when operation at an elevated ambient is required.

Since most varactor dice are bonded directly to a package pedestal on only one side, it is usually necessary to provide a good thermal path only on the pedestal side. With the ceramic packages, this pedestal is actually the side with the smaller diameter. The reason for this apparent anomaly is that the top cap, which is welded to the package, must have the larger diameter to allow the cap-welding electrodes to pass over the pedestal side.

Satisfactory holding collets for the ceramic packages are shown in Fig. 3. These collets, made of brass, grip the pedestal side of the varactor package. When additional heat sinking is required, fins can be attached to the collet.

As an alternative mounting method, the ceramic packages can be soldered to mounting studs as shown in Fig. 3. Often the varactor manufacturer performs this mounting. This mounting method offers the lowest system cost.

Synthesizing Varactor Specifications

One of the basic tasks of the multiplier engineer is to synthesize a set of varactor specifications that provide the desired performance. In some instances, the varactor data sheets will provide performance curves based on measured performance that will indicate the varactor's suitability. In other cases, however, it is necessary to calculate power, frequency and efficiency. The literature offers several usable

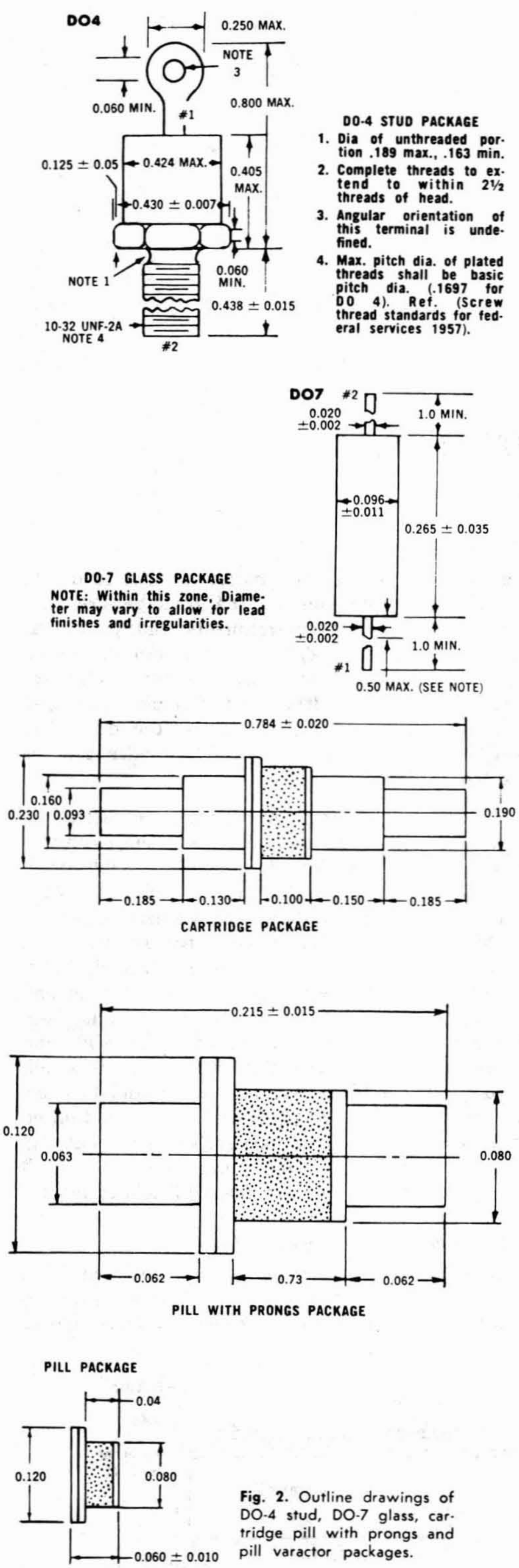
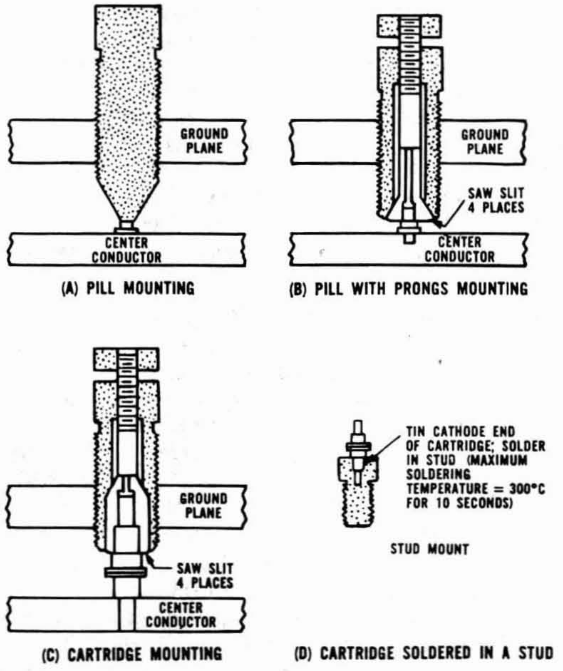

DO4
0.250 MAX.
NOTE 3
0.060 MIN.
#1
0.800 MAX.
0.125 ± 0.05
0.424 MAX.
0.405 MAX.
0.430 ± 0.007
NOTE 1
0.060 MIN.
0.438 ± 0.015
10-32 UNF-2A NOTE 4
#2
DO-4 STUD PACKAGE
1. Dia of unthreaded portion .189 max., .163 min.
2. Complete threads to extend to within 2½ threads of head.
3. Angular orientation of this terminal is undefined.
4. Max. pitch dia. of plated threads shall be basic pitch dia. (.1697 for DO 4). Ref. (Screw thread standards for federal services 1957).
DO7
#2
0.020 ±0.002
1.0 MIN.
0.096 ±0.011
0.265 ± 0.035
DO-7 GLASS PACKAGE
NOTE: Within this zone, Diameter may vary to allow for lead finishes and irregularities.
0.020 ±0.002
1.0 MIN.
#1
0.50 MAX. (SEE NOTE)
0.784 ± 0.020
0.160
0.230
0.093
0.190
0.185
0.130
0.100
0.150
0.185
CARTRIDGE PACKAGE
0.215 ± 0.015
0.120
0.063
0.080
0.062
0.73
0.062
PILL WITH PRONGS PACKAGE
PILL PACKAGE
0.04
0.120
0.080
0.060 ± 0.010

Fig. 2. Outline drawings of DO-4 stud, DO-7 glass, cartridge pill with prongs and pill varactor packages.


GROUND PLANE
CENTER CONDUCTOR
GROUND PLANE
SAW SLIT 4 PLACES
CENTER CONDUCTOR
GROUND PLANE
SAW SLIT 4 PLACES
CENTER CONDUCTOR
TIN CATHODE END OF CARTRIDGE; SOLDER IN STUD (MAXIMUM SOLDERING TEMPERATURE = 300°C FOR 10 SECONDS)
STUD MOUNT

(A) PILL MOUNTING

(B) PILL WITH PRONGS MOUNTING

(C) CARTRIDGE MOUNTING

(D) CARTRIDGE SOLDERED IN A STUD

Fig. 3. Suggested mountings for ceramic packages.

theories including those of Penfield and Rafuse[1], Burckhardt[2], and Rafuse and Steinbrecker[3]. (See Figs. 4 to 8.)

Of these, the Penfield and Rafuse model is the most popular. Its most important weakness is that it is based on a $\gamma = 1/2$ law (with some discussion for $\gamma = 1/3$) and that the voltage is limited to the range between 0 volt and voltage breakdown. Burkhardt has extended the Penfield and Rafuse theory to include the varactor into the forward voltage region. The amount of overdrive is somewhat arbitrary, but the results do indicate a considerable increase in power with smaller increases in efficiency and impedances. Burckhardt has also extended the theory to include step-recovery varactors. He also considered briefly the effect of a voltage variable R_s. He has not taken into account conductivity modulation resulting from many new carriers introduced into the high resistivity regions during the forward voltage portion of the cycle. The new Rafuse and Steinbrecker theory for step-recovery devices tends to confirm Burckhardt's results. A comparison of all three theories is shown in the table on p. 6.

A comparison of the predictions of these theories with the measured performance of a modern step-recovery varactor shows the discrepancies between theory and practice. For example, the 1N5155 varactor in a particular tripler circuit has an input of 5 watts at 2 gigacycles and an output of 2.1 watts at 6 gigacycles. The 1N5155 has a $V_B = 40$ volts, $C_{min} = 1.5$ picofarads, $W_c = 7.4 \times 10^9$, and $\gamma = 0$. Burckhardt would predict an efficiency of 70 per cent and an output of 0.64 for this device. Rafuse and Steinbrecker would predict an even higher efficiency, 89 per cent, and an output of 1.46 watts. The high efficiency and low-power output predictions of the theories can be explained by the conservative amount of overdrive assumed.

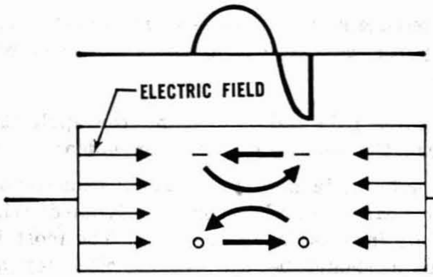


Fig. 4. Operation of a varactor occurs when a forward voltage is applied and carriers are injected across the junction. However, before they can combine and result in a d-c flow, the applied voltage reverses and the carriers are returned to the point of origin in a bunch. This results in an abrupt cessation of reverse current and the waveform is rich in harmonics.

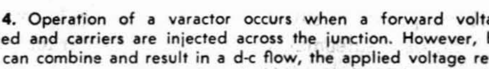
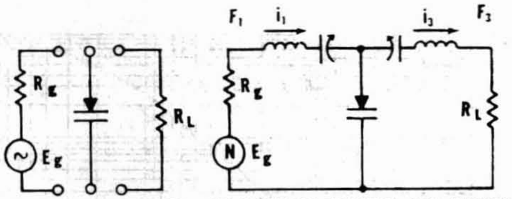


Fig. 5. Equivalent circuit of a varactor diode used by Penfield and Rafuse. The limitations of this model are that R_S is constant, C follows A $\gamma = 1/2$ law, the voltage is restricted between 0 volt and breakdown and that the package parasites are part of the external circuit.

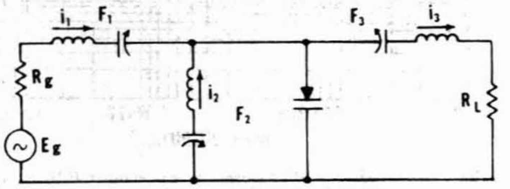
The recommended procedure for using the theories is to calculate an effective cutoff frequency from a known performance (for example, from results guaranteed by the manufacturer). Then efficiencies with other frequencies and multiplication ratios can be calculated with the formulas. With regard to power, it is safe to multiply the calculated power by about 4 without seriously overdriving the varactor. Impedance formulas can probably be used directly. Remember, however, that the resistances given by the formulas are in series with the effective junction capacitance, which typically is 2 C_{min} for $\gamma = 0$ devices.

The performance of varactors in circuits is a function of both varactor and circuit attributes. With reasonably careful circuit design, the varactor limits power, efficiency and operating temperature. However, the varactor has only secondary effects on bandwidth or tuning range limits. Once a design is completed, varactor uniformity can also have a profound effect on these performance parameters.

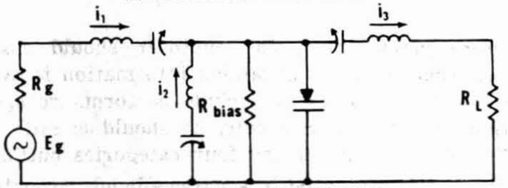
The most important aspect in specifying a varactor for a wideband or wide tuning application is device-impedance uniformity. This can be assured from capacity measurements and for higher frequencies in self-resonant frequency measurements. Though standard varactor tolerances are ordinarily much wider than desired for wideband applications, most manufacturers are willing to make suitable selections.



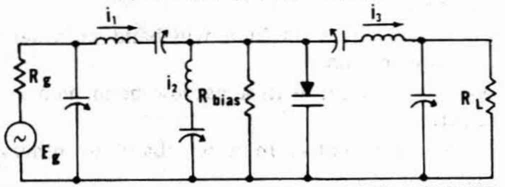
(A) SOURCE, VARACTOR. **(B) ADDITION OF INPUT AND OUTPUT CIRCUITS**



(C) ADDITION OF IDLER CIRCUIT



(D) ADDITION OF BIAS RESISTOR



(E) ADDITION OF INPUT AND OUTPUT MATCHING CAPACITORS

Fig. 6. Development of a harmonic generator circuit.

It is usually agreed that properly designed varactor multipliers do not generate noise. They amplify noise via parametric up-conversion. However, parametric oscillations can occur either with highly overdriven varactors or from unwanted idler resonances that typically occur in bias circuits. With all multiplier circuits, a spectral examination is recommended before the design is finalized.

How to Select Varactors

With basic concepts of varactors and multipliers in hand, the engineer is in a position to optimumly select his varactor. In this section, specific procedures are outlined that are based on the quantity potential and criticalness of the application.

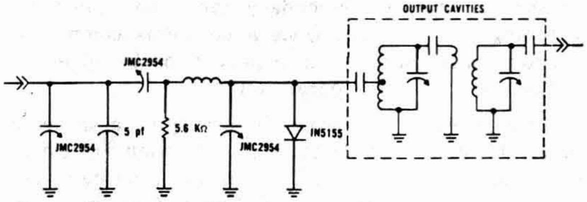


Fig. 7. One-step multiplier, 500 to 4,000 mc, based on step-recovery power varactor diode, Motorola type MV1810B.

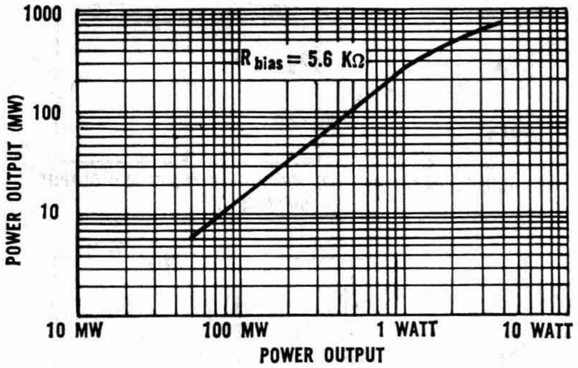


Fig. 8. The 1N5155 varactor diode used as an octupler (510 to 4,080 megacycles).

Before procurement, the engineer should assure himself that all varactor catalog information is available to him. This should include performance specifications and prices. Secondly, he should classify his application into one of the four categories outlined:

- High-volume potential in a narrow band, noncritical application.
- High-volume potential in a wideband or otherwise critical application.
- Low-volume potential in a narrow band, noncritical application.
- Low-volume potential in a wideband or otherwise critical application.

The first category offers the advantage of an attractive price. The recommended procurement procedure for this category is as follows:

- Select suppliers with standard devices having near-desired performance.
- Obtain quotes from suppliers through the OEM salesmen for guaranteed performance at one frequency and power in a mutually agreed-upon test circuit. With regard to this test circuit, the varactor should be easily removable to reduce testing costs.
- If elevated temperature performance is needed, specify thermal resistance θ_{jc} as determined from power dissipation and varactor case temperature.

$$\theta_{jc} = \frac{175^\circ\text{C} - T_{case}}{P_{diss}}$$

where P_{diss} is the allowable device dissipation in watts. (For a well-designed multiplier, approximately 80 per cent of the total power dissipated is in the varactor.) T_{case} is the case temperature of the varactor in °C. θ_{jc} is the thermal resistance in °C/watts.

- Specify mechanical requirements such as package strength or reliability, if needed.
- If possible, specify supplier-recommended limits on V_B and I_R. No other electrical parameters need be specified.

As an alternative to efficiency measurements, capacitance at 0 and 6 volts preferably, R_S or Q at 6 volts or V_B, lifetime and self-resonant frequency (where needed) all can be specified. Efficiency testing is cheaper and more reliable than all these measurements.

For high-volume critical applications such as wide bandwidth, the following steps should be added to the previous procedure:

- Specify capacitance at 0 volt and at 6 volts to insure uniform impedances. (A ±10 per cent tolerance is reasonable.)
- Specify self-resonant frequency or inductance if package parasites and operating frequencies warrant this.

Where volume potential is low and the application is noncritical, the following is recommended:

- Study supplier data sheets and application reports and order nearest standard product from distributors, as this insures fastest delivery. The most important data should be the typical efficiency and power curves.
- If these prove unsatisfactory, a call or letter via the local OEM salesman to the supplier's varactor applications group is often helpful.
- If minor variations in capacitance, θ_{jc}, V_B or efficiency are needed, make such a request through the local OEM salesman. Delivery of such selected units, however, will undoubtedly be slower than off-the-shelf units.

If the volume potential is low and the application is critical, the designer is in the least-favored position. Careful study of available products is then essential. The following procedure is then recommended:

- Obtain quotes via the local OEM salesman on selected devices.
- Specify power and efficiency at one point in standard supplier circuits. Specifying Q or R_S and T_L is an alternative.
- Specify capacitance at 0 volt and 6 volts. Allow a ±10 per cent tolerance if possible. However, a ±5 per cent tolerance is probably obtainable (at considerably increased price).
- Specify self-resonant frequency and inductance only if needed.
- Accept standard specs on V_B, I_R, θ_{jc} if possible.
- Expect and allow for considerable delay in delivery. However, closely related devices might be obtainable from distributors for the experimental work.

REFERENCES

1. P. Penfield and R. D. Rafuse, *Varactor Applications*, The MIT Press, Cambridge, Mass. 1962.
2. C. B. Burckhardt, *Analysis of Varactor Frequency Multipliers for Arbitrary Capacitance Varaction and Drive Level*, BSTJ, April 1965, pp 675-692.
3. R. D. Rafuse and D. H. Steinbrecker, *Harmonic Multiplication with Punch Through Varactors*, 1966 Solid State Circuits Conference, University of Pennsylvania, February 1966.

Comparison of Performance Formulas for Various Varactor Harmonic Generation Theories

CIRCUIT	EFFICIENCY	P_{out}	P_{in}	R_{in}	R_{out}
Doubler $\gamma = ½$					
if $\omega_c >> \omega_{in}$					
Penfield & Rafuse	$1 - 19.9\ \omega_{in}/\omega_c$	$0.0277\ V_B{}^2\ C_{min}\ \omega_{in}$		$0.08/\omega_{in}\ C_{min}$	$0.271/\omega_{out}\ C_{min}$
Burckhardt	$e^{-8.3\ \omega_{out}/\omega_c}$	$0.0835\ V_B{}^2\ C_{min}\ \omega_{in}$		$0.0977/\omega_{in}\ C_{min}$	$0.302/\omega_{out}\ C_{min}$
Doubler $\gamma = ⅓$					
if $\omega_c >> \omega_{in}$					
Penfield & Rafuse	$1 - 25.6\ \omega_{in}/\omega_c$	$0.0118\ V_B{}^2\ C_{min}\ \omega_{in}$		$0.0604/\omega_{in}\ C_{min}$	$0.204/\omega_{out}\ C_{min}$
Burckhardt	$e^{-6.9\ \omega_{out}/\omega_c}$	$0.0587\ V_B{}^2\ C_{min}\ \omega_{in}$		$0.126/\omega_{in}\ C_{min}$	$0.344/\omega_{out}\ C_{min}$
Doubler $\gamma = 0$					
Burckhardt	$e^{-4.7\ \omega_{out}/\omega_c}$	$0.0626\ V_B{}^2\ C_{min}\ \omega_{in}$		$0.213/\omega_{in}\ C_{min}$	$0.422/\omega_{out}\ C_{min}$
if $\omega_c >> \omega_{in}$					
Rafuse & Steinbrecker	$e^{-4.7\ \omega_{out}/\omega_c}$		$0.055\ V_B{}^2\ C_{min}\ \omega_{in}$	$0.212/\omega_{out}\ C_{min}$	$0.424/\omega_{out}\ C_{min}$
Tripler $\gamma = ½$ (idler)					
if $\omega_c >> \omega_{in}$					
Penfield & Rafuse	$1 - 34.8\ \omega_{in}/\omega_c$	$0.0241\ V_B{}^2\ C_{min}\ \omega_{in}$		$0.137/\omega_{in}\ C_{min}$	$0.184/\omega_{out}\ C_{min}$
Burckhardt	$e^{-9.8\ \omega_{out}/\omega_c}$	$0.07\ V_B{}^2\ C_{min}\ \omega_{in}$		$0.172/\omega_{in}\ C_{min}$	$0.217/\omega_{out}\ C_{min}$
Tripler $\gamma = 0$ (idler)					
Burckhardt	$e^{-7\ \omega_{out}/\omega_c}$	$0.0212\ V_B{}^2\ C_{min}\ \omega_{in}$		$0.185/\omega_{in}\ C_{min}$	$0.263/\omega_{out}\ C_{min}$
if $\omega_c >> \omega_{in}$					
Rafuse & Steinbrecker	$1 - 6.1\ \omega_{in}/\omega_c$		$0.0482\ V_B{}^2\ C_{min}\ \omega_{in}$	$0.415/\omega_{in}\ C_{min}$	$0.447/\omega_{out}\ C_{min}$
Octupler $\gamma = 0$ (no idler)					
Burckhardt	$e^{-21.7\ \omega_{out}/\omega_c}$	$0.0034\ V_B{}^2\ C_{min}\ \omega_{in}$		$0.0098/\omega_{in}\ C_{min}$	$0.085/\omega_{out}\ C_{min}$
if $\omega_c >> \omega_{in}$					
Rafuse & Steinbrecker	$e^{-24.7\ \omega_{out}/\omega_c}$		$0.00405\ V_B{}^2\ C_{min}\ \omega_{in}$	$0.010/\omega_{in}\ C_{min}$	$0.08/\omega_{out}\ C_{min}$

HIGH-POWER VARACTOR DIODES: THEORY AND APPLICATION

Introduction

Conventionally speaking, when we refer to a semiconductor diode we normally visualize a 2-terminal p-n junction operated in the forward conduction region (as a rectifier) or in the reverse avalanche region (as a zener diode). From this standpoint, the word diode applied to a varactor is actually a misnomer – for while the varactor is indeed a 2-terminal p-n junction, it operates neither as a rectifier, nor as an avalanche device. Rather, it operates principally in the region between forward conduction and reverse breakdown – the very region in which a conventional diode is considered to be cut off.

In this operating region the p-n junction can be represented by a capacitor in series with a resistor, Fig. 1. The capacitance, known as junction capacitance, is inherently associated with all p-n junctions and, while it represents an undesirable parasitic in conventional diode operation, it is the specific mechanism that permits the device to function as a varactor, or frequency multiplier. This is true because the capacitance value, as will be seen later, actually varies as a function of applied voltage and it is this factor that encourages the generation of harmonic frequencies.

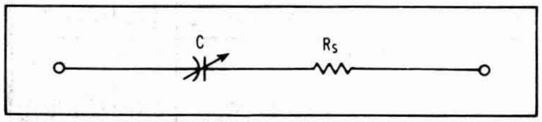


Figure 1 — Equivalent circuit of a varactor diode.

The resistor is the result of bulk and contact resistance of the semiconductor material. In varactor operation this resistance is the primary parasitic affecting varactor quality. Great pains are taken in varactor design, therefore, to hold this resistance value to an absolute minimum.

How They Work

The cause and behavior of the junction capacitance can be determined from basic semiconductor theory, as follows:

When a junction is formed between n-type and p-type material, there is a cross-migration of charges across the junction. Electrons from the n-region cross the junction to neutralize positive carriers near the junction in the p-region, and "holes" from the p-region cross the junction to neutralize the "excess" electrons near the junction in the n-region. As a result of this migration, all free charged particles are swept out of the immediate vicinity of the junction, creating a "depletion layer" in the junction area. And, in the process, a contact potential or space charge (about 0.5V for silicon) appears across the junction, Fig. 2a.

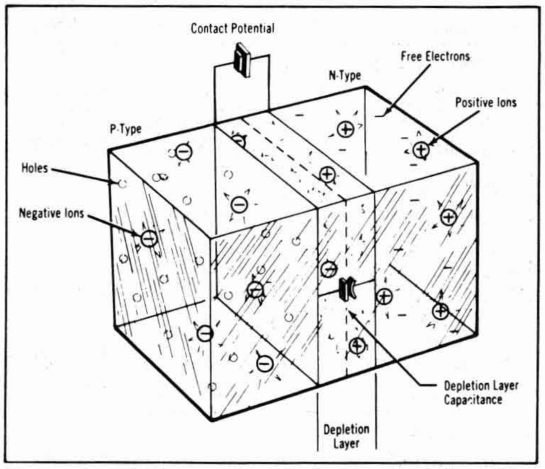


Figure 2 — (A) A representative p-n junction. The battery represents the contact potential which must be overcome before current can flow. Current carriers act as capacitor plates and the depletion layer is the dielectric.

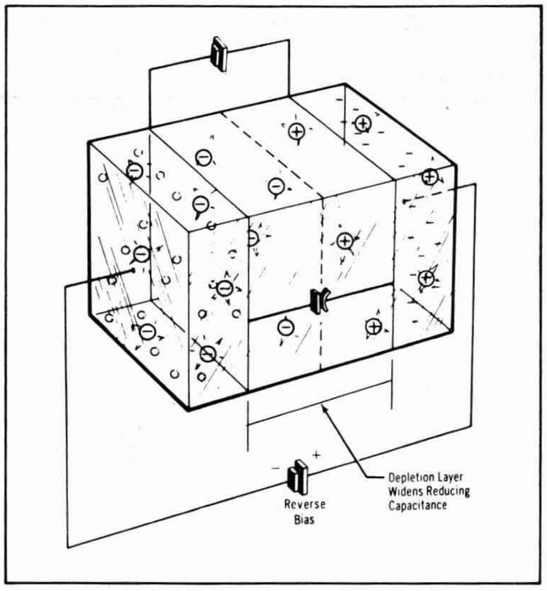


Figure 2 — (B) Reverse voltage forces carriers away from junction. This widens the depletion layer and reduces capacitance.

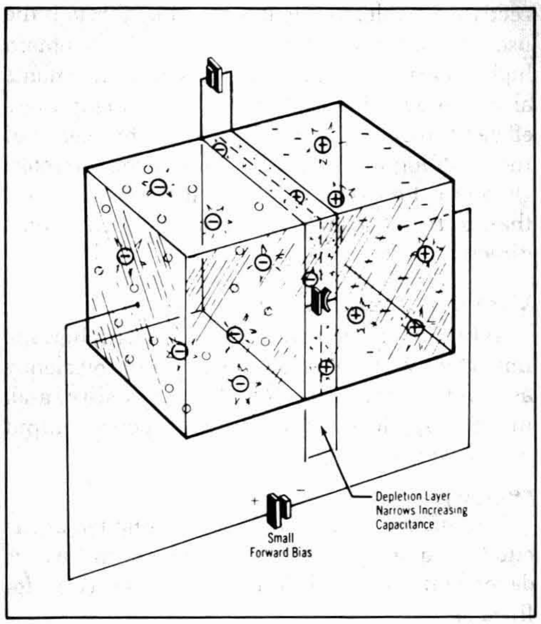


Figure 2 — (C) Forward voltage forces carriers closer to junction or across junction again changing capacitance.

This structure acts very much like a slightly charged capacitor, with the depletion layer representing the dielectric and the semiconductor material adjacent to the depletion layer representing the two conductive plates.

If an external voltage is connected across the p-n junction so as to reinforce the contact potential (reverse bias), the depletion layer increases, resulting in a capacitance decrease, Fig. 2b. If a forward voltage is applied, the depletion layer decreases, Fig. 2c. However, if the external forward voltage is made large enough to overcome the contact potential, forward conduction occurs and the capacitance effect is destroyed (except at very high frequencies, as discussed later).

It is obvious, therefore, that the value of the junction capacitance is a function of the externally applied voltage, so long as the junction itself remains reverse biased. This relationship is as follows:

$$C = \frac{C_O}{(1 + V/\phi)^{\gamma}} = \frac{\phi^{\gamma} C_O}{(\phi + V)^{\gamma}}$$

where C = capacitance at voltage V
C_O = capacitance at zero bias
V = voltage across the diode (reverse bias)
ϕ = contact potential
γ = power law of the junction, determined by impurity gradient.

A plot of this equation, Figure 3, shows that the capacitance-voltage relationship is nonlinear. Just how this condition is useful for frequency multiplication will be seen from the following derivation.

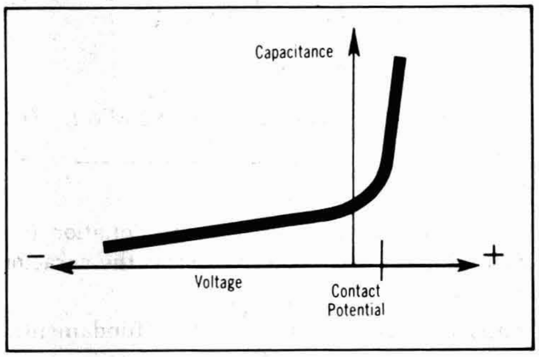


Figure 3 — Voltage-capacitance relationship for a typical varactor diode.

Assume that the voltage across a capacitor is given by the well-known relationship

$$V = \frac{Q}{C} \tag{2}$$

where Q = the charge on the capacitor
C = the capacitance

When a sinusoidal current is applied to a capacitance,

$$\begin{aligned} Q &= \int i dt \\ &= \int I_1 \sin \omega_1 t dt \\ &= A - \frac{I_1}{\omega_1} \cos \omega_1 t \end{aligned} \tag{3}$$

where i = instantaneous current
I_1 = maximum amplitude of the input current
ω_1 = $2\pi f_1$
f_1 = input frequency
A = constant of integration relating to the initial charge when time (t) = zero

Substituting Equations (1) and (3) into Equation (2) yields

$$V = \frac{A - \frac{I_1}{\omega_1} \cos \omega_1 t}{\frac{\phi^{\gamma} C_o}{(\phi + V)^{\gamma}}} \tag{4}$$

or, where $V >> \phi$

$$\frac{V}{V^{\gamma}} = V^{1-\gamma} = \frac{A - \frac{I_1}{\omega_1} \cos \omega_1 t}{\phi^{\gamma} C_o} \tag{5}$$

The exponent γ is a function of the impurity gradient of the p-n junction. It may vary from approximately 1/2, for step junctions, to about 1/6 for special graded junctions. If we consider the common case of a step junction, ($\gamma = 1/2$) Equation (5) resolves to

$$V = \left(\frac{A - \frac{I_1}{\omega_1} \cos \omega_1 t}{\phi^{1/2} C_o} \right)^2$$

$$= \frac{A^2 - 2A \frac{I_1}{\omega_1} \cos \omega_1 t + \left(\frac{I_1}{\omega_1} \right)^2 \cos^2 \omega_1 t}{\phi C_o^2} \qquad (6)$$

Looking at each of the terms in Equation (6) we find that the voltage (V) across the varactor consists of a dc term $\left(\frac{A^2}{\phi C_o^2} \right)$, a fundamental component $\left(\frac{2A \frac{I_1}{\omega_1} \cos \omega_1 t}{\phi C_o^2} \right)$, and the term $\frac{\left(\frac{I_1}{\omega_1} \right)^2 \cos^2 \omega_1 t}{\phi C_o^2}$

The latter, through trigonometric identities, expands to $\left(\frac{I_1}{\omega_1} \right)^2 \frac{(1/2 + 1/2 \cos 2\omega_1 t)}{\phi C_o^2}$, which reduces to another dc component plus *a second harmonic component.*

Although quite simplified, the above derivations clearly show the generation of second harmonic voltages across the varactor diode. This second harmonic voltage can be used to produce power at that frequency simply by providing a path and a load for the second harmonic current.

In the case of a step-junction device, the second harmonic is the only harmonic frequency directly available. While it is possible, through the use of graded junctions ($\gamma < 1/2$) to obtain higher harmonics directly, the second harmonic always predominates. In fact, it is normally more efficient to obtain higher harmonics by means of the doubling and mixing action of the varactor, through the use of idler circuits (see Fig. 4), than to try to obtain a desired higher harmonic directly.

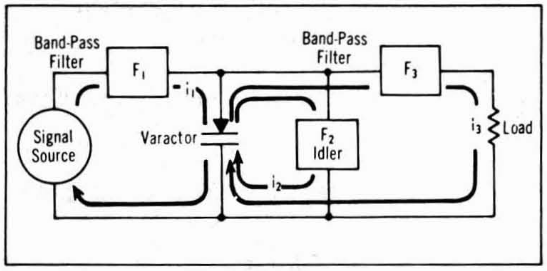


Figure 4 — Simplified multiplier circuit illustrating the use of an idler configuration to develop third and fourth harmonics.
An idler circuit is simply a tuned filter which permits the flow of a harmonic current needed to generate the desired output. If the third harmonic is desired, filter F_1 is tuned to the fundamental, idler F_2 is tuned to the 2nd harmonic, and F_3 is tuned to the 3rd harmonic. To obtain the fourth harmonic, F_3 is simply tuned to the fourth harmonic and permits the flow of the doubled 2nd harmonic current.

Varactor Characteristics

When operating as a frequency multiplier, the important varactor characteristics are: efficiency as a multiplier, power handling capability, and, in some applications, linearity of power output with changes in input power.

Efficiency

The efficiency of a varactor is a function of the cutoff frequency of the device which, in turn, is dependent on the diode quality factor (Q), defined as

$$Q = \frac{1}{2\pi f C R_S} \qquad (7)$$

From this, it is seen that Q is a function of both R_S and C. The ability to obtain a high Q device is directly related to the ability to make R_S extremely low. The cutoff frequency is arbitrarily defined as that frequency at which $Q = 1$, or where $\frac{1}{2\pi f C} = R_S$. Accordingly, cutoff frequency is given as

$$f_c = \frac{1}{2\pi C R_S} \qquad (8)$$

Since both R_S and C are voltage dependent, it is obvious that f_c, too, will vary with applied voltage. As reverse voltage increases, f_c will also increase. This is important in a comparative evaluation of devices since, in order to obtain a valid comparison, the f_c for the devices must be obtained at the same voltage.

Now, for varactors with step junctions, the maximum obtainable efficiency may be approximated from the expressions:(1)

For input frequencies of 0.01 f_c or less,

$$\epsilon = 1 - K \frac{f_1}{f_c} \qquad (9)$$

For input frequencies of 0.2 f_c or higher,

$$\epsilon = B \frac{f_c^2}{f_1^2} \qquad (10)$$

where f_c = cutoff frequency at V_B
f_1 = input frequency
K and B = constants whose values depend on the desired order of the harmonic.

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(1) Penfield & Rafuse, "Varactor Applications", MIT Press, Copyright 1962.

For doublers, K and B of Equations 9 and 10 are equal to 20 and .0039 respectively.

For triplers and quadruplers, K is equal to 35 and 62 respectively.

From these equations it is evident that the theoretical efficiency of varactors is quite high at input frequencies of 0.01 f_c or less.

Power Handling Capability

The relationship between power handling capability (P_r) and other varactor characteristics is given by

$$P_r \propto C_o V_B^2 \qquad (11)$$

where V_B = voltage breakdown of the junction
C_o = junction capacity at zero bias.

The validity of this proportionality is evident from the fact that the input power is obviously proportional to the square of the input voltage swing, which is limited at one end by V_B and on the other by the permissible amount of forward conduction. If the voltage swing in the forward direction is very much smaller than V_B, it can be neglected, and the input power is approximately proportional to V_B^2.

For large power handling capability it is desirable to make V_B as large as possible (assuming that the signal source can provide the necessary voltage swing from V_B to approximately zero). This requires that the resistivity of the material near the junction (at least on one side of the junction) be high. Yet, a high resistivity leads to a relatively high R_S which, in turn, lowers the Q of the diode and, consequently, the efficiency. Therefore, varactor diode design normally is a compromise between high power handling capability and high efficiency.

New Varactor Design Improves Power Handling Capability

Until recently most varactors for harmonic generator applications have been designed with step junctions and their characteristics closely follow the above discussion. Some improvement in performance has been observed in varactors of the 1N4386 type whose impurity profile, Fig. 5, differs considerably from that of the customary step-junction device. These improvements include:

1) higher power handling capability at a given frequency,
2) greater linearity of power output with changes in power input.

The increase in power handling capability can be explained as follows:

To increase P_r, it is necessary to increase V_B which demands a higher resistivity material at least on one side of the junction. If one attempts to increase the resistivity of a step-junction device, the value of R_S is increased significantly and efficiency is reduced accordingly. But, by employing the impurity profile shown in Fig. 5, the resistivity near the junction can be made comparatively high without changing the average resistivity. Moreover, when reverse voltage is applied, the spread of the depletion layer into the high resistivity regions actually dissipates them, leaving only the extremely low resistivity portion of the material to contribute to R_S. And, since the time that the varactor is in the reverse-voltage condition is very large compared with the time in the forward-biased condition, the average total series resistance is substantially reduced despite the increase in resistivity at the junction and a resulting increase in V_B.

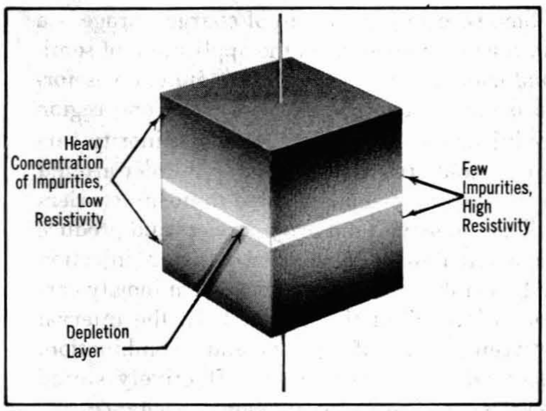

Heavy Concentration of Impurities, Low Resistivity
Few Impurities, High Resistivity
Depletion Layer

Figure 5 — Resistivity of 1N4386 is high near the junction and low near the lead contacts. When a reverse voltage is applied the depletion layer rapidly dissipates the high resistivity regions and thus, the average series resistance (R_s) is low.

By this means, it is possible to almost double the power handling capability of varactors over step-junction devices, without adversely affecting efficiency, at least as it is affected by R_S.

It might be argued that the impurity profile used in the 1N4386 type should result in lower efficiency because the capacity-voltage law (γ in Equation 1) is reduced to about a 1/5 power, thus reducing the degree of reactive nonlinearity. Indeed, this would result in a lower efficiency of harmonic generation if it were not compensated by the reduction of series resistance described above.

In addition there appears to be an added nonlinearity resulting directly from the parabolic graded impurity profile — the phenomenon of "step-recovery". Not only does step-recovery make up for the reduced junction-capacity nonlinearity, but it leads to a linear power output advantage when driven slightly into the forward bias region at the positive peak of the signal swing.

Step-recovery is a result of charge storage — a familiar phenomenon in the application of semiconductor devices. When a p-n junction is forward biased, charged carriers from one region are injected into the other to form minority carriers in that area. If permitted to wander around in the area long enough, these minority carriers will combine with majority carriers and produce a current flow. The interval between injection and recombination is related to the minority carrier "lifetime" of the material. In the interval between the time of injection and recombination, these minority carriers are effectively stored charges contributing to junction capacitance.

If the period of the applied forward voltage is less than the carrier lifetime, as is usually the case, most of the injected carriers can be brought back to the point of origin before recombination. Step-recovery comes about when the injected minority carriers are returned to the point of origin in a compact bunch. Such a movement of carriers constitutes a current waveform as shown in Fig. 6. Because of the sudden cessation of reverse current when all of the carriers are returned to their original regions, the waveform is rich in harmonics which can be utilized as an added nonlinearity to enhance multiplier action.

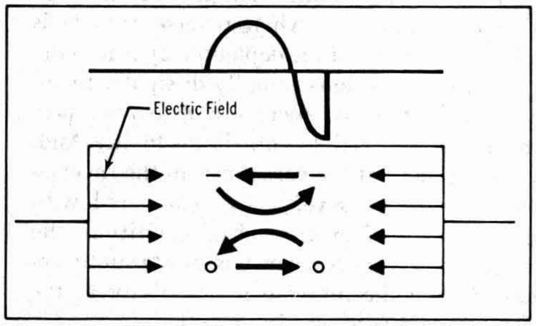


Figure 6 — When a forward voltage is applied, carriers are injected across the junction. However, before they can combine and result in a dc current flow, the applied voltage reverses and the carriers are returned to the point of origin in a bunch. This results in an abrupt cessation of reverse current and the waveform is rich in harmonics.

The impurity profile of Fig. 7 enhances step-recovery because the electric fields set up by the steep impurity gradient a short distance away from the depletion region keep the minority carriers close to the depletion layer, rather than permitting them to wander to random depths into the opposite regions. Thus, when the voltage is reversed, they return to their point of origin in a compact bunch.

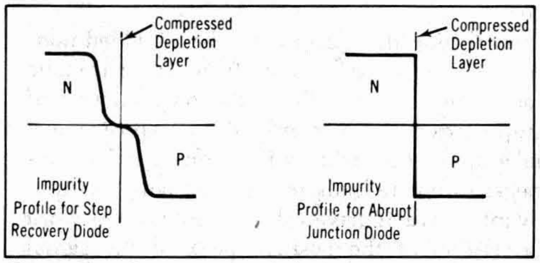


Figure 7 — Comparison of the impurity profiles for a step recovery and step junction diodes.

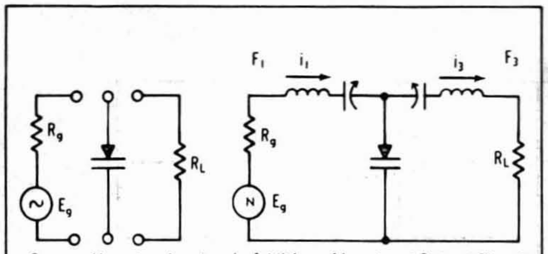
Varactors vs. Transistors

In view of the fact that varactors provide no amplification, but merely convert an applied signal of one frequency to some higher frequency, one might logically ask, "Why not use transistors to directly generate the desired signal?" The answer to this is simply that there are no transistors that will provide the amount of power obtainable from varactors in the VHF and UHF regions. The best transistors today are limited to producing about 25 watts at 100 mc, and about 5 watts at 500 mc. Varactors, by contrast, can supply about three times that amount of power at those frequencies. Moreover, many VHF and UHF transmitters demand crystal control, which requires a relatively low-frequency oscillator with subsequent frequency multiplication. And, as yet, no other device operates as efficiently as a varactor for this purpose.

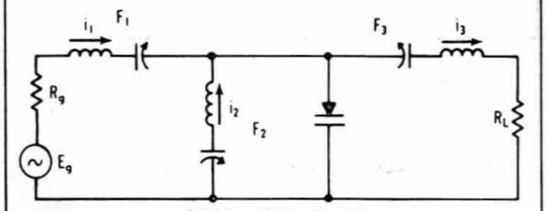
Even as transistors are improved, it is reasonable to assume that varactor development will keep pace, so that the latter will remain well ahead of transistors in power-frequency capabilities. As a result, it is anticipated that the varactor will become an increasingly important component in high-power, high-frequency applications.

The step-recovery phenomenon, which is not as pronounced in step junctions because of the constant impurity level in such devices, provides an additional nonlinearity to the 1N4386 which contributes to harmonic generation.

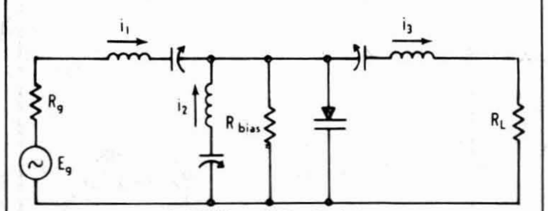
Step-recovery results also in a device with more linear power characteristics because the percentage of harmonic current generation is not a function of signal level. It is only a function of the waveform and the abruptness of the decline of reverse current. And if self-biasing is employed, the shape of the current wave remains constant over a considerable power input range. This leads to a more constant efficiency of harmonic generation as a function of signal level than obtainable with devices dependent on junction-capacitance variations alone. This is an important feature when using varactors in amplitude modulated circuits.



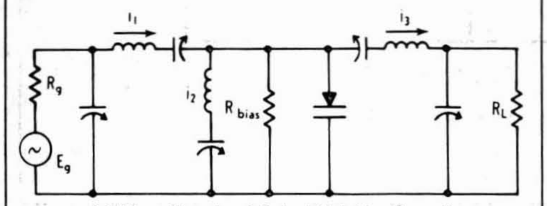
a. Source, Varactor, Load b. Addition of Input and Output Circuits



c. Addition of Idler Circuit



d. Addition of Bias Resistor



e. Addition of Input and Output Matching Capacitors

Figure 8 — Development of a harmonic generator circuit.

Harmonic Generator Circuits

Development of a varactor multiplier circuit is illustrated in Fig. 8. The basic premise, as shown in (a) is the conversion of a signal from a signal source to a harmonic current through the load (R_L) by means of a varactor. The necessary considerations entail 1) provisions for the necessary current paths and associated filters, 2) proper matching of source to load, and 3) development of suitable bias voltage for the varactor.

The first step in the design is the addition of suitable current paths, as shown in (b). If the output is to be the second harmonic, filter F_1 is tuned to the fundamental frequency, and F_2 is tuned to the 2nd harmonic. In designing the tuned circuits, the capacitance of the varactor must be taken into account. Since this varies over the applied signal cycle, the "average" varactor capacitance should be used. This can be approximated by the capacitance value at one-third the voltage breakdown rating of the varactor (assuming a signal voltage swing from about V_B to some small positive value). Since this average capacitance varies with signal power, some circuit detuning occurs if input power is changed appreciably. This detuning effect is less pronounced with devices of the 1N4386 structure than with step-junction devices.

If the desired load current is at the third or fourth harmonic, the configuration in (c) may be used. Here, F_1 is again tuned to the fundamental and F_2 is an idler tuned to the 2nd harmonic. This permits fundamental and 2nd harmonic current flow to mix in the varactor to provide a voltage component of F_1, F_2, $F_1 + F_2$, and $2F_2$ across the varactor. (Even if F_2 were omitted, there would be components of higher order harmonics, such as F_3 and F_4 across the varactor, but, as mentioned previously, it is normally more efficient to employ a suitable addition or multiple of the fundamental and second harmonic.) Filter F_3 is then tuned to the desired third or fourth harmonic so that only the desired current will flow through the load.

Bias voltage for the varactor is obtained by shunting the varactor with a high value (around 100 KΩ) bias resistor, as in (d). Bias current is provided when the varactor is driven slightly into conduction at the peaks of the applied signal.

Proper matching between source and load can be accomplished by adding matching capacitors as shown in (e). Tapped input and output coils could accomplish the same purpose.

Obviously, the simple circuit developed in Fig. 8 can be improved upon from a performance standpoint. Higher-frequency, distributed-element circuits could be fabricated based on a circuit equivalent to Fig. 8. More complex filters, such as double-tuned circuits, may be employed for greater bandwidth and better rejection of spurious signals. In practical applications, the final circuit almost always will be more complex.

Characteristics of 1N4386

The 1N4386 varactor was designed to handle efficiently more than 50 watts of input power with output frequencies up to 300 mc. Typical efficiency of the device as a function of power input at 50 mc (tripler operation) is shown in Fig. 9.

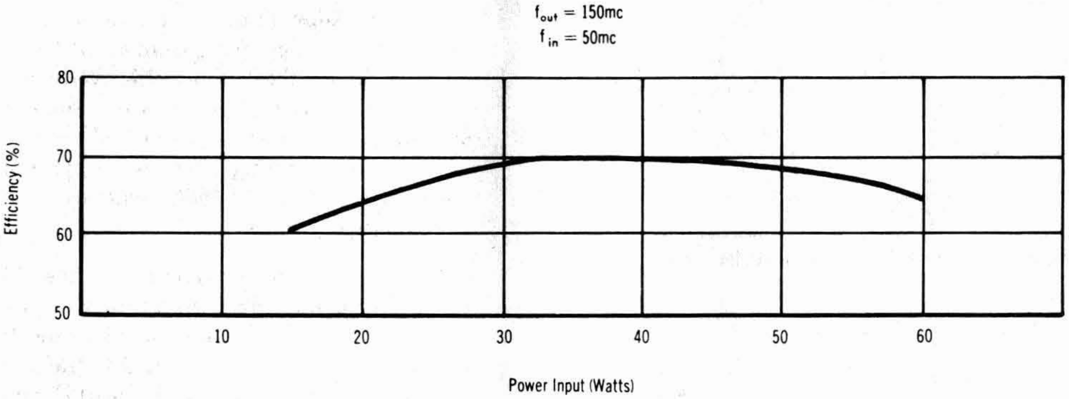


Figure 9 — Typical efficiency vs power input curve for the 1N4386 in a tripler circuit.

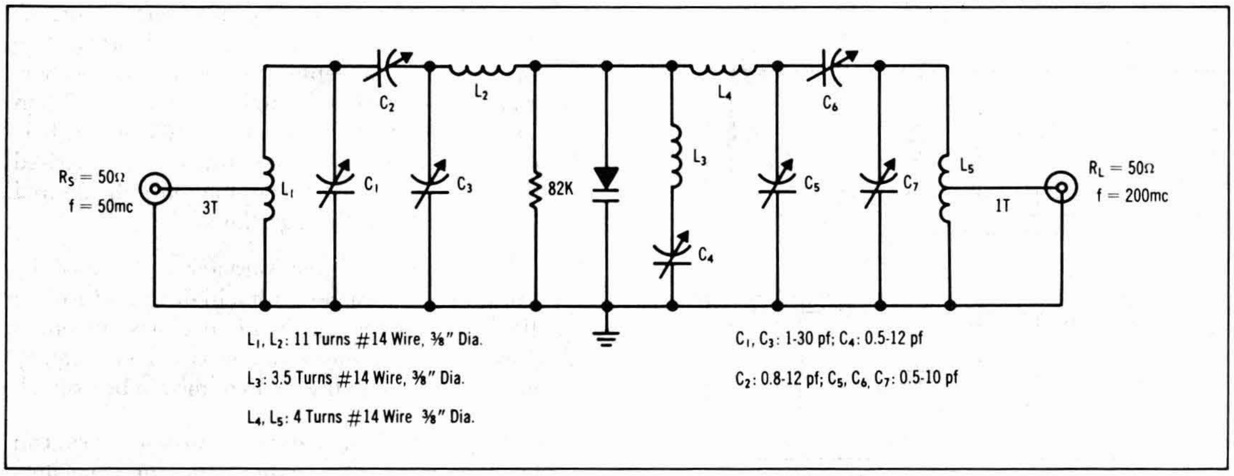

R_S = 50Ω
f = 50mc
3T
L_1
C_1
C_2
C_3
L_2
82K
L_3
C_4
L_4
C_5
C_6
C_7
L_5
1T
R_L = 50Ω
f = 200mc
L_1, L_2: 11 Turns #14 Wire, 3/8" Dia.
L_3: 3.5 Turns #14 Wire, 3/8" Dia.
L_4, L_5: 4 Turns #14 Wire 3/8" Dia.
C_1, C_3: 1-30 pf; C_4: 0.5-12 pf
C_2: 0.8-12 pf; C_5, C_6, C_7: 0.5-10 pf

Figure 10 — 50-200 mc Varactor quadrupler

EPICAP VVC TUNING OF RESONANT CIRCUITS

EPICAP VVC TUNING OF RESONANT CIRCUITS

Most RF tuning situations involve changing circuit resonant frequencies. Heretofore this has usually been accomplished by mechanically variable capacitors. The resultant tuning assemblies are large, slow acting, and relatively unreliable. The circuit designer has long wanted to replace his mechanical tuning assembly with electrical counterparts. Unfortunately the quality of the available electric tuning elements had been too poor for circuits. Now with the introduction of the high Q Epicap VVC tuning diode, the designer can re-examine his tuner designs with the view of eliminating the disadvantages inherent with mechanical parts.

On the basis of new interest in electric tuning due in part to the better component availability, this Epicap VVC application note is being presented. This note is intended to aid the Epicap VVC user to determine rapidly the resonant circuit tuning range possible.

Epicap VVC's are voltage-variable capacitors based on reverse biased PN junction phenomena. A complete description of these phenomena as well as a description of Epicap characteristics is given in Application Note AN-178.

THE EPICAP VVC-TUNED RESONANT CIRCUIT

Most Epicap VVC resonant circuits take the form of Fig. 1 for the parallel circuit, or Fig. 2 for the series circuit. In either case the equations and graphs of this report apply. The effective circuit inductance is given by L, although in some cases for biasing purposes there are additional RF chokes which, if properly chosen, have negligible effect on the resonant frequency. Circuit capacity shunting the varactor is given by C_{ckt}. The Epicap VVC capacity is given by $C_c + C_J$, the sum of case and junction capacitances. For this note it is assumed that the resonant frequencies are well below diode self-resonant frequency so the Epicap VVC inductance can be neglected. A short discussion of the effect of this inductance, however, is included.

In the design of electrically tuned circuits, a major concern is the tuning range. A graph has been developed from which tuning range can be predicted using the voltage tunable capacitance and external circuit parameters. The development, discussion and use of that graph is the major thesis of this report.

The expression for resonant frequency is given by

$$f_o = \frac{1}{2\pi (LC_T)^{1/2}} \qquad (1)$$

where

$$C_T = C_{ckt} + C_J + C_c$$

$$C_J = \frac{C_o}{(1 + V/\phi)^{\gamma}} = \frac{C_o}{(1 + 2V)^{1/2}} \qquad (2)$$

where

γ the law of the diode = 0.5 for Epicap VVC's

C_o is the zero bias capacity

ϕ the contact potential = 0.5 volts

V is the magnitude of the reverse voltage

The maximum capacity occurs when the minimum bias voltage is applied and vice versa for the minimum capacity.

$$C_{max} = \frac{C_o}{\left(1 + \frac{V_{min}}{\phi}\right)^{1/2}} \qquad (3)$$

$$C_{min} = \frac{C_o}{\left(1 + \frac{V_{max}}{\phi}\right)^{1/2}} \qquad (4)$$

The mean capacity between C_{max} and C_{min} is usually chosen to resonate the circuit at the design center frequency

$$C_{cf} = (C_{max}\, C_{min})^{1/2} \qquad (5)$$

From eqs. (3) and (4)

$$C_{min} = C_{max} \frac{(\phi + V_{min})^{1/2}}{(\phi + V_{max})^{1/2}} \qquad (6)$$

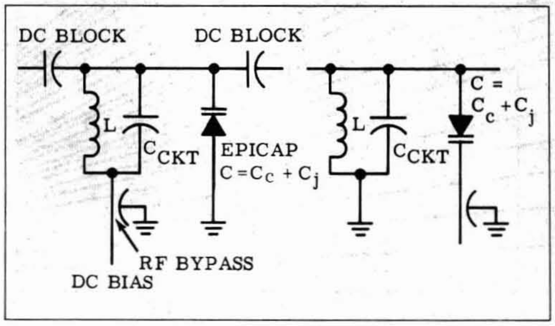


FIGURE 1 — TWO EPICAP VVC TUNED PARALLEL RESONANT CIRCUITS

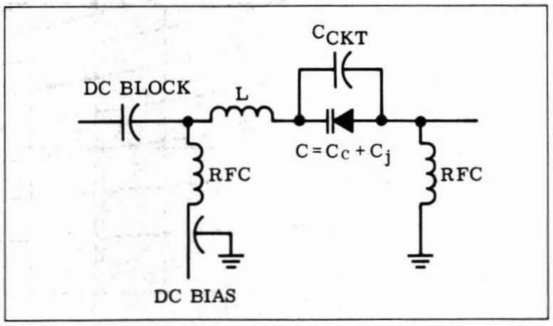


FIGURE 2 — EPICAP VVC TUNED SERIES RESONANT CIRCUIT

Circuit diagrams are included as a means of illustrating typical semiconductor applications, consequently, complete information sufficient for construction purposes, is not necessarily given. The information in this application note has been carefully checked, and is believed to be entirely reliable. However, no responsibility is assumed for inaccuracies. Furthermore, such information does not convey to the purchaser of the semiconductor devices described any license under the patent rights of Motorola Inc. or others.

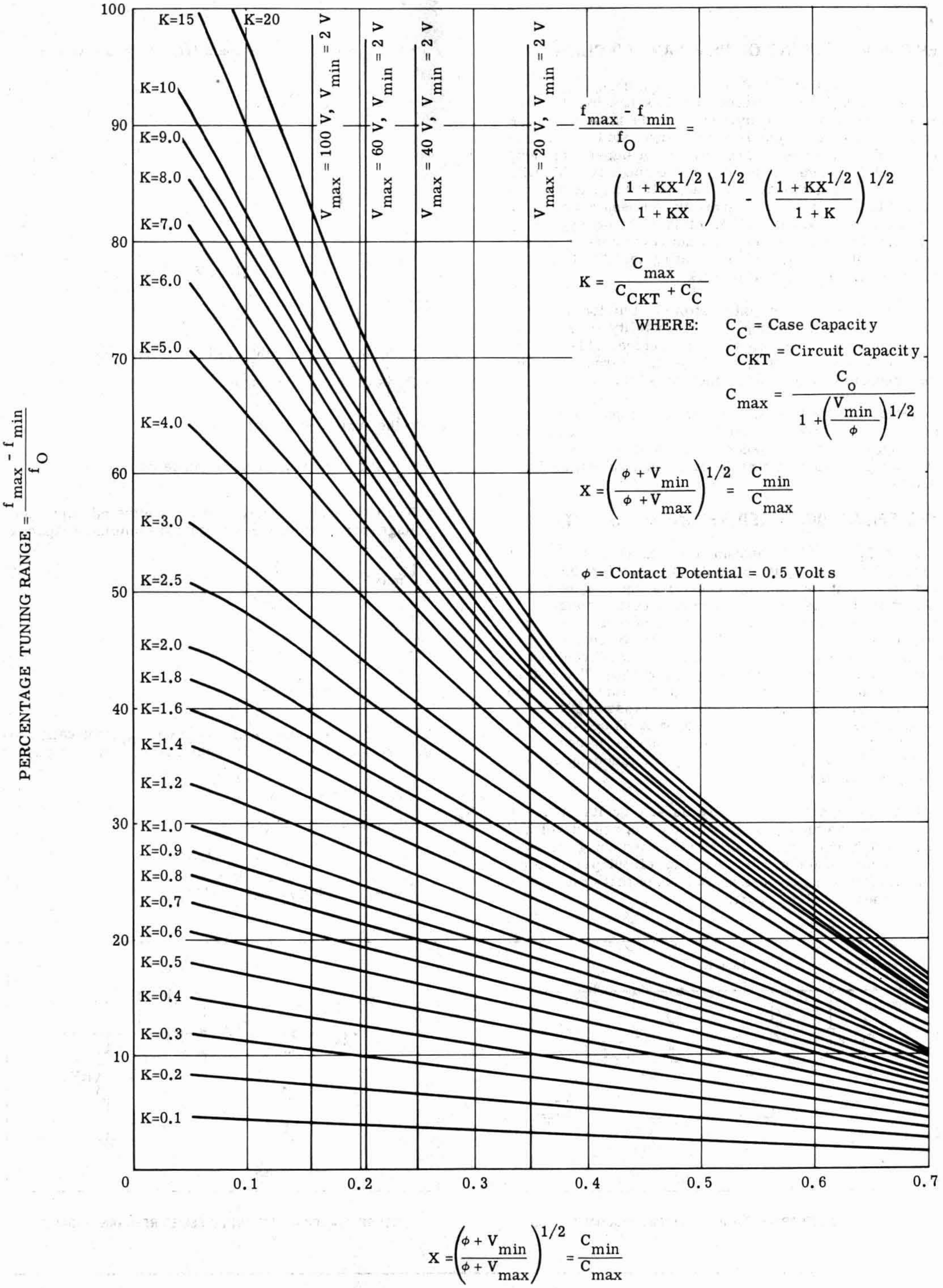


FIGURE 3 — PERCENTAGE RESONANT CIRCUIT TUNING RANGE

hence

$$C_{cf} = C_{max} \frac{(\phi + V_{min})^{1/4}}{(\phi + V_{max})^{1/4}} \qquad (7)$$

Defining

$$\frac{(\phi + V_{min})^{1/2}}{(\phi + V_{max})^{1/2}} = X \qquad (8)$$

$$C_{min} = X\, C_{max} \qquad (9)$$

$$C_{cf} = X^{1/2}\, C_{max} \qquad (10)$$

The maximum, minimum, and center resonant frequencies are given by

$$f_{max} = \frac{1}{\left[L(C_{ckt} + C_c + C_{min})\right]^{1/2}}$$

$$= \frac{1}{\left[L(C_{ckt} + C_c + X\, C_{max})\right]^{1/2}} \qquad (11)$$

$$f_{min} = \frac{1}{\left[L(C_{ckt} + C_c + C_{max})\right]} \qquad (12)$$

$$f_o = \frac{1}{\left[L(C_{ckt} + C_c + C_{cf})\right]^{1/2}}$$

$$= \frac{1}{\left[L(C_{ckt} + C_c + X^{1/2}\, C_{max})\right]^{1/2}} \qquad (13)$$

Tuning range percentage is

$$\frac{f_{max} - f_{min}}{f_o} = \left[\frac{C_{ckt} + C_c + X^{1/2}\, C_{max}}{C_{ckt} + C_c + X\, C_{max}}\right]^{1/2} - \left[\frac{C_{ckt} + C_c + X^{1/2}\, C_{max}}{C_{ckt} + C_c + C_{max}}\right]^{1/2} \qquad (14)$$

Defining

$$K = \frac{C_{max}}{C_{ckt} + C_c}$$

eq. 14 can be simplified to

$$\frac{f_{max} - f_{min}}{f_o} = \left(\frac{1 + K\,X^{1/2}}{1 + K\,X}\right)^{1/2} \left(\frac{1 + K\,X^{1/2}}{1 + K}\right)^{1/2} \qquad (15)$$

Equation (15) is plotted versus $X = \frac{C_{min}}{C_{max}}$ for several $K = \frac{C_{max}}{C_{ckt} + C_c}$ as parameters in Fig. 3. Using Fig. 3, circuits can be designed and Epicap VVC's specified. Actually Fig. 3 can be used for any variable capacitor as long as the abcissa is kept in terms of the minimum to maximum capacity ratio. Using Epicap VVC's, the abcissa is also given in terms of minimum and maximum voltage.

USE OF THE TUNING RANGE DESIGN GRAPH

To illustrate the use of Fig. 3 (design graph) a sample design is given.

Assume a tuning range is desired between 60 and 90 MHz with a fixed circuit capacity of 10 pF present. (This might be due to collector capacity.) The percentage tuning range is $\frac{90-60}{(90\text{x}60)^{1/2}}$ x 100% = 41%. With Epicap VVC's MV1864B through 1N5148 the maximum usable voltage is 60 volts. Voltage breakdown determines this upper voltage limit. The lower voltage limit is determined by temperature stability and/or intermodulation effects because the junction capacity varies sharply at low voltages. Temperature dependence enters via the contact potential which is more significant with low applied bias voltages. It is generally accepted that a lower limit of two volts is to be used for most applications. Therefore, for V_{max} = 60 V, V_{min} = 2 V and tuning range = 41% the minimum allowable K is 2.5, or $C_{-4\ V} > 26$ pF/1.34 = 19.4 pF.

All Epicap VVC's are identified by a four volt capacity value. The two volt value which corresponds to C_{max} is simply obtained by multiplying $C_{4\ V}$ by 1.34 which is obtained from the ratio of capacity at 2 V to the capacity at

$$4\ V = \left(\frac{1 + 4/0.5}{1 + 2/0.5}\right)^{1/2} = 1.34$$

With C_{ckt} = 10 pF and C_c = 0.3 for the glass diode C_{max} must be greater than K_{min} $(C_{ckt} + C_c)$ or $C_{max} > 2.5$ (10.3) = 26 pF.

Any Epicap VVC having a -4 V capacity over 19.4 pF would tune the desired range; however, usually the lower the capacity value the higher the Q so that the lowest capacity device should be selected (where Q is important). For this problem the recommended Epicap VVC is the 1N5144 which has a 22 pF 4 volt capacity. This allows for a standard tolerance of ±10% in the Epicap VVC capacity.

Where the best temperature stability is desired the minimum voltage should be as high as possible. In that case the X is reduced so that the minimum tolerable K is increased. Larger Epicap VVC's, e.g., the 1N5148 with $C_{-4\ V}$ = 47 pF, would have to be used. Similar conditions would prevail if the maximum control voltage is limited.

Completing the circuit design, for tuning 22 pF x 1.34 + 10 pF + 0.3 pF = 39.8 pF at 60 MHz a coil of 0.179 μH is needed. To account for variations of ±2.2 pF in the Epicap VVC tolerance, it is recommended that this coil be tunable by insertion of a ferrite slug. The ferrite core is the simplest possible trimming in this frequency range. For considerably higher frequencies, capacity trimming would have to be selected.

The maximum voltage needed can be calculated from

$$K = \frac{22 \times 1.34}{10 + 0.3} = 2.85$$

From Fig. 3 with a 41% tuning range and K = 2.85 the required X is 0.24 or

$$V_{max} = \frac{(2.5)}{(0.24)^2} - 0.5 = 43\ \text{V}$$

In the worst case where the 22 pF value is at the lower limit of 19.8 pF,

$$K = \frac{19.8 \times 1.34}{10.3} = 2.55$$

Then the full 60 volts would be needed for V_{max}.

For cases where V_{min} and V_{max} have to remain fixed no matter what the circuit and Epicap VVC values are (within the prescribed tolerances) the circuit has to be designed around a constant K value. This means $\frac{C_{max}}{C_{ckt} + C_c}$ has to be fixed no matter what C_{max} or C_{ckt} are. Also for tuning the proper frequency $C_{max} + C_{ckt} + C_c$ has to remain constant.

$$L(C_{max} + C_{ckt} + C_c) = \frac{1}{(2\pi f_{min})^2} \tag{16}$$

$$\frac{C_{max}}{C_{ckt} + C_c} = K \tag{17}$$

By placing a trimmer capacitor in the circuit in addition to a variable inductance the conditions of eqs. (16) and (17) can be maintained. In the example above with C_{max} - 19.8 x 1.34 = 25.5 pF f_{min} = 60 MHz, K = 2.5, C_c = 0.3 pF.

$$L(C_{ckt} + 26.8 \times 10^{-12}) = \frac{1}{(2\pi\ 62 \times 10^6)^2}$$

$$C_{ckt} = \frac{C_{max}}{K} - C_c = \frac{26.5}{2.5} - 0.3 = 10.3\ \text{pF}$$

$$L = 0.192\ \mu\text{H}$$

If C_{max} = 24.2 x 1.34 = 32.5 pF, f_{min} = 60 MHz, K = 2.5, C_c = 0.3.

$$C_{ckt} = \frac{32.5}{2.5} - 0.3 = 12.7\ \text{pF}$$

$$L = 0.156\ \mu\text{H}$$

Hence to maintain constant tuning voltage within the standard Epicap VVC tolerances, the circuit inductance has to be tunable from 0.156 μH to 0.192 μH, and a trimmer capacity adjustable from 0.3 pF to 2.7 pF has to be added to the 10 pF circuit capacity. A summary of this design procedure is given in the following.

SUMMARY OF EPICAP VVC RESONANT CIRCUIT DESIGN

If f_{max}, f_{min}, C_{ckt}, V_{max}, and V_{min} are given,

1. From f_{max} and f_{min} determine $f_o = (f_{max}\ f_{min})^{1/2}$
2. Obtain percentage bandwidth = $\frac{f_{max} - f_{min}}{f_o}$
3. Determine $X = \left(\frac{0.5 + V_{min}}{0.5 + V_{max}}\right)^{1/2} = \frac{C_{min}}{C_{max}}$
4. Using Fig. 3 find $K = \frac{C_{max}}{C_{ckt} + C_c}$ at the intersection of constant percentage bandwidth and X lines.
5. Knowing C_{ckt} (use maximum value possible) and 0.3 pF for C_c if glass Epicap VVC is used (1.0 pF for large pill and 0.3 for small pill or pill with prong Epicap VVC) determine a trial C_{max} = C' max.
6. The Epicap VVC selected must have a four volt capacity $C_{-4\ V\ DC} > 1.1 \times \left(\frac{0.5 + V_{min}}{4.5}\right)^{1/2} C'_{max}$ The The 1.1 is to allow for standard 10% Epicap VVC tolerance (1.05 for a 5% tolerance unit).
7. Once an Epicap VVC is selected assume the minimum possible $C_{-4\ V\ DC}$ and calculate $C_{max} = \left(\frac{4.5}{0.5 + V_{min}}\right)^{1/2} C_{-4\ V\ DC}$.
   a. Using K from step 4 calculate a new C_{ckt}. The difference between this new C_{ckt} and that of the circuit has to be positive; otherwise a higher capacity Epicap VVC has to be selected. The capacity difference is the minimum value required for a trimmer capacitor placed in parallel with the Epicap VVC.
   b. Determine inductance from

   $$L = \frac{1}{(2\pi f_{min})^2\ (C_{max} + C_{ckt} + C_c)}$$

   where C_{ckt} includes the trimmer value, this L is the maximum value of the variable L.
8. Assume the maximum possible $C_{-4\ V\ DC}$ and calculate a corresponding

   $$C_{max} = \left(\frac{4.5}{0.5 + V_{min}}\right)^{1/2} C_{-4V\ DC}$$

   a. Using K from step 4, calculate a new C_{ckt}. The difference between this new C_{ckt} and that of the circuit is the maximum value required to the trimmer capacity.
   b. Determine inductance as in step 7b only, using the C_{ckt} and C_{max} for this step. This L is the minimum value of the variable L.
9. Check the calculations by determining f_{max} using V_{max} for both upper and lower Epicap VVC tolerances

   $$C_{min} = C_{max}\left(\frac{0.5 + V_{min}}{0.5 + V_{max}}\right)^{1/2}$$

   $$f_{max} = \frac{1}{2\pi\ (C_{min} + C_{ckt} + C_c)^{1/2}\ (L)^{1/2}}$$

   Be sure to use a consistent set of values for C_{min}, C_{ckt}, and L in one case from step 7 and in the other case from step 8.

EPICAP VVC-USAGE NEAR THE SELF-RESONANT FREQUENCY

If Epicap VVC inductance has an appreciable reactance compared to the junction reactance the design procedure has to be altered. An equivalent capacitance can be calculated but it is now a function of frequency.

$$Y = j\omega C_{eq} = \frac{j\omega C_j}{1 - \omega^2 L_s C_j} \tag{18}$$

or

$$C_{eq} = \frac{C_j}{1 - (2\pi f)^2 L_s C_j} \tag{19}$$

For the glass Epicap VVC's an L_s = 5 nH can be assumed with 1/16" leads and for the pill Epicap VVC's L_s = 0.4 nH. Using the proper inductance value with minimum and maximum frequencies and junction capacities, limits on C_{eq} can be obtained. From the C_{eq} limits an X can be calculated and using Fig. 3 a percentage bandwidth obtained.

In general, operation near self resonance is not recommended because the design procedures are not as definitive and the device Q is degraded.

CONCLUSIONS

Presented in this note is a design method for the use of Epicap VVC's in tuned resonant circuits. To aid the designer the pertinent equation of percentage bandwidth versus a function of minimum and maximum voltage is graphed with maximum Epicap VVC capacity to circuit capacity ratio as a parameter.

This design method applies to both parallel or series resonances in lumped circuit form. Future notes will extend the design procedure to distributed circuits.

SCR POWER CONTROL FUNDAMENTALS

INTRODUCTION

Recent high volume production techniques have brought SCR prices down to the point that almost any electrical product can benefit from electronic control. But how? What do SCRs do? How are they applied? Let's take a look at some fundamentals of power control using these devices.

OUTPUT POWER CHARACTERISTICS

The most common form of SCR power control is phase control. In this mode of operation, the SCR is held in an "off" condition (in which the SCR blocks all current flow in the circuit except for a small milliampere leakage current) for a portion of the positive half cycle and then is triggered into an "on" condition at a time in the half cycle determined by the control circuitry (in which the circuit current is limited only by the load – the entire line voltage except for a nominal one volt drop across the SCR is aplied to the load).

One SCR alone can control only one half cycle of the waveform. For full wave AC control, two SCR's are connected in inverse parallel (the anode of each connected to the cathode of the other). For full wave DC control, two methods are possible. Two SCR's may be used in a bridge rectifier or one SCR may be placed in series with a diode bridge (see Figure 1).

Figure 2 shows the voltage waveform along with some common terms used in describing SCR operation. Delay angle is the time, measured in electrical degrees, during which the SCR is blocking the line voltage. The period during which the SCR is on is called the conduction angle.

It is important to note that the SCR is a voltage controlling device. The load and power source determine the circuit current.

Now we arrive at a problem. Different loads respond to different characteristics of the AC waveform. Some loads are sensitive to peak voltage, some to average voltage and some to r. m. s. voltage. Figures 3 and 4 show the various characteristic voltages plotted against the conduction angle for half wave (Figure 3) and full wave (Figure 4) circuits. These voltages have been normalized to the r. m. s. of the applied voltage. To determine the actual peak, average or r. m. s. voltage for any conduction angle, we simply multiply the normalized voltage by the r.m.s. value of the applied line voltage. (These normalized curves also apply to current in a resistive circuit.) Since the greatest majority of circuits are either 115 or 230 volt power, the curves have been redrawn for these voltages in Figures 5 and 6.

A relative power curve has been added to Figures 3 and 4 for constant impedance loads such as heaters. (Incandescent lamps and motors do not follow this curve precisely since their relative impedance changes with applied voltage.) To use the curves, we find the full wave rated power of the load, then multiply by the fraction associated with the phase angle in question. For example, a 180° conduction angle in a half wave circuit provides 0. 5 x full wave full-conduction power.

An interesting point is illustrated by the power curves. A conduction angle of 30° provides only three per cent of full power in a full wave circuit, and a conduction angle of 150° provides 97 per cent of full power. Thus, the control circuit can provide 94 per cent of full power control with a pulse phase variation of only 120°. Thus, it becomes pointless in many cases to try to obtain conduction angles less than 30° or greater than 150°.

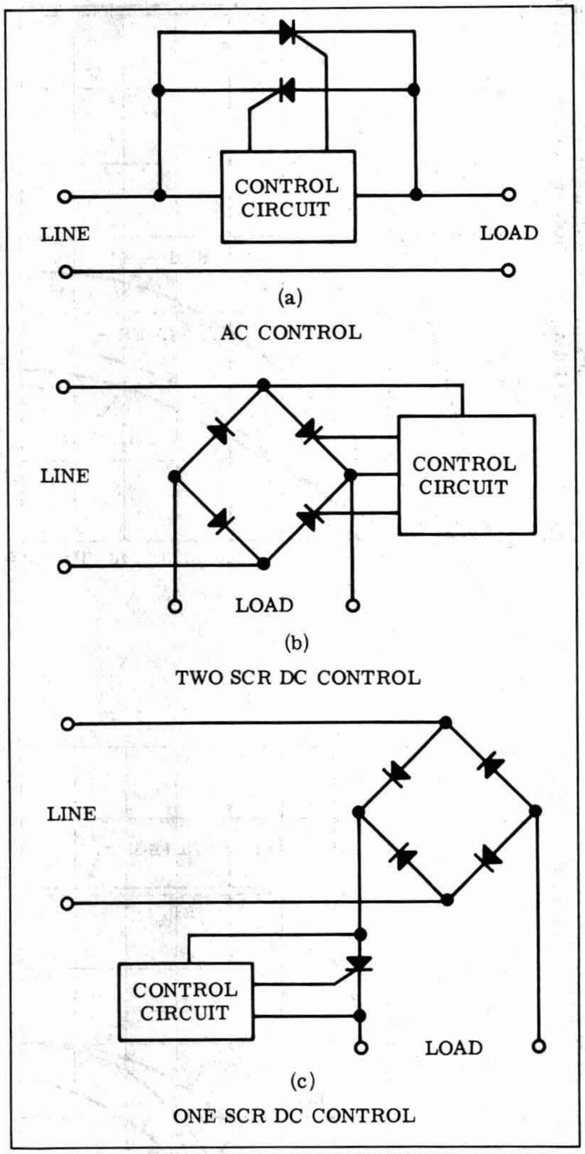


FIGURE 1 – SCR CONNECTIONS FOR VARIOUS METHODS OF PHASE CONTROL

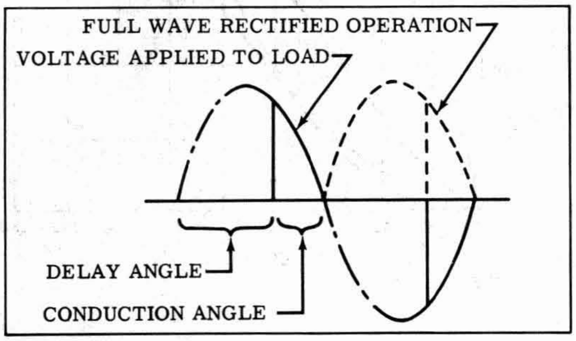


FIGURE 2 – SINE WAVE SHOWING PRINCIPLES OF PHASE CONTROL

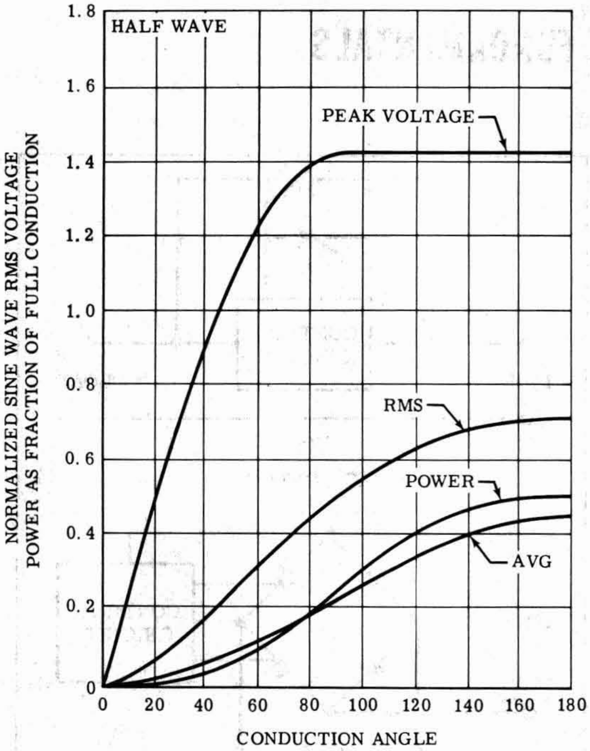


FIGURE 3

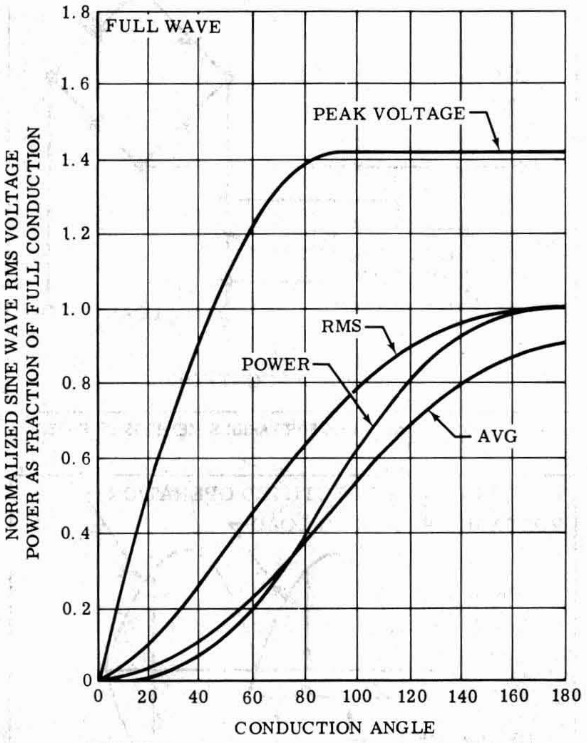


FIGURE 4

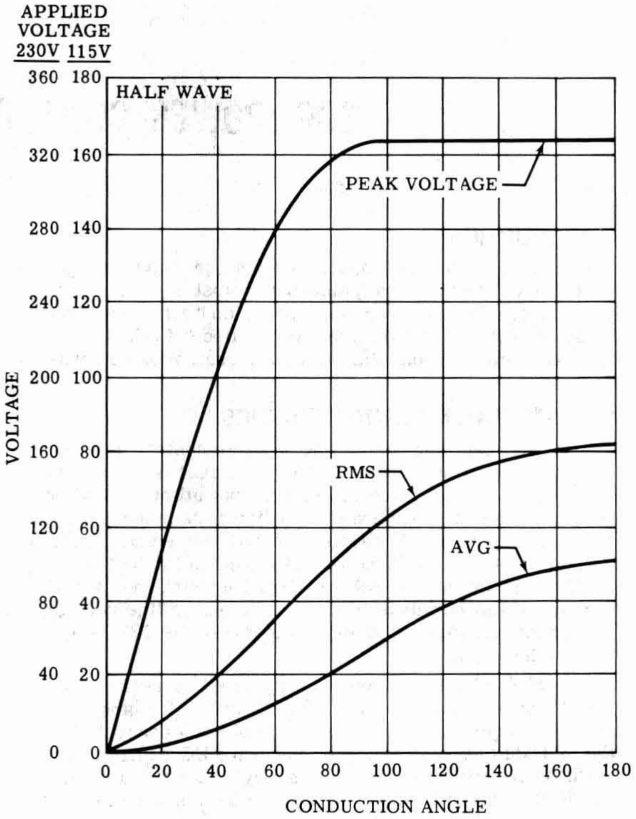


FIGURE 5

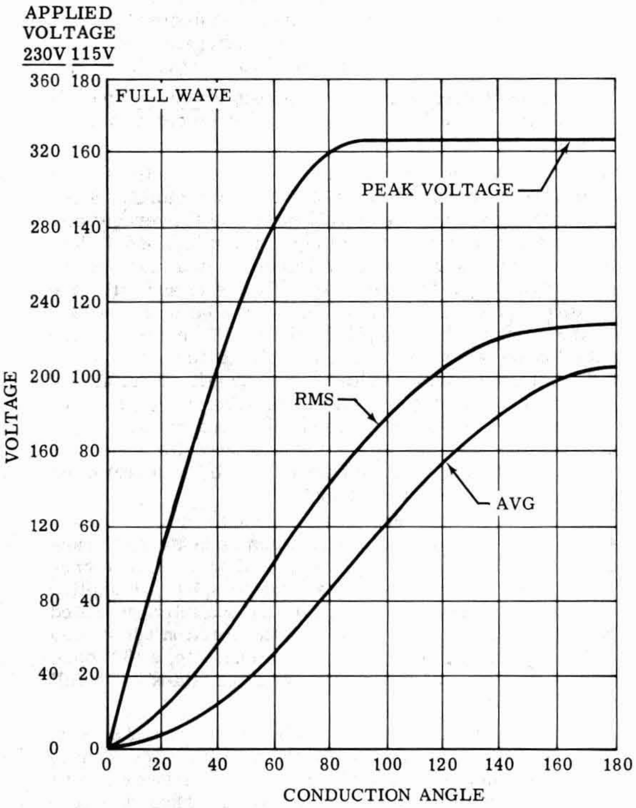


FIGURE 6

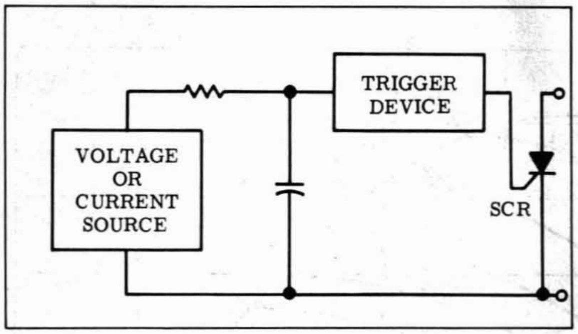


FIGURE 7 – RELAXATION OSCILLATOR SCR TRIGGER CIRCUIT

CONTROL CHARACTERISTICS

The simplest and most common control circuit for phase control is a relaxation oscillator. This circuit is shown diagramatically as it would be used with an SCR in Figure 7. The capacitor is charged through the resistor from a voltage or current source until the breakover voltage of the trigger device is reached. At that time, the trigger device changes to its "on" state, and the capacitor is discharged through the gate of the SCR. Turn-on of the SCR is thus accomplished with a short, high current pulse. Commonly used trigger devices are unijunction transistors, neon bulbs, and three, four, or five layer semiconductor trigger devices. Phase control of the output waveform is obtained by varying the RC time constant of the charging circuit so that the trigger device breakdown occurs at varying phase angles within the controlled half cycle.

If the relaxation oscillator is to be operated from a pure DC source, the capacitor voltage-time characteristic is shown in Figure 8 and Figure 9. Figure 8 shows the capacitor voltage as it rises all the way to the supply voltage through several time constants. Figure 9 shows the charge characteristic in the first time constant greatly expanded. It is this portion of the capacitor charge characteristic which is most often used in SCR control circuits.

Generally, a design starting point is selection of a capacitance value which will reliably trigger the SCR when the capacitor is discharged. SCR gate trigger characteristics and trigger device characteristics both play a part in the selection. Since not all of the important device characteristics for this selection are completely specified, experimental determination is often the best method.

Once a capacitor is selected, the curve of Figure 8 or Figure 9 may be used to determine the charging resistance necessary to obtain the desired control characteristics.

One note of caution should be injected at this point. Although many circuits begin each half cycle with the capacitor voltage at or near zero, some circuits leave a relatively large residual voltage on the capacitor after discharge (primarily neon lamp and three-layer semiconductor trigger circuits). In these latter circuits, the charging resistor must be determined on the basis of the additional charge necessary to raise the capacitor to trigger potential.

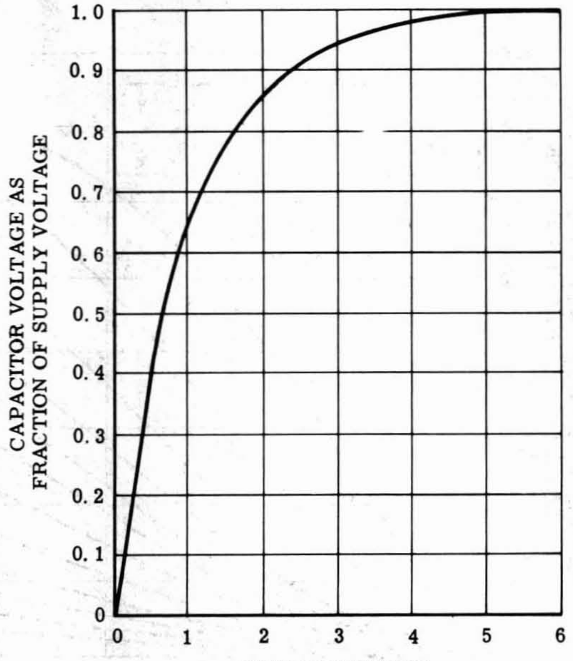


FIGURE 8 – CAPACITOR CHARGING FROM DC SOURCE

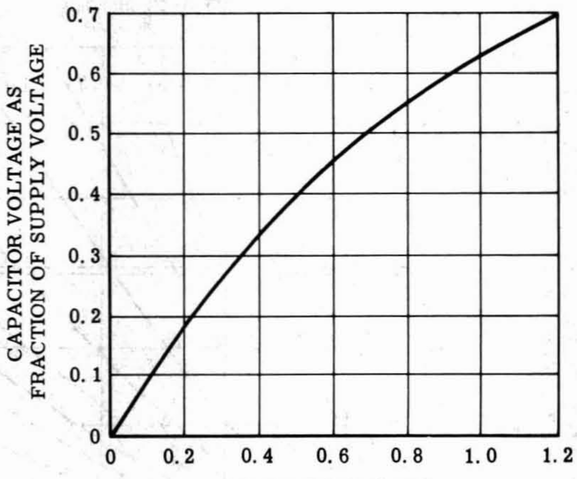


FIGURE 9 – EXPANDED SCALE OF FIGURE 8

An example will demonstrate the procedure. Let us assume that we wish to trigger an MCR 2304 SCR with a 32 volt 3-layer trigger. We have determined that a 0.1 μF capacitor will supply the necessary SCR gate current with the trigger diode. Assume a 50 volt DC power supply, 30° minimum conduction angle and 150° maximum conduction angle with a 60 Hz anode power source. The trigger diode triggers at approximately 32 volts and leaves 10 volts on the capacitor after firing. Thus, 22 volts must be added to the capacitor potential in order to trigger, and 40 volts additional (50-10) are available. The capacitor must charge to 22/40 or 0.55 of the available charging voltage in the desired time. Referring to Figure 9, we see that 0.55 of charging voltage represents 0.8 time constant. The 30° conduction angle requires that the firing pulse be delayed 150° or 6.92 milliseconds. (8.33 milliseconds is the period of 1/2 cycle at 60 Hz.) To obtain this time delay,

$$6.92 \text{ ms} = 0.8 \text{ RC}$$

$$\text{RC} = 8.68 \text{ ms}$$

If $C = 0.10\ \mu\text{F}$,

$$R = \frac{8.68 \times 10^{-3}}{0.1 \times 10^{-6}} = 86,800 \text{ ohms}$$

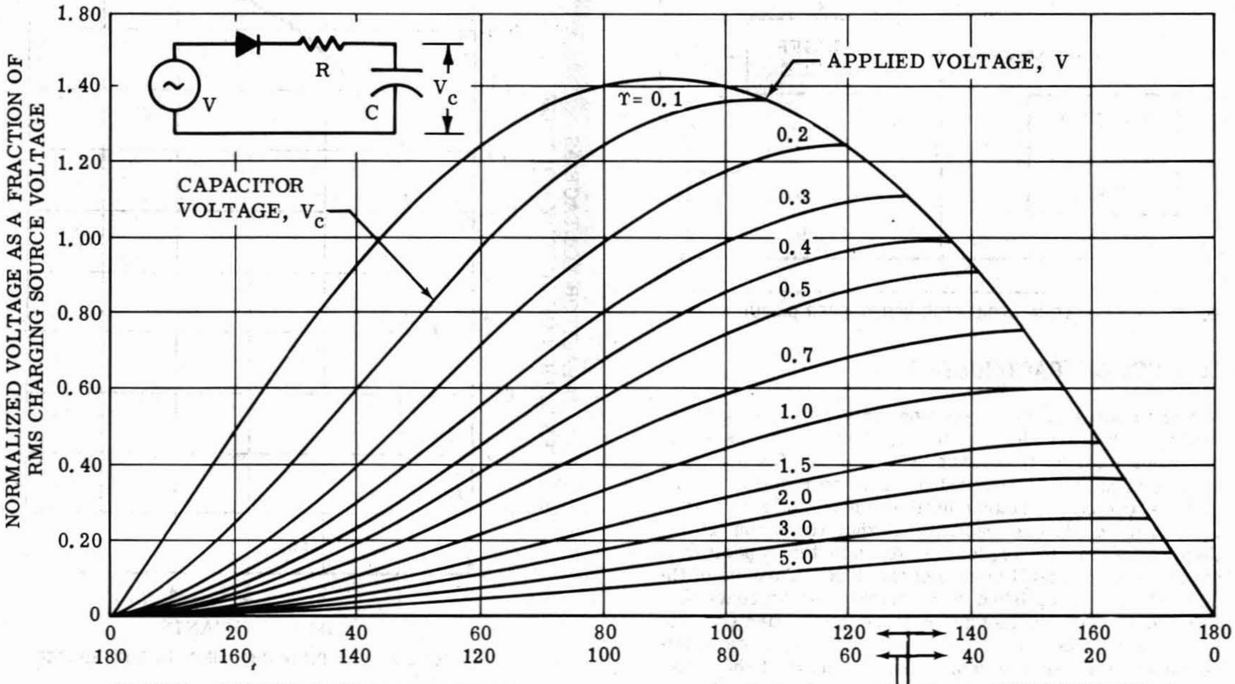


FIGURE 10 – CAPACITOR VOLTAGE WHEN CHARGED

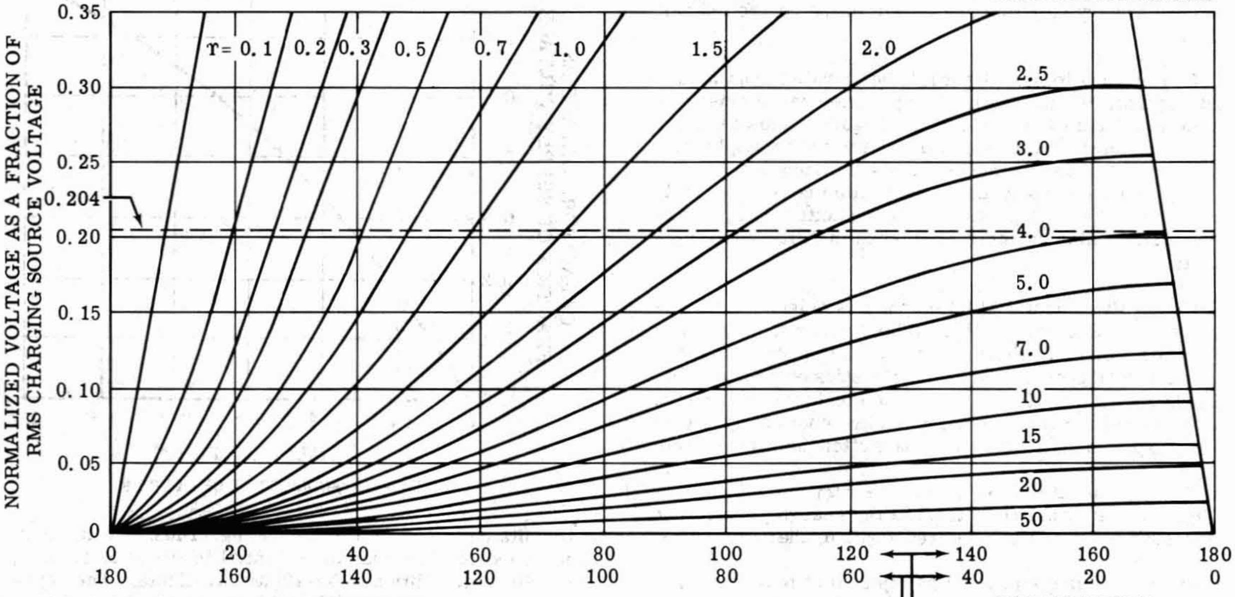


FIGURE 11 – EXPANSION OF FIGURE 10

To obtain minimum R, 150° conduction angle, the delay is 30° or

$$30/180 \times 8.33 = 1.39 \text{ ms}$$

$$1.39 \text{ ms} = 0.8 \text{ RC}$$

$$\text{RC} = 1.74 \text{ ms}$$

$$R = \frac{1.74 \times 10^{-3}}{0.10 \times 10^{-6}} = 17,400 \text{ ohms.}$$

Using practical values, a 100K ohm potentiometer with up to 17K minimum resistance, will serve this purpose. Similar calculations using conduction angles between the maximum and minimum values will give the control resistance versus power characteristic of this circuit.

In many of the recently proposed circuits for low cost operation, the timing capacitor of the relaxation oscillator is charged through a rectifier and resistor using the AC power line as a source. Calculations of charging time with this circuit become exceedingly difficult, although they are still necessary for circuit design. The curves of Figures 10 and 11 simplify the design immensely. These curves show the voltage-time characteristic of the capacitor charged from one half cycle of a sine wave. Voltage is normalized to the r.m.s. value of the sine wave for convenience of use. The parameter of the curves is a new term, the ratio of the RC time constant to the period of one half cycle, and is denoted by the Greek letter ϒ. ϒ may most easily be calculated from the equation

$\Upsilon = 2RCf$. Where:
R = resistance in Ohms
C = capacitance in Farads
f = frequency in Hertz

To use the curves when starting the capacitor charge from zero each half cycle, a line is drawn horizontally across the curves at the relative voltage level of the trigger breakdown compared to the r. m. s. sine wave voltage. The Υ is determined for maximum and minimum conduction angles and the limits of R may be found from the equation for Υ. If a trigger circuit which leaves residual voltage on the capacitor is used with a DC SCR circuit, the curves may be used with moderate accuracy by subtracting 0. 71 times the residual voltage from the charging sine wave r. m. s. voltage, providing the residual voltage is less than 25% of the sine wave r. m. s. Ballpark estimates may be obtained with residual voltages as high as 50% of the sine wave r. m. s. using this method.

An example will again clarify the picture. Consider the same problem as the previous example, except that the capacitor charging source is the 115V AC, 60 Hz power line. Since the 10 volt residual charge is less than 25% of 115 volts, the curves will give us an acceptable result. Correcting the source voltage,

$$E_s = 115 - 0.71 \times 10 = 108 \text{ volts}$$

The ratio of the additional voltage necessary to break over the trigger diode to the equivalent r.m.s. changing voltage is then

$$22/108 = 0.204$$

A line drawn at 0. 204 on the ordinate of Figure 11 shows that for a conduction angle of 30°, $\Upsilon = 3.80$, and for a conduction angle of 150°, $\Upsilon = 0.27$. Therefore, since

$$R = \frac{\Upsilon}{2Cf}$$

$$R_{max} = \frac{3.8}{2 \times .01 \times 10^{-6} \times 60} = 316,000 \text{ ohms}$$

$$R_{min} = \frac{0.27}{2 \times 0.1 \times 10^{-6} \times 60} = 22,500 \text{ ohms}$$

These values would require a potentiometer of 300k ohms in series with a 22k minimum fixed resistance. Figure 12 shows a DC power control circuit capable of controlling a 600 watt load using the values just derived.

For AC design, 0.71 x the residual voltage is added to the line voltage, since on each half cycle the residual voltage from the previous half cycle is of opposite polarity to the applied voltage. Figure 13 shows an AC control circuit derived from that of Figure 12. To obtain full wave control, this circuit uses the bidirectional 3-layer trigger and the built-in gate shunt resistor of the MCR 2304 series of SCR's which allow triggering in both half cycles.

Incandescent lamps and some motors require full range control for maximum benefit. The circuit of Figure 14 was derived from that of Figure 13 and uses a double phase shift network to obtain reliable triggering at conduction angles as low as 5°.

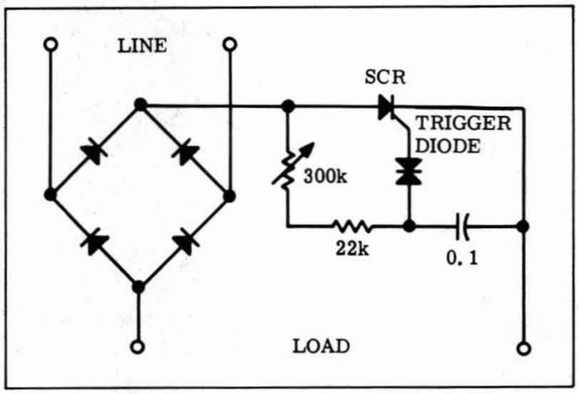


FIGURE 12 – SIMPLE DC POWER CONTROL CIRCUIT

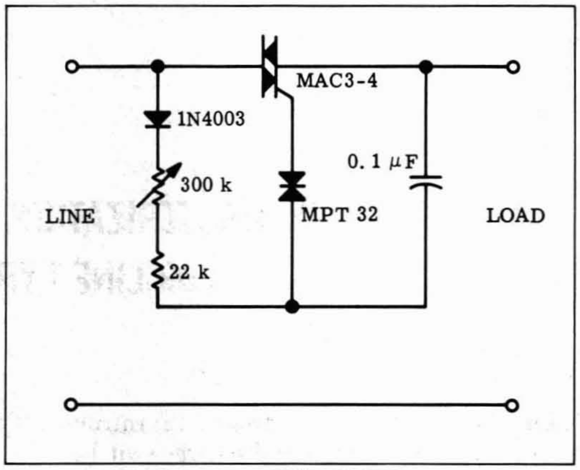


FIGURE 13 – SIMPLE FULL-WAVE POWER CONTROL

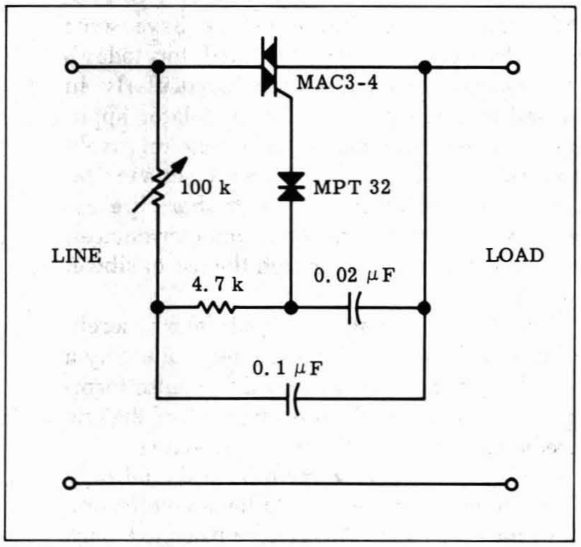


FIGURE 14 – FULL RANGE AC POWER CONTROL

SUMMARY

With new low SCR prices and simplified circuits, automatic control is a possibility for many electrical products in the consumer market. These simple circuits discussed in this paper will give the product designer a good feel for the nature of SCR circuits and their design. As he becomes more familiar with the control techniques, more sophistication, such as speed or temperature feedback circuits can be developed. The degree of control obtainable with very simple circuits using SCR's is a remarkable phenomenon. Consumer products will benefit greatly both in usability and marketability as a result.

CHARACTERIZATION OF SCR'S AS SWITCHES FOR LINE TYPE MODULATORS

Since World War II, hydrogen thyratrons have been used extensively as discharge switches for line type modulators. In general, such devices have been highly satisfactory from an electrical performance standpoint, but they have some major drawbacks when evaluated for today's more sophisticated equipment, particularly in low and medium power pulse modulator applications. These drawbacks, including relatively large size and weight, low efficiency (due to filament power requirements), and short life expectancy compared with semiconductor devices, now can be eliminated through the use of silicon controlled rectifiers.

A line type modulator is a modulator wherein output-pulse characteristics are determined by a lumped-constant transmission line (pulse forming network) and by the proper match of the line impedance (PFN) to the load impedance.

A switch for this type modulator should only initiate conduction and should have no effect on pulse characteristics. This is in contrast to a hard switch modulator wherein output pulse characteristics are determined by the "hard" relationship of grid (base) control of conduction through a vacuum tube (transistor) switch.(1)

Referring to the schematic (see back page), when the power supply is first turned on, no charge exists in the PFN, and energy is transferred from the power supply to the PFN via the resonant circuit comprising the charging choke and PFN capacitors. At the time that the voltage across the PFN capacitors reaches twice the power supply voltage, current through the charging choke tries to reverse and the power supply is disconnected due to the back biased impedance of the hold-off diode. If we assume this diode to be perfect, the energy remains stored in the PFN until the discharge switch is triggered to its "on" state. When this occurs, assuming that the pulse transformer has been designed to match the load impedance to the PFN impedance, all energy stored in the PFN reactance will be transferred to the load if we neglect switch losses. Upon completion of the transfer of energy the switch must return to its "off" condition before allowing transfer of energy once again from the power supply to the PFN storage element.

OPTIMUM SWITCH CHARACTERISTICS

Forward Breakover Voltage

Device manufacturers normally apply the variable-amplitude output of a half-wave rectifier across the SCR. Thus, forward voltage is applied to the device for only a half cycle and the rated voltage is applied only as an ac peak. While this produces a satisfactory rating for ac applications, it does not hold for dc.

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(1) A comprehensive discussion of line type and hard tube modulators is given in Volume 5, *Pulse Generators*, Glasoe and Lebacqz, MIT Radiation Laboratory Series.

The author has found that an estimated 90% of devices tested for minimum breakover voltage (V_{BO}) in a dc circuit will not meet the data sheet performance specifications. A switch designed for the pulse modulator application should therefore specify a minimum continuous forward breakover voltage at rated maximum leakage current for maximum device temperature.

The "OFF" Switch

The maximum forward leakage current of the SCR must be limited to a low value at maximum device temperature. During the period of device nonconduction it is desired that the switch offer an "off" impedance in the range of megohms to hundreds of megohms. This is required for two reasons: (1) to prevent diminishing the efficiency of recharge by an effective shunt path across the PFN, and (2) to prevent the bleeding off of PFN charge during the interpulse period. This second factor is especially important in the design of radar transponders wherein the period between interrogations is variable. Change of the PFN voltage during the interpulse period could result in frequency shift, pulse instabilities, and loss of power from the transmitter being modulated.

The "ON" Switch

At present, SCR design is more limited in the achievable maximum forward sustaining voltage than in the current that the device will conduct. For this reason modulators utilizing SCR's can be operated at lower impedance levels than comparable thyratron circuits of yesterday. It is not uncommon for the characteristic impedance of the pulse forming network to be in the order of 5 to 10 ohms or less. Operating the SCR at higher current to switch the same equivalent pulse power as a thyratron requires the SCR "on" impedance to be much lower so that the I^2R loss is a reasonable value, in order to maintain circuit efficiency. Low switch loss, moreover, is mandatory because internal power dissipation can be directly translated into junction-temperature-rise and associated leakage current increase which, if excessive, could result in thermal runaway.

Turn-On Time

In radar circuits the *pulse-power* handling capability of an SCR, rather than the normally specified *average-power* capability, is of primary importance.

For short pulses at high PRF's the major portion of semiconductor dissipation occurs during the initial turn-on during the time that the anode rises from its forward leakage value to its maximum value. It is necessary, therefore, that turn-on time be as short as possible to prevent excessive power dissipation.

The function of radar is to provide distance information measured as a function of time. It is important, therefore, that any delay introduced by a component be fixed in relation to some variable parameter such as signal strength or temperature. For radar pulse modulator applications, a minimal delay variation versus temperature is required and any such variation must be repetitive from SCR to SCR, in production lots, so that adequate circuit compensation may be provided.

Pulse Gate Current to Fire

The time of delay, the time of rise, and the delay variation versus temperature associated with SCR turn-on are functions of the gate triggering current available and the trigger pulse duration. In order to predict pulse circuit operation of the SCR, the pulse gate current required to turn the device on when switching the low-impedance modulator should be specified and the limits of turn-on-time variation for the specified pulse trigger current and collector load should be given at the high and low operating temperature extremes.

Recovery Time

After the cessation of forward conducting current in the "on" device, a time of SCR circuit isolation must be provided to allow the semiconductor to return to its "off" state. Recovery time cannot be given as an independent parameter of device operation, but must include factors as determined by the external circuit, such as: (1) pulse current and rate of decay; (2) availability of an inverse voltage immediately following pulse-current conduction; (3) level of base bias following pulse current conduction; (4) rate of rise of reapplied positive voltage and its amplitude in relation to SCR breakover voltage; and (5) maximum circuit ambient temperature.

In the reverse direction the controlled rectifier behaves like a conventional silicon diode. Under worst circuit conditions, if an inverse voltage is generated through the existence of a load short circuit, the current available will be limited only by the impedance of the pulse forming network and SCR inverse characteristics. The reverse current is able to sweep out some of the carriers from the SCR junctions. Intentional design of the load impedance to something less than the network impedance allows development of an inverse voltage across the SCR immediately after pulse conduction, enhancing switch turn-off time. Careful use of a fast clamp diode in series with a fast zener diode, the two in shunt across the SCR, allows application of a safe value of circuit-inverse-voltage without preventing the initial useful reverse current. Availability of a negative base-bias following pulse current conduction provides a similar enhancement of switch turn-off time.

If removal of carriers from the SCR junction enables a faster switch recovery time, then, conversely, operation of the SCR at high temperatures with large forward currents and with slow rate of current decay all increase device recovery time.

Holding Current

One of the anomalies that exist in the design of a pulse SCR is the requirement for a high holding current. This need can be determined by examining the isolation component that disconnects the power supply from the discharge circuit during the time that PFN energy is being transferred to the transmitter and during the recovery time of the discharge switch. An inductance resonating with the PFN capacitance at twice the time of recharge is normally used for power supply isolation. Resonant charging restricts the initial flow of current from the power supply, thereby maximizing the time at which power supply current flow will exceed the holding current of the SCR. If the PFN recharge current from the power supply exceeds the holding current of the SCR before it has recovered, the SCR will again conduct without the application of a trigger pulse. As a result continuous conduction occurs from the power supply through the low impedance path of the charging choke and "on" switch. This lock-on condition can completely disable the equipment employing the SCR switch.

The charging current passed by the inductance is given as (the PFN inductance is considered negligible):(2)

$$i_c(t) = \frac{E_{bb} - V_n\,(0)}{\sqrt{L_c/C_n}} \left(\frac{\cos \dfrac{T_r - 2t}{2\sqrt{L_c C_n}}}{\sin \dfrac{T_r}{2\sqrt{L_c C_n}}} \right)$$

Where

E_{bb} = power supply voltage

$V_n\,(0)$ = 0 volts if the PFN employs a clamp diode or is matched to the load

T_r = time of resonant recharge and is usually equal to $\frac{1}{\text{PRF}}$

L_c = value of charging inductance

C_n = value of total PFN capacity

For a given radar pulse modulator design, the values of power supply voltage, time of resonant recharge, charging choke inductance, and PFN capacitance are established. If the time (t) represents the recovery time of the SCR being used as the discharge switch, i_c then represents the minimum value of holding current required by the SCR to prevent power supply lock-on. Conversely, if the modulator design is about an existing SCR where holding current, recovery time, and forward breakover voltage are known, the charge parameters can be derived by rewriting the above formula as follows:

$$I_H = \frac{V_{BO} - V_n(0)}{\sqrt{L_c/C_n}} \left(\frac{\cos \dfrac{T_r - 2(\text{recovery time})}{2\sqrt{L_c C_n}}}{\sin \dfrac{T_r}{2\sqrt{L_c C_n}}} \right)$$

The designer may find that for the chosen SCR the desired characteristics of modulator pulse width and pulse repetition frequency are not obtainable.

One means of increasing the effective holding current of an SCR is for the semiconductor to exhibit some turn-off gain characteristic for the residual current flow at the end of the modulator pulse. The circuit designer then can provide turn-off base current, making the SCR more effective as a pulse circuit element.

The SCR as a Unidirectional Switch

When triggered to its "on" state, the SCR, like the hydrogen thyratron, is capable of conducting current in one direction. A load short circuit could result in an inverse voltage across the SCR due to the reflection of voltage from the pulse forming network. The circuit designer may wish to provide an intentional load-to-PFN mismatch such that some inverse voltage is generated across the SCR to enhance its turn-off characteristics. Nevertheless, since the normal circuit application is unidirectional, the semiconductor device designer could take advantage of this fact in restricting the inverse-voltage rating that the SCR must withstand. The circuit designer, in turn, can accommodate this lack of peak-inverse-voltage rating by use of a suitable diode clamp across the PFN or across the SCR.

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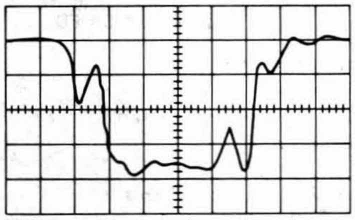
(2) *Pulse Generators.* Volume 5, Page 359, Glasoe and Lebacqz. MIT Radiation Laboratory Series.

A Practical Pulse Modulator SCR

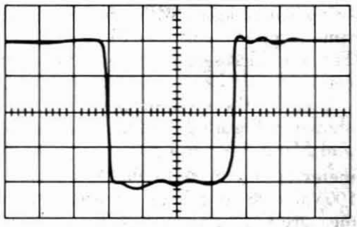
In the absence of commercially available SCR's suitably designed and specified for a specific project at Motorola's Western Military Electronics Center, the cooperation of the Semiconductor Products Division was secured for the development of a device to meet the requirements outlined above. This has resulted in the MCR729 — an SCR specifically designed for pulse modulator applications, and specified accordingly.(3)

One actual use of the MCR729 has been in a radar modulator requiring pulse outputs of 60 and 450 nanoseconds at a peak pulse power of 2700 watts and a PRF of 10,000 pps. Detected RF pulse rise time, to a large extent dependent on the SCR rate of current rise, is only 20 nanoseconds.



Vertical 5 amps/cm ▲
Horizontal.2μsec/cm
Current Pulse Through An MCR 729-9, Driving Magnetron Load

Vertical set to 4CM
Horizontal .2μsec/cm
Detected RF Magnetron Pulse ▼



A second application uses a single MCR729 to switch 5000 watts of peak pulse power, with a circuit recovery time of 45 microseconds at an 85°C ambient temperature. Maximum duty cycle of this circuit is 0.0024. The current and detected RF waveforms were obtained using an MCR729-9 with this circuit. The current pulse being switched is 18 amperes. Pulse width is approximately 0.75 microsecond. The rise and fall times of the detected RF pulse are both less than 50 nanoseconds.

Measurements made on the MCR729 prior to circuit use have shown the switch to be stable, fast, and efficient. Pulse "on" impedance has consistently measured less than 0.5 ohm. Delay variation versus temperature is typically ± 20 nanoseconds measured from — 55°C to + 105°C. Time of delay averages about 300 nanoseconds.

TEST OF SCR's FOR PULSE CIRCUIT APPLICATION

The suitability for pulse circuit applications of SCR's not specifically characterized for such purposes can be determined from measurements carried out with relatively simple test circuits under controlled conditions. Applicable test circuits and procedures are outlined in the following section.

Test of Forward Blocking Voltage and Leakage Current

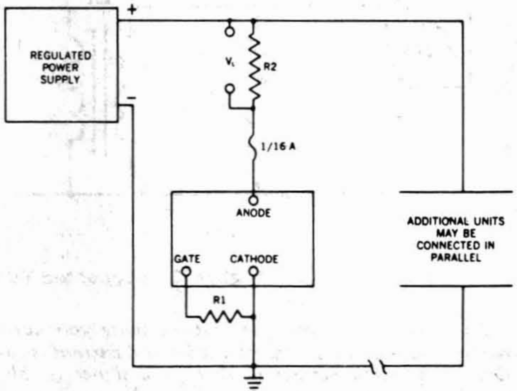


Figure 1 — Test Setup for SCR Forward Blocking Voltage and Leakage Current Measurements.

Resistor R1 is used only if manufacturer calls for bias resistor between gate and cathode. Resistor R2 can have any small value which, when multiplied by maximum allowable leakage current, will provide a convenient reading of voltage V_L.

PROCEDURE:
Mount the SCR's to a heat sink and connect the units to be tested as shown in Figure 1. Place the assembly in an oven and stabilize at maximum SCR rated temperature. Turn on the power supply and raise the voltage to rated V_{BO}. Allow units to remain with the voltage applied for a minimum of four hours. At the end of the temperature soak, determine if any units exhibit thermal runaway by checking for blown fuses (without removing the power). Reject any units which have blown circuit fuses. The forward leakage current, I_{LF}, of the remaining units may be calculated after measuring the voltage V_L, across resistor R2. Any units with a leakage current greater than manufacturer's rating should be rejected.

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(3) A data sheet characterizing the MCR729 SCR can be obtained by writing to the Technical Information Center, Motorola Semiconductor Products Inc.

Measurement of Turn-On Time, Turn-On Time Variation, and "On" Impedance

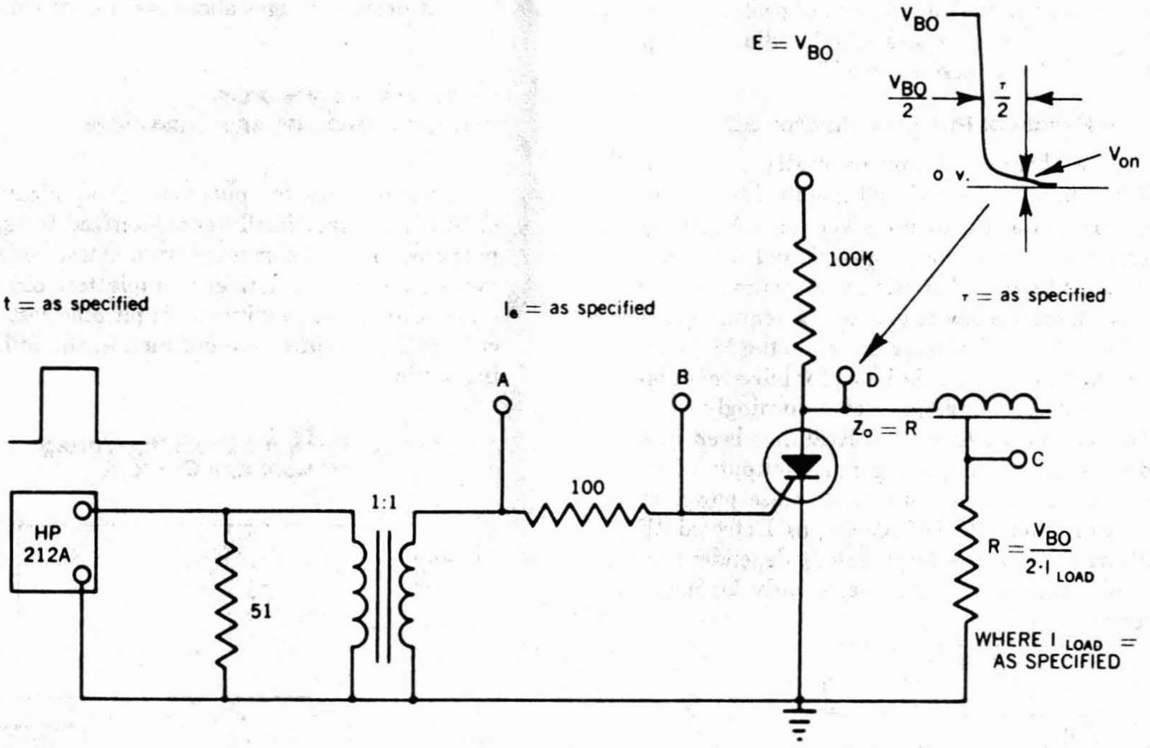


Figure 2–Suggested Test Circuit for SCR "On" Measurements.

The above circuit assumes that the pulse gate current required to switch a given modulator load current is specified by the manufacturer or that the designer is able to specify the operating conditions. Typical operating values might be:

Time of trigger pulse $t = 1$ microsecond
Pulse gate current $I_G = 200$ milliamps
Forward blocking voltage $V_{BO} = 400$ volts
Load current $I_{Load} = 30$ amps

PROCEDURE:

Turn-On Time Measurement ($T_D + T_R$)

Using a Tektronix 545 oscilloscope (or equivalent) with a dual trace type CA plug-in, connect probes of Channels A and B to Test Points A and B. Place the Mode selector switch in the Added Algebraically position and the Channel B Polarity switch in the Inverted position. Adjust the HR212A pulse generator to give a positive pulse 1.0 microsecond wide (100 pps) as viewed at Test Point A. Adjust the amplitude of the "added" voltage across the 100-ohm base resistor for the specified pulse gate current (200 milliamps in this example).

Switch the Mode selector knob to the alternate position. Connect Channel A to Test Point D. Leave the oscilloscope probe, Channel B, at Test Point B, thereby displaying the input trigger waveform. Measure the time between the 50 per cent voltage amplitudes of the two waveforms. This is the Turn-On Time ($T_D + T_R$).

Turn-On Time Variation Versus Temperature

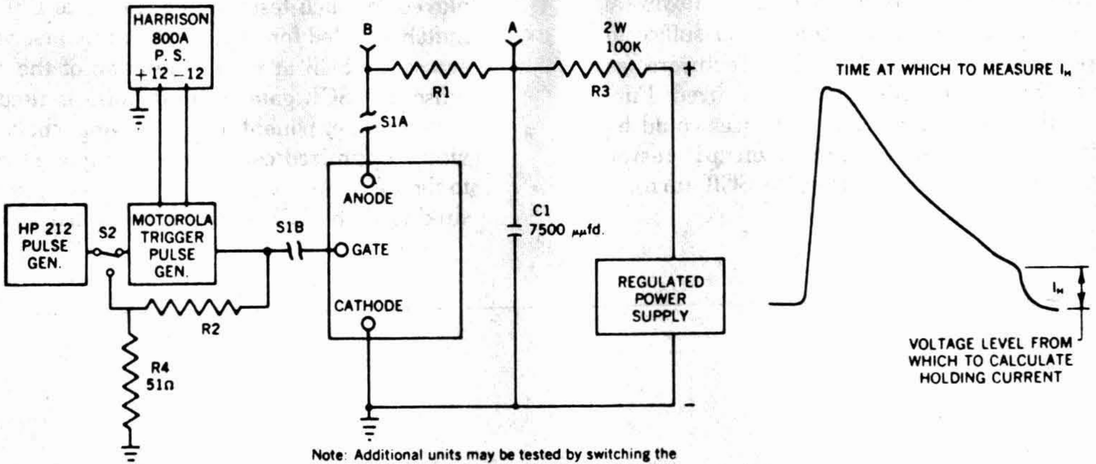
Place the device to be tested on a suitable heat sink and place the assembly in a temperature chamber. Stabilize the chamber at minimum rated (cold) temperature. Repeat the above measurements. Raise the chamber temperature to maximum rated (hot) temperature and stabilize. Repeat the measurements above.

Measurement of "On" Impedance

For the specified current load, the "on" impedance can be measured as an SCR forward voltage drop. The point in time of measurement shall be half the output pulse width. For a 1 microsecond output pulse, the measurement procedure would be:

Connect the oscilloscope probe, Channel B, to Point D shown in Figure 2. Use the oscilloscope controls Time/CM and Multiplier to a setting of 0.5 microsecond per centimeter or faster. With the Amplitude Control set to view 100 volts per centimeter (to prevent amplifier overloading) measure the amplitude of the voltage drop, V_F, across the SCR 0.5 microsecond after the PFN voltage waveform has dropped to half amplitude. It may be necessary to check ground reference several times during this test to provide the needed accuracy of measurement.

Holding Current


HARRISON
800A
P. S.
+12 −12
B
A
2W
100K
R1
R3
+
S1A
ANODE
HP 212
PULSE
GEN.
S2
MOTOROLA
TRIGGER
PULSE
GEN.
S1B
GATE
C1
7500 μμfd.
CATHODE
R2
REGULATED
POWER
SUPPLY
R4
51Ω
−
TIME AT WHICH TO MEASURE I_H
I_H
VOLTAGE LEVEL FROM
WHICH TO CALCULATE
HOLDING CURRENT

Note: Additional units may be tested by switching the anode and gate connections to similarly mounted SCR's. Short lead lengths are desirable.

Figure 3 — Test Setup for Measuring Holding Current.

The SCR holding current can be measured with or without a gate turn-off current, according to the position of switch S2. The Motorola Trigger Pulse Generator is a transistor circuit capable of generating a 1.5 microsecond turn-on pulse followed by a variable-duration turn-off pulse. Measurements should be made at the maximum expected temperature of operation. Resistor R1 should be chosen to allow an initial magnitude of current flow at the device pulse current rating.

PROCEDURE:

Connect the SCR's under test as illustrated. Place SCR's in oven and stabilize at maximum expected operating temperature. View the waveform across R1 by connecting the oscilloscope probe (Tektronix 545 with CA plug-in) Channel A to Point A, and Channel B to Point B. Place the Mode Selector switch in the Added Algebraically position. Place the Polarity switch of Channel B in the Inverted position. Adjust both Volts/CM switches to the same scale factor, making sure that each Variable knob is in its Calibrated position. Adjust pulse generator for a positive pulse, 1.0 microsecond wide, and 1,000 pps pulse repetition frequency. Adjust power supply voltage to rated V_{BO}. Adjust input pulse amplitude until unit fully triggers. Measure amplitude of voltage drop across R1, V(A — B), and calculate holding current in milliamperes from the equation

$$ma = \frac{V(A-B)}{R1} + \frac{V_{BO}}{100\ K\ ohms}$$

Any unit which turns on but does not turn off has a holding current of less than

$$\frac{V_{BO}\ volts}{100\ K\ ohms}$$

The approximate voltage setting to view the amplitude of the holding current will be 10 or 20 volts per centimeter. The approximate sweep speed will be 2 to 5 microseconds per centimeter. These settings will, of course, vary, depending upon the holding current of the unit under test.

Test of Recovery Time

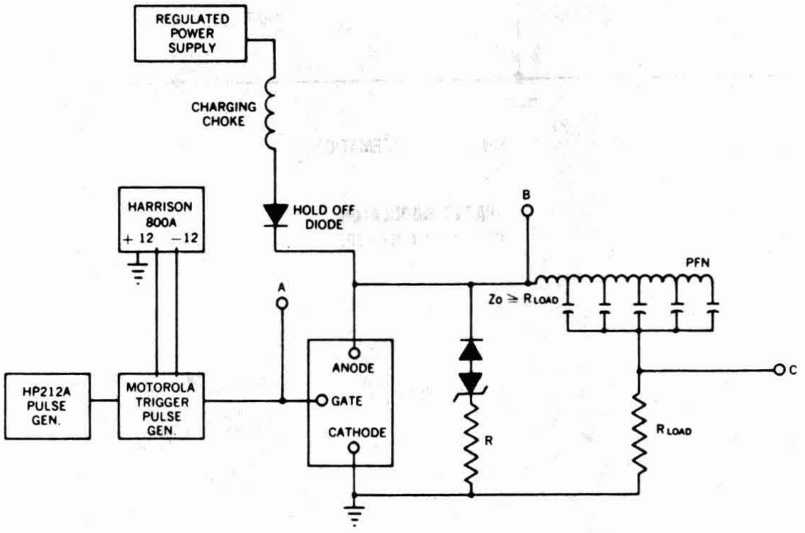
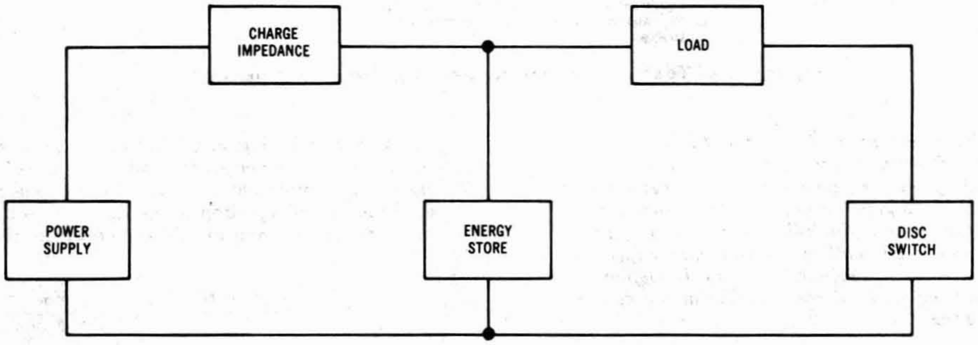
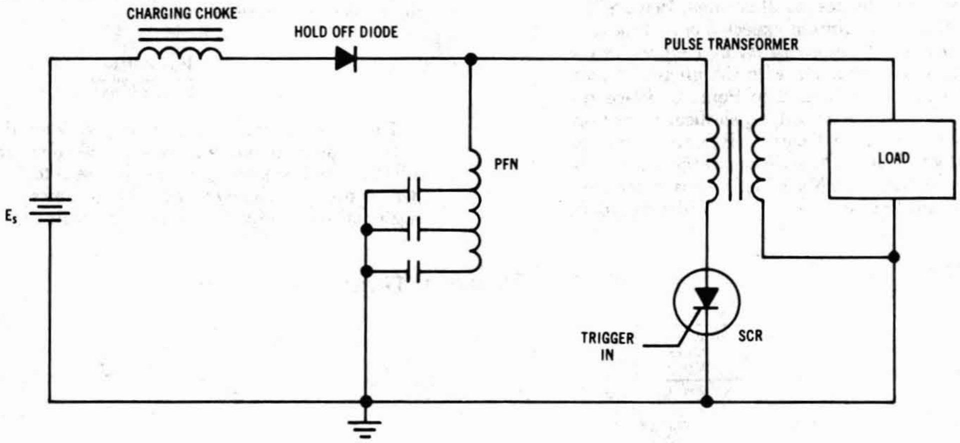

REGULATED
POWER
SUPPLY
CHARGING
CHOKE
HARRISON
800A
+12 −12
HOLD OFF
DIODE
B
PFN
A
Zo ≥ R_LOAD
ANODE
C
HP212A
PULSE
GEN.
MOTOROLA
TRIGGER
PULSE
GEN.
GATE
CATHODE
R
R_LOAD

Figure 4 — Modulator Circuit for SCR Tests.

SCR recovery time is greatly dependent upon the circuit in which the device is used. However, any test of SCR recovery time should suffice to compare devices of various manufacturers, as long as the test procedure is standardized. Further evaluation of the selected devices could be made in an actual modulator circuit tester wherein techniques conducive to SCR turn-off are used. The above circuit setup can be employed for such tests. A slight load to PFN mismatch is called for to generate an inverse voltage across the SCR at the termination of the output pulse. An SCR gate turn-off pulse is used. The recharge component is a charging choke, providing optimized conditions of reapplied voltage to the PFN (and across the SCR). Adequate heat sinking of the SCR should be provided.


CHARGE IMPEDANCE
LOAD
POWER SUPPLY
ENERGY STORE
DISC SWITCH

BLOCK DIAGRAM


CHARGING CHOKE
HOLD OFF DIODE
PULSE TRANSFORMER
PFN
LOAD
E$_s$
TRIGGER IN
SCR

SIMPLIFIED SCHEMATIC

RADAR MODULATOR
RESONANT LINE TYPE

THEORY AND CHARACTERISTICS OF THE UNIJUNCTION TRANSISTOR

INTRODUCTION

The unijunction transistor or UJT is by no means a newcomer to the semiconductor industry. In 1948 the feasibility of such a device was demonstrated by Heinrich Welker in France and a year later Shockley and Haynes wrote a paper describing the basic principles of UJT operation. The first commercially available UJT was developed by I.A. Lesk* in 1952.

This note will first discuss the theory associated with UJT operation, followed by a table explaining unijunction transistor nomenclature. The conventional UJT structures are then described as well as the annular method by which the Motorola UJT is manufactured. Finally, some of the more important characteristics of the UJT and their behavior under different operating conditions will be discussed.

THEORY OF OPERATION

The unijunction transistor (UJT) is a three terminal device, the three terminals being the emitter, base one and base-two.

The UJT (or double base diode as it was called in early papers) has, as the name implies, only a single P-N junction, and the characteristics of the UJT are for this reason quite different from those of the conventional transistor. Table I shows the commonly used UJT symbols and their proper definitions in accordance with the Joint Electron Device Engineering Council (JEDEC) Standard.

In order to explain the operation of the unijunction transistor it is convenient to use the so called bar structure as a model (the bar structure will be discussed in detail later in the paper). This structure is shown somewhat simplified in Figure 1a and the electrical equivalent circuit is shown in Figure 1b. The equivalent circuit is valid for emitter currents equal to or less than the peak point current.

When voltage V_{B2B1} is applied, a current will flow in the silicon bar from base-two to base-one. Since the bar is essentially a resistor of magnitude r_{BB}, the current that flows into base-two is determined by $I_{B2} = \frac{V_{B2B1}}{r_{BB}}$.

A fraction of the applied voltage V_{B2B1} will appear at point A where the emitter is alloyed onto the silicon bar, and this fraction is denoted as η. The voltage at point A is therefore $\eta\ V_{B2B1}$, the P-N junction formed by the emitter and the silicon bar is reverse biased and only a small reverse leakage current flows in the emitter lead.

As the voltage V_E at the emitter is increased, a point will be reached where V_E equals the voltage at point A plus the forward voltage drop of the P-N junction, V_D. The emitter voltage at this point is called the peak point emitter voltage V_P. The peak point voltage can be written as:

$$V_p = V_D + \eta V_{B2B1}. \qquad (1)$$

The P-N junction is now forward biased, and holes will be injected from the emitter into the silicon bar. The electric field inside the bar set up by V_{B2B1} is of such a direction that the injected holes will be moved toward the base-one terminal. Conductivity σ of a semiconductor material is given by the equation:

$$\sigma = q\,(\mu_e n + \mu_h p) \qquad (2)$$

where q = electronic charge (1.6×10^{-19} coulomb)

μ_e = mobility of conduction electrons

μ_h = mobility of conduction holes

n = electron concentration

p = hole concentration

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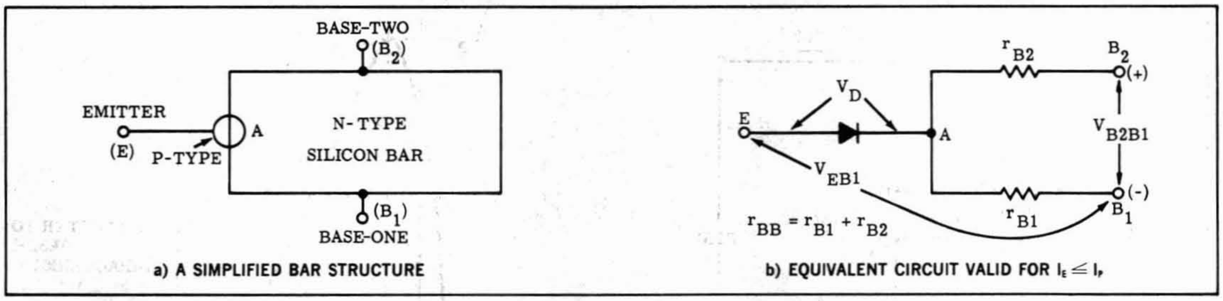
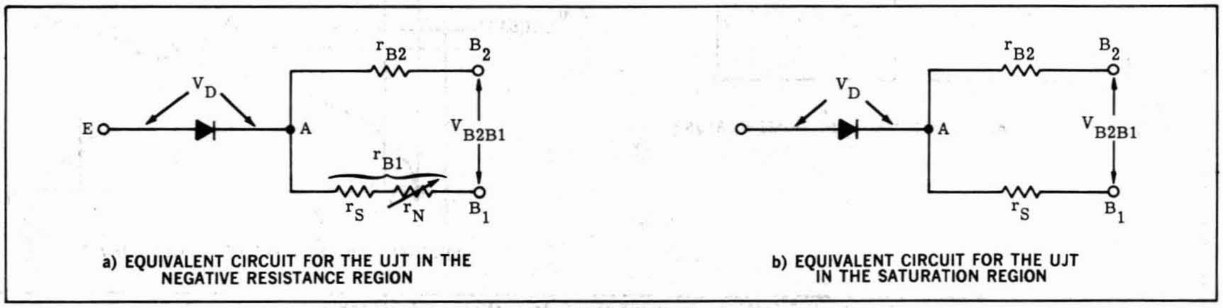
*Presently Director of Engineering, Motorola Semiconductor Products Division.



a) A SIMPLIFIED BAR STRUCTURE

b) EQUIVALENT CIRCUIT VALID FOR $I_E \leq I_P$

FIGURE 1



a) EQUIVALENT CIRCUIT FOR THE UJT IN THE NEGATIVE RESISTANCE REGION

b) EQUIVALENT CIRCUIT FOR THE UJT IN THE SATURATION REGION

FIGURE 2

When the holes are injected into the bar from the emitter, an equal amount of electrons will be injected from base-one to maintain charge neutrality. Since both the electron and hole concentrations increase in the silicon bar between the emitter and base-one, the conductivity will also increase according to equation (2). Resistivity ρ is defined as the reciprocal of conductivity or:

$$\rho = \frac{1}{\sigma} \tag{3}$$

and hence the resistivity will decrease. This process is called "conductivity modulation". The decrease in resistivity will cause a decrease in the voltage drop from emitter to base-one, which in turn allows more holes to be injected from the emitter, and the conductivity will increase further. This is clearly a regenerative process, and the UJT is now in the so-called negative resistance region. An equivalent circuit for this region is shown in Figure 2a. At emitter currents equal to or less than I_p the resistance r_{BB} can be divided into two parts; r_{B1} and r_{B2} according to the relations:

$$r_{B1} = \eta r_{BB} \text{ and } r_{B2} = r_{BB} - r_{B1}. \tag{4}$$

(As shown in Figure 1b)

In the negative resistance region, resistor r_{B1} can be thought of to consist of a fixed portion r_s, and a variable portion r_N, where r_s is the saturation resistance and r_N is the negative resistance, the magnitude of which decreases with increasing emitter current. r_N will be equal to zero when the hole concentration in the silicon bar is approximately $10^{16} \frac{\text{carriers}}{\text{Cm}^3}$ † and under that condition the saturation resistance r_s will be only resistance between emitter and base-one. When $r_{B1} = r_s$, the UJT is no longer in the negative resistance region. The reason for this is that the high density of carriers in the bar has decreased the lifetime τ of the carriers sufficiently to counteract the effects of the new carriers being generated. Mobility is related to lifetime by the equations:

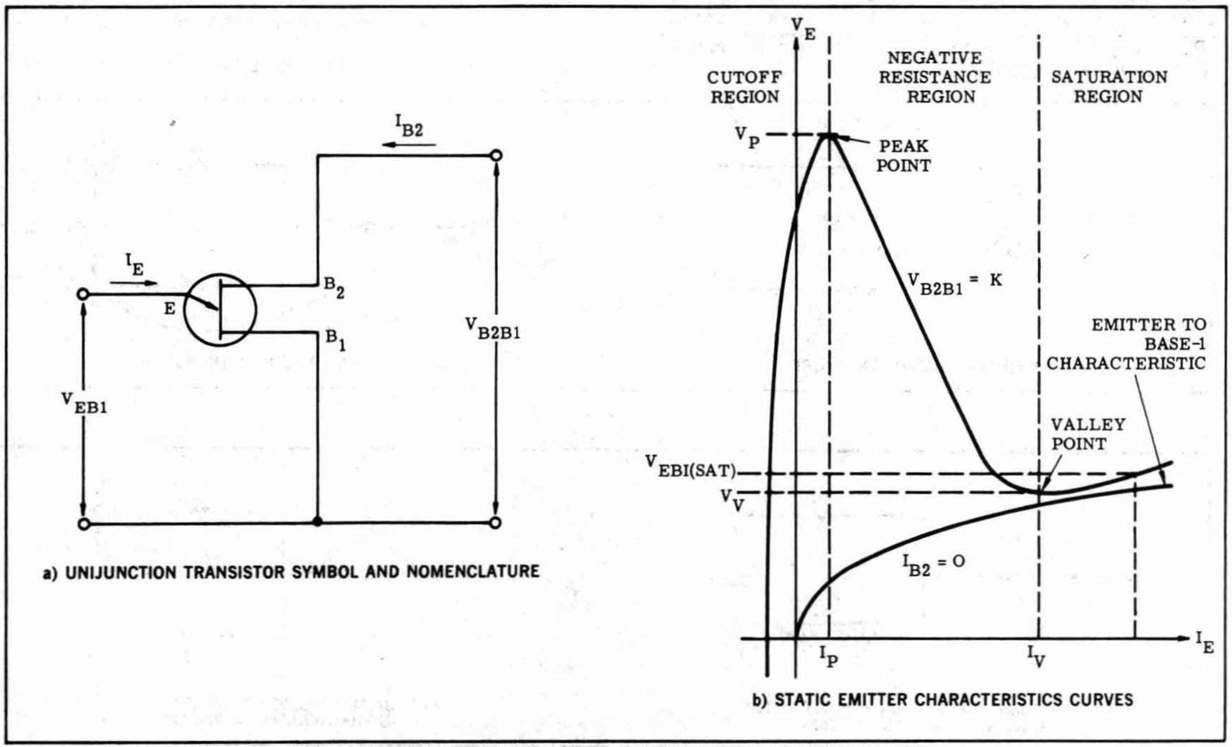
$$\mu_e = \frac{q\tau}{m_e} \quad \text{and} \quad \mu_h = \frac{q\tau}{m_h} \tag{5}$$

where m_e and m_h are the effective mass of electrons and holes, respectively. Mobility therefore decreases when lifetime decreases, and the conductivity given by equation (2) is found to remain relatively constant for emitter currents up to 500 mA.

The point on the emitter characteristic where r_{B1} just reaches its minimum value is called the valley point. The emitter current and voltage at this point are the valley point emitter current I_V, and the valley point emitter voltage V_V.

When the emitter current is increased beyond I_V, the unijunction transistor enters the so-called saturation region where the emitter current is essentially a linear function of the emitter voltage. The equivalent circuit for the saturation region is shown in Figure 2b.

The standard unijunction transistor symbol with appropriate terms for current and voltage is given in Figure 3a, and a static emitter characteristic curve for a single value of V_{B2B1} is shown in Figure 3b. It should be noted that the emitter curve is not drawn to scale in order to show the different operating regions in more detail. The region to the left of the peak point is called the "cutoff region", the emitter junction being reverse biased in most of this region and slightly forward biased at the peak point. The region between the peak point and the valley point, where the emitter junction is forward biased and conductivity modulation takes place, is called the "negative resistance region". The region to the right of the valley point, where the emitter current is limited by r_s, is called the "saturation region". The curve for base-two current (I_{B2}) equal to zero is essentially the forward characteristic of a silicon diode.



a) UNIJUNCTION TRANSISTOR SYMBOL AND NOMENCLATURE

b) STATIC EMITTER CHARACTERISTICS CURVES

FIGURE 3 — UJT SYMBOLS, NOMENCLATURE, AND EMITTER CHARACTERISTICS

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† R.B. Adler, et al: Introduction to Semiconductor Physics page 34 Wiley

VARIOUS UJT STRUCTURES

Early unijunction transistors were the bar structure and the cube structure, the cross-section diagrams of which are shown in Figure 4a and 4b, respectively.

The bar structure in Figure 4a is formed by mounting a high resistivity N-type silicon bar on a ceramic platform having an air gap in the center and gold-antimony film deposited on each side of the gap. Base-one and base-two are ohmic contacts that are formed between the silicon bar and the gold. A single P-type emitter is formed by alloying an aluminum wire onto the bar opposite from the base contacts.

The cube structure, shown in Figure 4b, employs a high resistivity N-type silicon cube. The cube is mounted on a header with a gold-antimony alloy contact between the bottom of the cube and the header. The base-two ohmic contact is made to the gold-antimony area. Base-one is formed by alloying a gold wire to the top of the silicon bar and the emitter is similarly formed by alloying an aluminum wire to a side of the cube.

Although the bar and cube structures have been in use for many years, they are not readily adapted to modern automatic production methods. For this reason, Motorola has evolved a new and different design in which the die is fabricated using processes similar to those used for silicon annular overlay transistors. A simplified outline of the production steps is given in Figure 5. Referring to Figure 5a, using photo-resist techniques and starting with an oxide passivated die of high resistivity N-type silicon, the emitter is diffused in using P-type boron. In Figure 5b the whole structure is again oxide protected. Windows are then etched in the oxide, and base-one and the annular ring are formed by the diffusion of N-type phosphorus. The structure is oxide protected again in Figure 5c, followed by a selective etching that removes the oxide in the emitter and base-one areas. Aluminum is then evaporated onto the structure to make contact with the emitter and base-one, while gold is evaporated onto the bottom of the die to form the base-two contact. In Figure 5d the exact contact geometries are determined by a final etch. In practice the above production steps are not performed on a single die but to a whole wafer. After the final etch the wafers are tested, scribed, and broken into several hundred dice.

Figure 6 shows a photo micrograph of the 2N4851 UJT geometry. In actual practice two base-one regions are formed, and before the bonding is performed, the die is probed and the base-one region providing the optimum characteristics is selected.

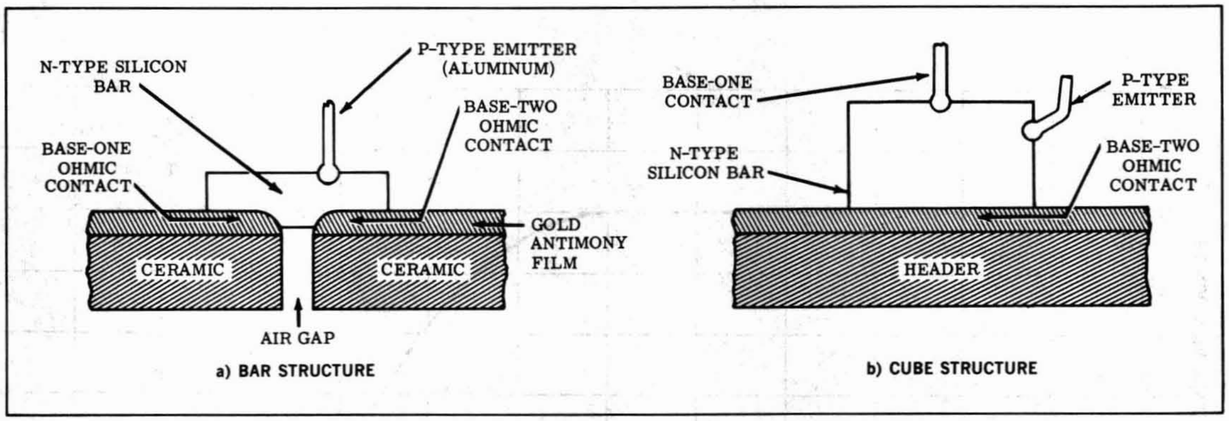
N-TYPE SILICON BAR
P-TYPE EMITTER (ALUMINUM)
BASE-TWO OHMIC CONTACT
BASE-ONE OHMIC CONTACT
GOLD ANTIMONY FILM
CERAMIC
CERAMIC
AIR GAP
a) BAR STRUCTURE
BASE-ONE CONTACT
P-TYPE EMITTER
N-TYPE SILICON BAR
BASE-TWO OHMIC CONTACT
HEADER
b) CUBE STRUCTURE

FIGURE 4 — EARLY UJT STRUCTURES

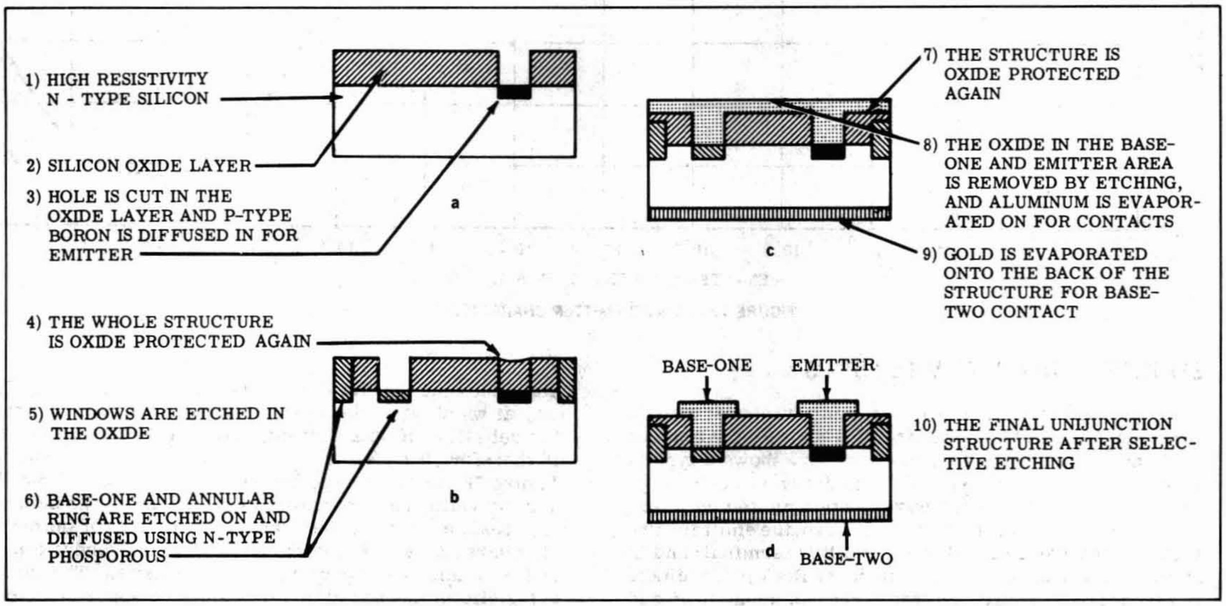
1) HIGH RESISTIVITY N - TYPE SILICON
2) SILICON OXIDE LAYER
3) HOLE IS CUT IN THE OXIDE LAYER AND P-TYPE BORON IS DIFFUSED IN FOR EMITTER
a
4) THE WHOLE STRUCTURE IS OXIDE PROTECTED AGAIN
5) WINDOWS ARE ETCHED IN THE OXIDE
6) BASE-ONE AND ANNULAR RING ARE ETCHED ON AND DIFFUSED USING N-TYPE PHOSPOROUS
b
7) THE STRUCTURE IS OXIDE PROTECTED AGAIN
8) THE OXIDE IN THE BASE-ONE AND EMITTER AREA IS REMOVED BY ETCHING, AND ALUMINUM IS EVAPORATED ON FOR CONTACTS
9) GOLD IS EVAPORATED ONTO THE BACK OF THE STRUCTURE FOR BASE-TWO CONTACT
c
BASE-ONE
EMITTER
10) THE FINAL UNIJUNCTION STRUCTURE AFTER SELECTIVE ETCHING
d
BASE-TWO

FIGURE 5 — THE ANNULAR UNIJUNCTION

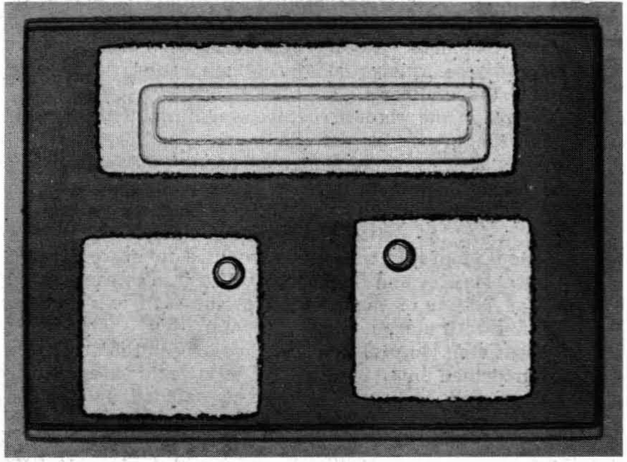

FIGURE 6 — PHOTOMICROGRAPH OF MOTOROLA ANNULAR UJT STRUCTURE

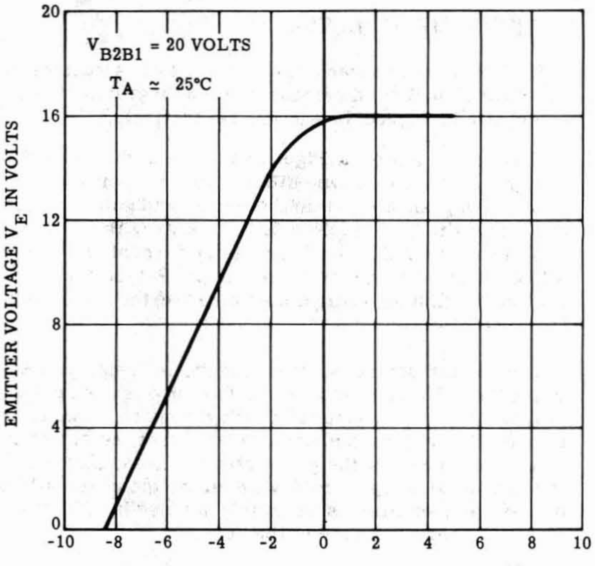

FIGURE 7a — STATIC EMITTER CHARACTERISTIC

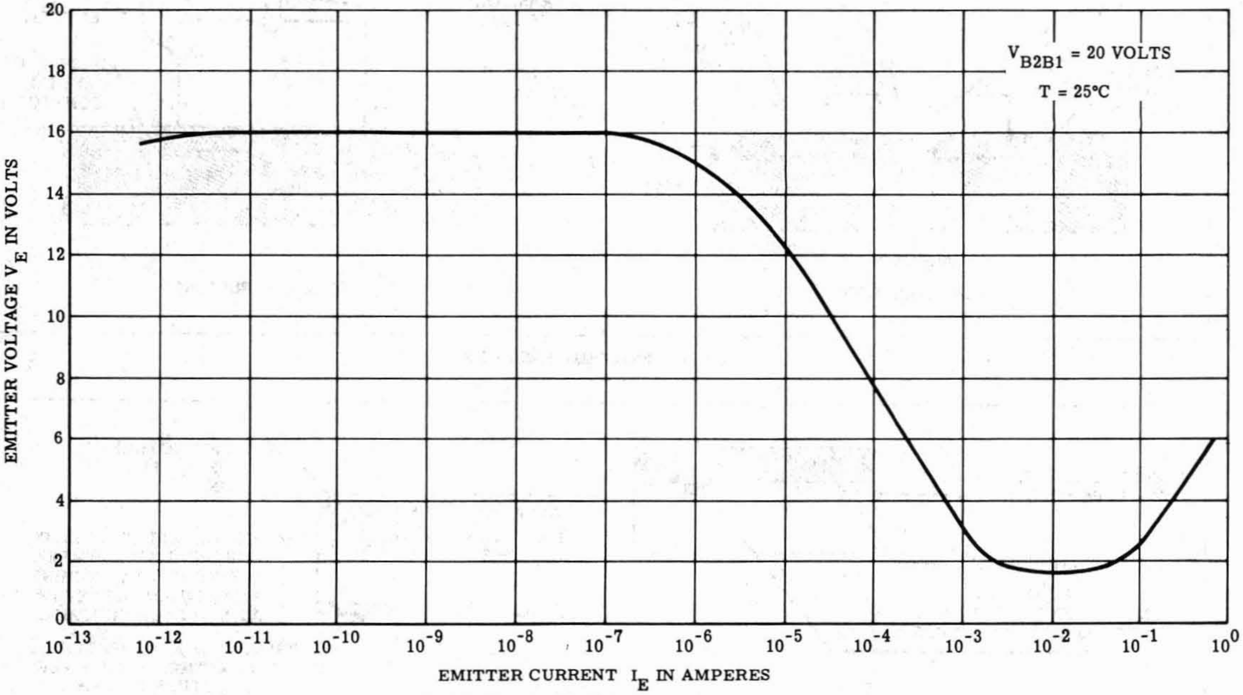

FIGURE 7b — STATIC EMITTER CHARACTERISTIC

STATIC EMITTER CHARACTERISTICS

As previously mentioned, the emitter characteristic shown in Figure 3b was not drawn to scale for the reasons explained. Figure 7a and 7b, however, shows a typical emitter curve for V_{B2B1} = 20 volts drawn to scale. Figure 7a shows part of the cutoff region plotted on linear scale. When the emitter voltage is zero, the emitter current is negative, i.e.: out of the emitter terminal, and is approximately equal to 1 nanoampere. Peak point voltage is reached at a forward emitter current of about 10 pA and as can be seen from Figure 7B the voltage remains constant until the emitter current reaches approximately 0.1 μA, at which point the voltage starts to decrease. From the definition of peak current, I_p for this particular device is therefore 0.1 μA and V_p equals 16 volts. Referring to Figure 7b, valley voltage can be seen to be about 1.6 volts and the valley current approximately 8 mA. The saturation resistance r_s can be found from the slope of the emitter characteristic in the saturation region (above 8 mA) and is in this case approximately 5.0 ohms. The characteristic in the negative resistance region was determined by the use of a constant-current source.

THE DIODE VOLTAGE DROP V_D

Some of the most important characteristics of the UJT are those that appear in the formula for peak voltage:

$$V_p = V_D + \eta V_{B1B2} \qquad (6)$$

Changes in the peak voltage would be very undesirable in applications like timers and oscillators, the accuracy of which depends on the repeatability of V_p.

V_D is defined as the forward voltage drop of the emitter junction and since it is essentially equivalent to the forward voltage drop of a silicon diode, the value of V_D is dependent both on forward current and temperature. V_D can be measured several ways, but it is important to hold the emitter current near I_p when the measurement is made since it really is V_D at I_p that is required in equation 6. One simple way of measuring V_D is shown in Figure 8. A constant current equal to I_p is applied between the emitter and base-one, and a potentiometric voltmeter is used to measure the voltage from emitter to base-two. This type of voltmeter has essentially infinite input impedance when the meter is "nulled" and there is no current flowing in the base-two lead. The voltage measured is therefore equal to V_D.

Figure 9 shows V_D as a function of temperature for an emitter current of 1 µA. The variation of V_D is essentially linear over the temperature range considered and is equal to -2.7 mV/°C. The diode voltage drop therefore decreases with increasing temperature and V_D can be written as:

$$V_D = V_{DN} - (T - 25) \circ K_D$$

where V_{DN} is the value of V_D at $T_A = 25°C$ and $K_D = -2.7$ mV/°C. (Note that K_D is current dependent and the value for K_D given applies only at 1 µA.)

THE INTRINSIC STANDOFF RATIO η

The intrinsic standoff ratio defined by:

$$\eta = \frac{V_p - V_D}{V_{B2B1}} = \frac{r_{B1}}{r_{BB}} \qquad (7)$$

is generally believed to be essentially independent of temperature variations. However, this is not true. Figure 10 shows typical variations of η with temperature for unijunctions from three different manufacturers. There may be several reasons why η varies with temperature; the interbase resistance r_{BB} might not have a uniform temperature coefficient throughout the base-two, base-one region, or the temperature might not be uniform over the entire interbase resistance. Surface recombination might also be a factor.

η can be measured directly or it can be calculated from equation (7) when V_p and V_D are known.

The curve A-A in Figure 10 represents the Motorola annular UJT, and the variation of η is relatively linear with temperature over the temperature region considered. η can therefore be expressed by the formula:

$$\eta = \eta_N - (T - 25)\ K_\eta$$

where η_N is the value of η at 25°C, and K_η is a temperature coefficient expressed in %/°C. For the Motorola annular devices $K_\eta \cong \frac{0.06\%}{°C}$.

The intrinsic standoff ratio is also slightly dependent on V_{B2B1}, but the variation is so small that for all practical purposes η can be said to be independent of voltage.

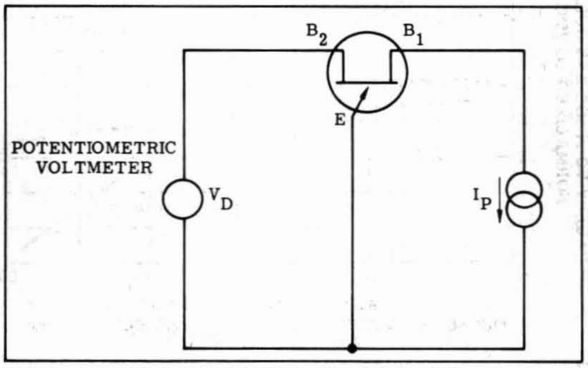

FIGURE 8 — CIRCUIT FOR MEASURING V_D

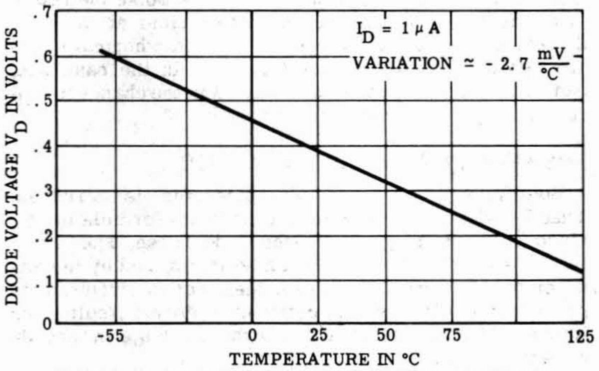

FIGURE 9 — DIODE VOLTAGE V_D versus TEMPERATURE FOR THE ANNULAR UNIJUNCTION

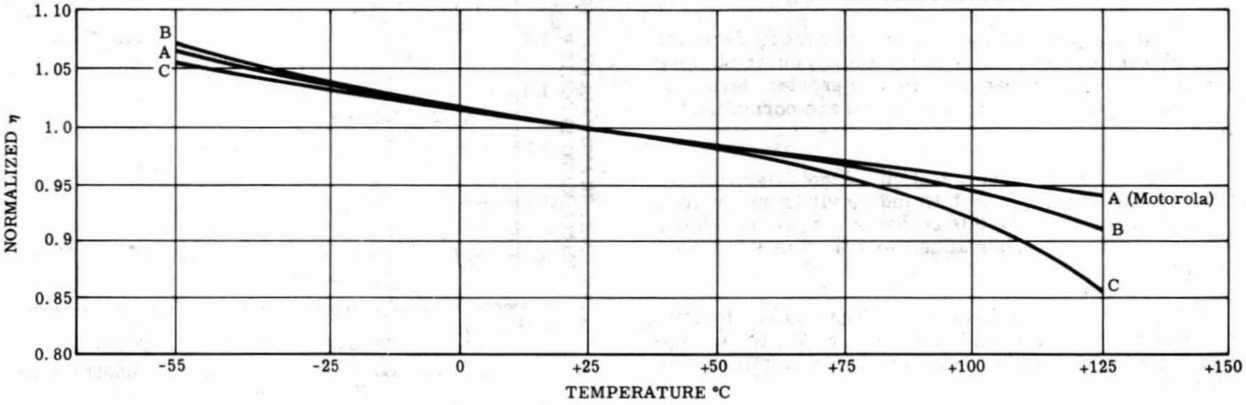

FIGURE 10 — NORMALIZED INTRINSIC STANDOFF RATIO versus TEMPERATURE FOR 3 DIFFERENT MANUFACTURERS (A, B, & C)

THE INTERBASE RESISTANCE r_{BB}

The resistance from base-two to base-one is highly temperature dependent. A typical r_{BB} vs. temperature characteristic curve for $V_{B2B1} = 3$ volts is shown in Figure 11. At very low temperatures, near absolute zero, few of the impurity atoms in the semiconductor material are ionized and the resistivity of the doped silicon is quite high. At -55°C however, most of the impurity atoms are fully ionized, and the carrier concentration is relatively constant as the temperature is increased. The lattice mobility decreases with increasing temperature due to increased lattice scattering, and hence the resistivity will increase. As the temperature is increased beyond 125°C, the impurity concentration becomes swamped by carriers produced by thermal generation, and the resistivity decreases rapidly as the temperature is increased. The measurements were performed on a pulsed basis to avoid heating due to power dissipation. In the temperature region from 0 to +125°C, the increase in r_{BB} with temperature is essentially linear, and r_{BB} can be expressed by the formula:

$$r_{BB} = r_{BBN} + (T - 25) \cdot K_r$$

where r_{BBN} is the value of r_{BB} at 25°C, and K_r is given as a %/°C variation of r_{BBN}. For the annular devices K_r is found to be:

$$K_r \simeq 0.8\%/C \cdot r_{BBN}$$

In addition, r_{BB} is also found to vary with interbase voltage V_{B2B1}. A typical curve is shown in Figure 12 where r_{BBN} is normalized to the value of r_{BB} for $V_{B2B1} = 3$ volts, the voltage usually specified on the manufacturer's data sheet.

This increase in r_{BB} with voltage is in part due to a current limiting effect in the base one contact area. Knowing r_{BB} at $V_{B2B1} = 3$ V for an annular device, r_{BB} at any other value of V_{B2B1} can be found with a reasonable degree of accuracy from Figure 12. These readings have also been obtained by a low duty-cycle pulse method in order to avoid heating due to power dissipation. T_j is therefore approximately equal to T_A. For normal operating conditions, the temperature rise in the base-one, base-two region must be calculated and the change in r_{BB} due to temperature taken into account.

THE PEAK POINT CHARACTERISTICS

Both V_p and I_p decrease as temperature is increased. That V_p will decrease is evident from the formula for V_p since both η and V_D were found to decrease. The variation of V_p with temperature can be minimized by the addition of an external resistor in the base two circuit. This procedure is discussed in detail in Motorola Application Note AN-294. V_p varies with interbase voltage in accordance with equation (6).

THE VALLEY POINT CHARACTERISTICS

Both valley point voltage V_V and current I_V decrease as ambient temperature is increased. A curve showing typical temperature behavior for the annular device is given in Figure 13 where the curves are normalized to the value at 25°C.

I_V and V_V are also dependent on the interbase voltage. When V_{B2B1} increases both I_V and V_V will increase also. Typical curves showing this behavior are given in Figure 14. I_V and V_V are normalized to the value at 10 volts V_{B2B1}.

Valley current is a relatively difficult characteristic to measure since, as can be seen in Figure 7b, the voltage is relatively constant for large variations in emitter current around the valley point.

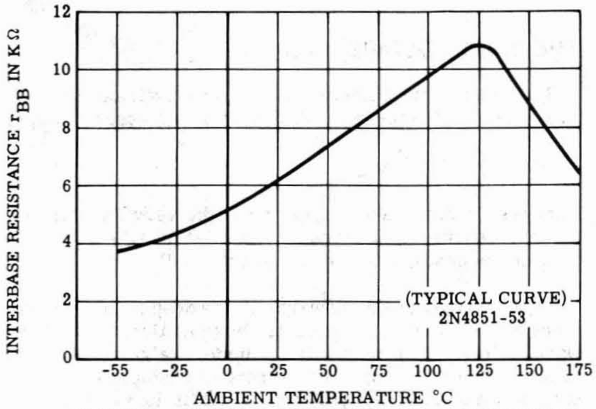

FIGURE 11 — INTERBASE RESISTANCE r_{BB} versus TEMPERATURE

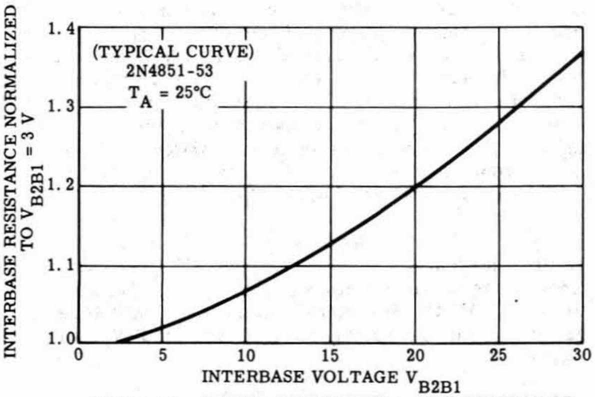

FIGURE 12 — TYPICAL VARIATION OF r_{BB} AS A FUNCTION OF INTERBASE VOLTAGE V_{B2B1}

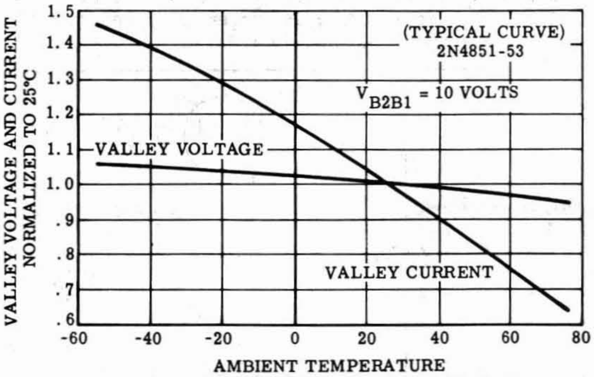

FIGURE 13 — VALLEY VOLTAGE AND VALLEY CURRENT versus AMBIENT TEMPERATURE

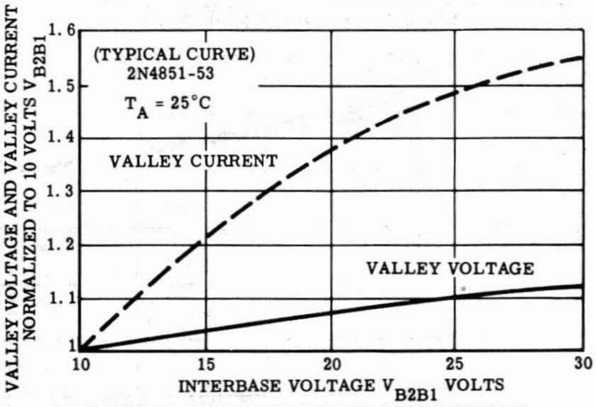

FIGURE 14 — VALLEY VOLTAGE AND VALLEY CURRENT versus INTERBASE VOLTAGE V_{B2B1}

THE EMITTER REVERSE CURRENT I_{EO} (or I_{EB2O})

The emitter reverse current is generally specified as the current flowing from base-two to the emitter with 30 volts applied between base-two and the emitter, (positive at base-two), and the base-one terminal open circuited. I_{EO} is highly temperature dependent since it actually is the leakage current of a silicon diode. This leakage current consists mainly of charge generation current, since diffusion current has little effect in silicon in the temperature range considered.

A curve showing typical variation of I_{EO} with temperature for a 2N4851 is shown in Figure 15 with I_{EO} being approximately 1.5 nA at 25°C.

INTERBASE CHARACTERISTICS

The measurement of base-two current I_{B2} as a function of interbase voltage and emitter current was performed on a sweep basis to avoid heating effects due to power dissipation. The test circuit for this measurement is shown in Figure 16a. A constant current was applied to the emitter from time t_o to time t_1 and simultaneously a voltage ramp going from 0 to 30 volts was applied to base-two. Base-one was grounded. The current I_{B2} was measured with a current probe and applied to the vertical input of an oscilloscope, and the voltage ramp was applied to the horizontal input. As I_E and the ambient temperature were varied, the curves shown in Figure 16b, c, and d were observed.

It can be seen from the curves that the percentage increase in I_{B2} decreases with increasing emitter current and temperature. The modulated interbase current $I_{B2(mod)}$ is usually measured at $I_E = 50$ mA and $V_{B2B1} = 10$ volts. From Figure 16c this can be found to be approximately 11 mA.

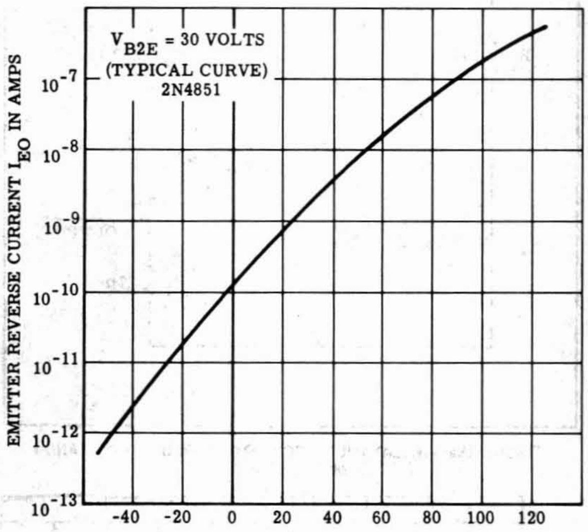

FIGURE 15 – EMITTER REVERSE CURRENT I_{EO} versus AMBIENT TEMPERATURE

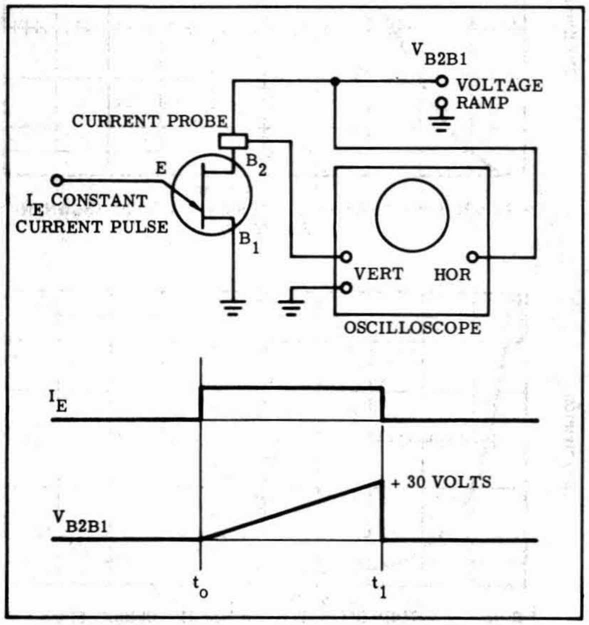

FIGURE 16a – TEST CIRCUIT USED TO DETERMINE THE INTERBASE CHARACTERISTIC

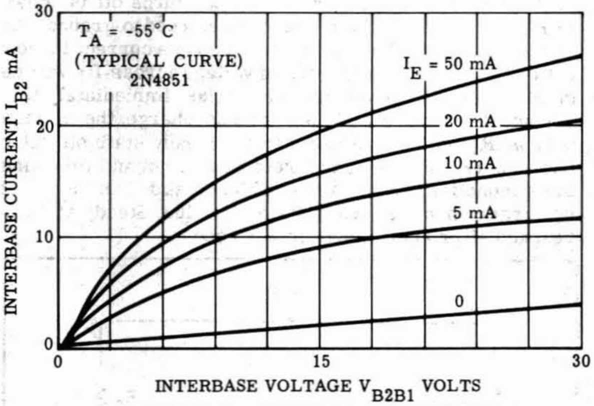

FIGURE 16b – INTERBASE CHARACTERISTIC

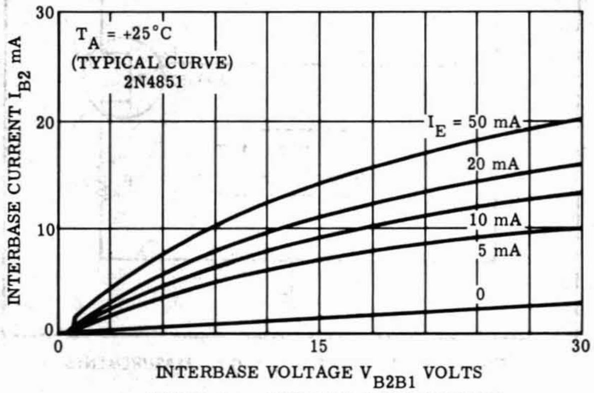

FIGURE 16c – INTERBASE CHARACTERISTIC

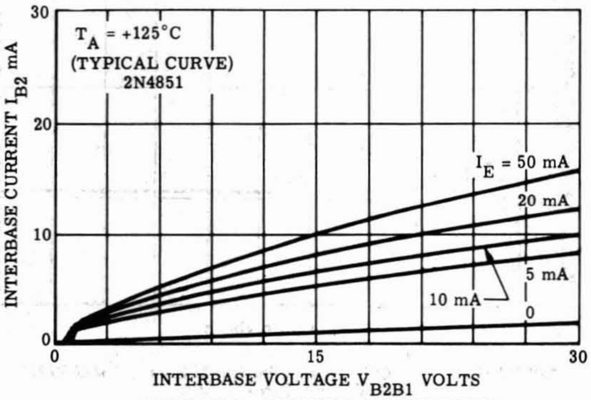

FIGURE 16d – INTERBASE CHARACTERISTIC

TRANSIENT CHARACTERISTICS

Switching times as specified for conventional junction transistors are generally not given on a UJT data sheet. Rather a parameter f_{max} is given which indicates the maximum frequency of oscillation that can be obtained using the UJT in a specified relaxation oscillator circuit.

In some applications such as critical timers, however, it might be of interest to determine "turn-on" and "turn-off" times associated with the UJT. Since these parameters are generally not specified, no fixed procedure has been established for their measurement, and two different methods with accompanying results will therefore be discussed here.

The circuit shown in Figure 17 was used to measure t_{on} and t_{off} for the case where the emitter circuit is purely resistive. Typical switching time values were found to be t_{on} = 1 µsec and t_{off} = 2.5 µsec. The waveform observed at the base-one terminal when the UJT turns off is shown in Figure 18. When the emitter is returned to ground, the stored charge in the junction will cause a current to flow out of the emitter and the output voltage across R_1 will be smaller than the steady state off value. Immediately following the removal of the excess charge, the voltage across R_1 will go higher than the steady state off value because r_{B1} has still not returned to normal following the conductivity modulation in the on state, and I_{B2} will be larger than the steady state off value. Steady state is reached after approximately 2.5 µsec.

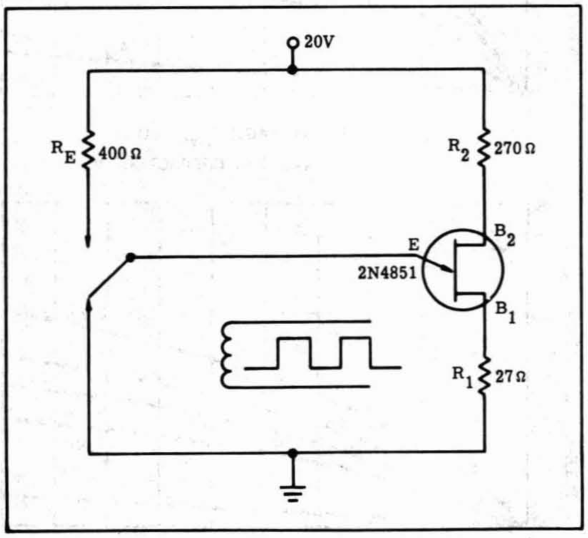

FIGURE 17 — CIRCUIT FOR t_{on} AND t_{off} MEASUREMENTS

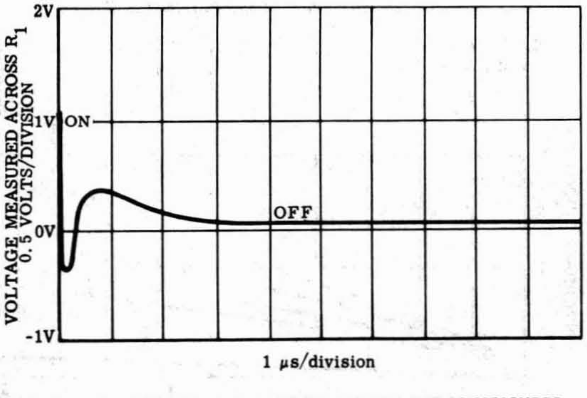

FIGURE 18 — "TURN-OFF" WAVEFORM FOR THE UJT AS MEASURED IN THE CIRCUIT IN FIGURE 17

In most practical applications, however, there will be both a resistor and a capacitor in the emitter circuit, and it is therefore of interest to determine what the switching times are under these conditions. The test circuit in this case was the relaxation oscillator circuit shown in Figure 19a, and turn-on and turn-off waveforms as observed at base-one are shown in Figure 19b, and 19c. Turn-on time measured from the start of turn-on to the 90% point is approximately 0.5 µsec and increases with increasing capacitance C_E. Turn-off time measured from the start of turn-off to the 90% point is about 12 µsec, due to the long discharge time of the capacitor. t_{off} also increases with C_E.

The effect of the capacitance C_E on switching time is shown in Figure 20a and 20b.

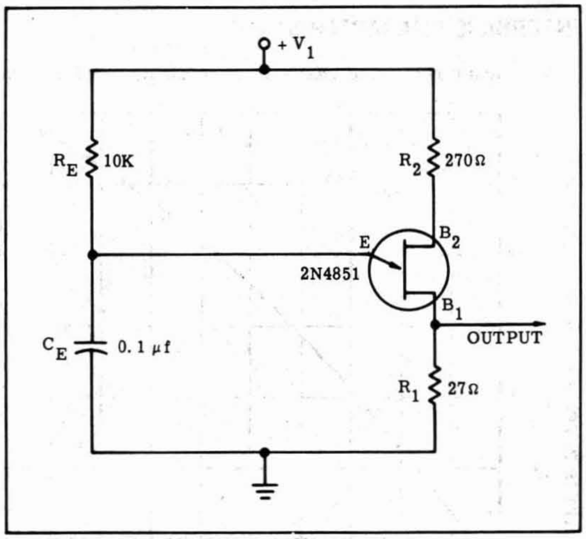

FIGURE 19a — RELAXATION OSCILLATOR CIRCUIT FOR t_{on} AND t_{off} MEASUREMENTS

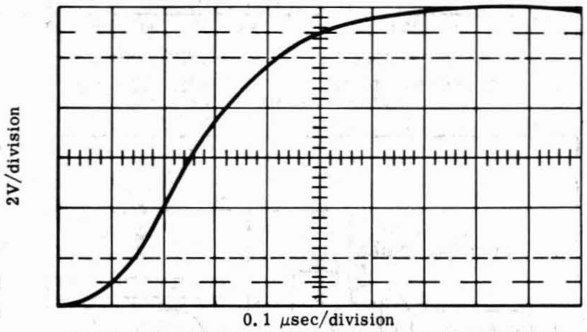

FIGURE 19b — TURN-ON WAVEFORM FOR CIRCUIT SHOWN IN FIGURE 19a

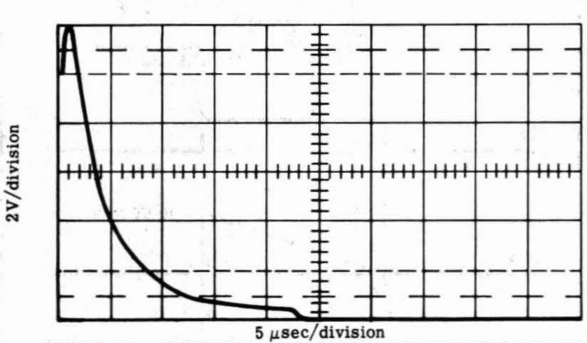

FIGURE 19c — TURN-OFF WAVEFORM FOR THE CIRCUIT SHOWN IN FIGURE 19a

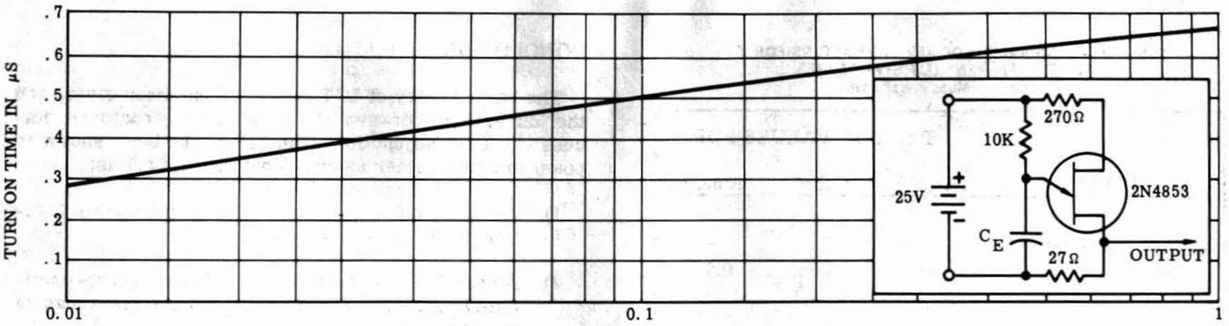

FIGURE 20a – TURN-ON TIME versus EMITTER CAPACITANCE C_E

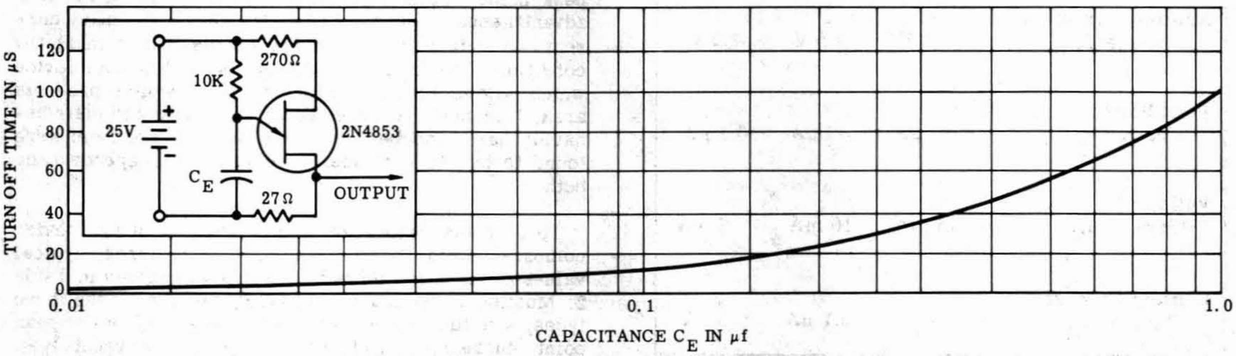

FIGURE 20b – TURN-OFF TIME versus EMITTER CAPACITANCE C_E

TABLE 1 – UNIJUNCTION TRANSISTOR NOMENCLATURE

Symbol	Definition
I_E	Emitter current.
I_{EO}	Emitter reverse current. Measured between emitter and base-two at a specified voltage, and base-one open-circuited.
I_p	Peak point emitter current. The maximum emitter current that can flow without allowing the UJT to go into the negative resistance region. (Peak point is the lowest current on the emitter characteristic where: $\frac{d\,V_{EB1}}{d\,I_E} = 0$.)
I_V	Valley point emitter current. The current flowing in the emitter when the device is biased to the valley point. (Valley point is the second lowest current on the emitter characteristic where: $\frac{d\,V_{EB1}}{d\,I_E} = 0$.)
r_{BB}	Interbase resistance. Resistance between base-two and base-one measured at a specified interbase voltage.
V_{B2B1}	Voltage between base-two and base-one. Positive at base-two.
V_p	Peak point emitter voltage. The maximum voltage seen at the emitter before the UJT goes into the negative resistance region.
V_D	Forward voltage drop of the emitter junction.
V_{EB1}	Emitter to base-one voltage
$V_{EB1(SAT)}$	Emitter saturation voltage. Forward voltage drop from emitter to base-one at a specified emitter current (larger than I_V) and specified interbase voltage.
V_V	Valley point emitter voltage. The voltage at which the valley point occurs with a specified V_{B2B1}.
V_{OB1}	Base-one peak pulse voltage. The peak voltage measured across a resistor in series with base-one when the unijunction transistor is operated as a relaxation oscillator in a specified circuit.
η	Intrinsic standoff ratio. Defined by the relationship: $= \frac{V_p - V_D}{V_{B2B1}}$
α_{rBB}	Interbase resistance temperature coefficient. Variation of resistance between B_2 and B_1 over the specified temperature range and measured at the specific interbase voltage and temperature with emitter open circuited.
I_{B2}(mod)	Interbase modulation current. B2 current modulation due to firing. Measured at a specified interbase voltage, emitter and temperature.

TABLE 2 — COMPARISON OF KEY PARAMETERS FOR THE THREE DIFFERENT UJT STRUCTURES.
Typical values are shown.

	TYPICAL VALUES FOR		
PARAMETER	Bar	Cube	Annular
Intrinsic Standoff Ratio η	0.6	0.65	0.7
Interbase Resistance r_{BB}	7 K	7 K	7 K
Emitter Saturation Voltage $V_{EB1\,(SAT)}$	3 V	1.5 V	2.5 V
Peak Point Current I_p	2 μA	1 μA	0.1 μA
Valley Point Current I_V	15 mA	10 mA	7 mA
Emitter Reverse Current I_{EO}	1 μA	0.1 μA	5 nA

CONCLUSION

The basic theory of UJT operation has been given, and the difference between the three UJT structures discussed. The unijunction transistor has been shown to possess some rather unique capabilities such as;

1) An emitter firing voltage V_P that is a certain fraction of the interbase voltage.

2) A negative resistance region which suggests oscillators and trigger circuits as possible areas of applications.

In addition, the annular device was found to have a low peak point current and emitter reverse current which is advantageous in long duration timers. Low valley current and voltage assures low power dissipation in the ON condition. The annular UJT is also a low cost device which allows its application in the consumer products area. The most common UJT parameters and their behavior have also been covered, and most of them were found to be either temperature or voltage dependent, or both.

To give the reader an idea of how the annular device compares with the bar and cube structures, typical values of six parameters for each type are given in Table 2. Most of the values are relatively uniform for the three types, with the annular device offering slightly lower peak point current I_P and emitter reverse current I_{EO}.

UNIJUNCTION TRANSISTOR TIMERS AND OSCILLATORS

INTRODUCTION

The unijunction transistor (UJT) is a three-terminal device. One terminal is called the emitter, while the two other terminals are called base-one and base-two, respectively.

The UJT has only a single P-N junction, and the characteristics of the device are for this reason quite different from the conventional junction transistor. Some of the characteristics are in fact quite unique; for example, a negative resistance region, and an emitter firing voltage V_p that is a certain fraction of the interbase voltage V_{B2B1} (1).

In addition, the annular* UJT manufactured by Motorola has extremely low peak point current and emitter reverse current, which are advantageous in many types of circuit applications, and particularly in timer and oscillator circuits.

This paper will first discuss the UJT relaxation oscillator, which is the basic building block in most timer and oscillator circuits. The conditions required for oscillation will be derived, and load lines for different circuit conditions will be shown. A variety of practical timer and oscillator circuits are then shown and circuit values given.

The peak point voltage, V_p, is quite temperature dependent, and methods of temperature stabilization of this point are given in the appendix. Also in the appendix are included dynamic operating paths for different types of loads.

THE BASIC RELAXATION OSCILLATOR CIRCUIT

The UJT relaxation oscillator which is the basic building block in most UJT timer and oscillator circuits is shown in Figure 1A. The circuit operation is as follows:

When power is applied, the capacitor C_E charges exponentially through the resistor R_E until the voltage on the capacitor equals the emitter firing voltage V_p. At this voltage, the emitter base-one junction becomes forward biased and the emitter characteristic goes into the negative resistance region. The capacitor C_E discharges through the emitter and a positive going pulse will be available at base-one. This pulse is shown in Figure 1B for a circuit having
$R_E = 10\ \text{k}\Omega$ $C_E = 0.01\ \mu\text{F}$, $R2 = 200\ \Omega$, $R1 = 47\Omega$, and $V1 = 20$ V.

Prior to firing, a current I_{B2} is flowing from base-two to base-one. When emitter current starts to flow, this current will increase to $I_{B2(\text{mod})}$ since the resistance from base-two to ground is decreasing. A negative going voltage pulse will therefore appear at base-two, and this waveform is shown in Figure 1C.

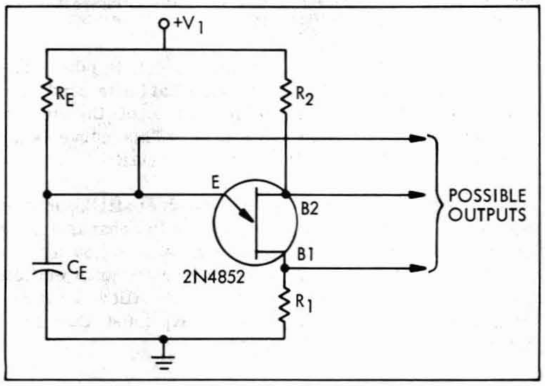

FIGURE 1A - UJT RELAXATION OSCILLATOR

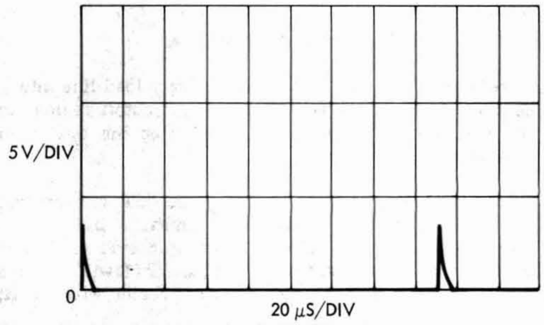

FIGURE 1B - BASE-ONE WAVEFORM

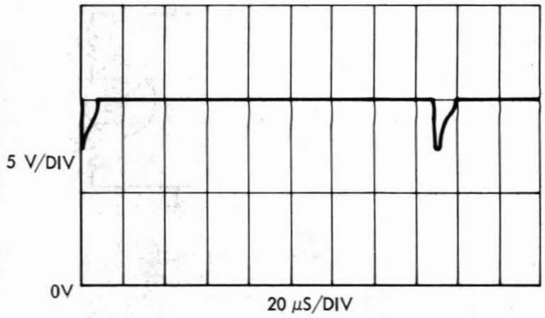

FIGURE 1C - BASE-TWO WAVEFORM

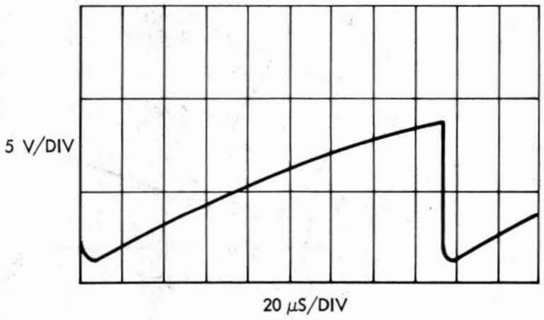

FIGURE 1D - EMITTER WAVEFORM

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(1) UJT theory and characteristics are treated in Application Note AN293

*Annular, Trademark of Motorola Inc.

Circuit diagrams external to Motorola products are included as a means of illustrating typical semiconductor applications; consequently, complete information sufficient for construction purposes is not necessarily given. The information in this Application Note has been carefully checked and is believed to be entirely reliable. However, no responsibility is assumed for inaccuracies. Furthermore, such information does not convey to the purchaser of the semiconductor devices described any license under the patent rights of Motorola Inc. or others.

When the voltage at the emitter has decreased to V_0, a voltage approximately equal to the valley voltage when R1 is purely resistive, the UJT will turn off if R_E meets certain conditions. C_E will start to charge up again, and the cycle repeats. The waveform that appears at the emitter is shown in Figure 1D.

In order for the above sequence of events to take place, R_E has to meet certain conditions. What these conditions are can best be explained by means of the emitter characteristic curve in Figure 2. (This curve is not drawn to scale in order to show more detail.)

The emitter capacitor C_E, will charge until the emitter voltage is equal to V_p. At this point on the characteristic curve peak point emitter current I_p will be flowing, and in order to fire the unijunction, the value of emitter resistor R_E must be small enough to allow a current somewhat larger than I_p to flow. R_E must, therefore, meet the following requirement:

$$R_E < \frac{V_1 - V_p}{I_p} = R_{E\,(max)} \qquad (1)$$

where V1 is the applied bias voltage.

Referring to Figure 2, this means that a load line intersecting the characteristic curve in the cutoff region, as illustrated by load line one, would keep the UJT from ever firing.

Having selected $R_E < R_{E(max)}$, the UJT will turn on, and C_E will discharge through the emitter. If R_E is too small, however, and allows an emitter current larger than the valley current I_V to flow, the UJT will not turn off. A stable state in the saturation region will result, and the load line will intersect the emitter characteristic curve somewhere to the right of the valley point. Load line 2 in Figure 2 intersecting the characteristic curve at P2 illustrates this condition.

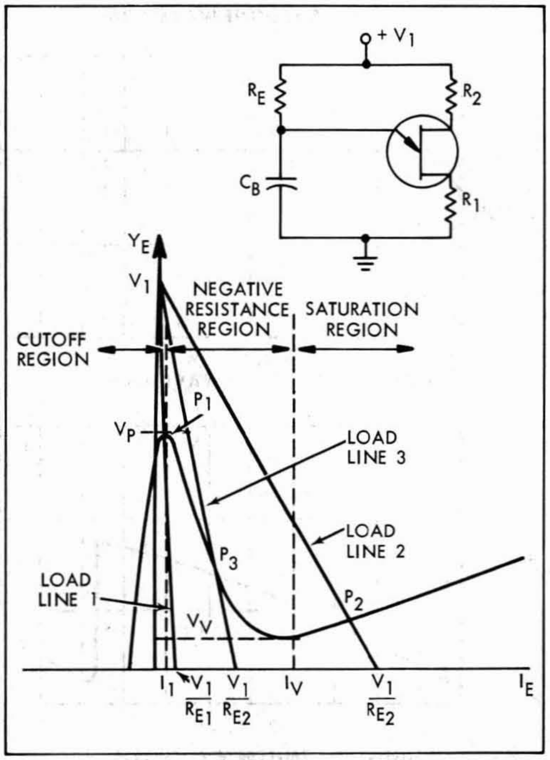


FIGURE 2 - UJT EMITTER CHARACTERISTIC LOAD LINES

The minimum R_E that can be used in order to assure oscillation can be defined by this formula:

$$R_E > \frac{V_1 - V_v}{I_v} = R_{E(min)} \qquad (2)$$

where V_v is the valley voltage.

An emitter resistance selected to meet the requirements in equations (1) and (2) will result in a load line which intersects the characteristic curve somewhere in the negative resistance region. An example is given by load line 3, intersecting the curve at P3.

In practice, however, the variation of the emitter voltage in the neighborhood of the valley point is so small that in order to assure turn-off, R_E should be selected two to three times larger than $R_{E(min)}$. The theory explaining the turn-off will be given in the appendix.

The time required for a complete period can be calculated. The voltage on C_E at any time is given by the equation:

$$V_{CE} = V_v + (V_1 - V_v)\,(1 - e^{-t/R_E C_E}) \qquad (3)$$

Substituting $V_{CE} = V_p = V_D + \eta V_{B2\,B1}$ *

$$V_D + \eta V_{B2\,B1} = V_v + (V_1 - V_v)\,(1 - e^{-t/R_E C_E}) \qquad (4)$$

Solving this equation for t will give the time to charge C_E from V_v to V_p.

$$t = R_E\,C_E\,\ln \frac{V_1 - V_v}{V_1 - V_D - \eta V_{B2\,B1}} \qquad (5)$$

A complete period T also includes the switching time of the UJT and the formula for T becomes:

$$T = R_E\,C_E\,\ln \frac{V_1 - V_v}{V_1 - V_D - \eta V_{B2\,B1}} + t_{on} + t_{off} \qquad (6)$$

The following simplifications can be made in this formula:

The turn-on time is generally much smaller than t_{off} and can be omitted. V1 is also usually on order of magnitude larger than V_D or V_v, and when R1 and R2 are small, $V_{B2\,B1} \approx$ V1. Equation (6) can therefore be written:

$$T \approx R_E\,C_E\,\ln \frac{1}{1 - \eta} + t_{off} \qquad (7)$$

To summarize: The condition for stable operation of the relaxation oscillator in Figure 1 is that R_E must be chosen such that the load line intersects the emitter characteristic in the negative resistance region. The approximate period can be found from Equation (7).

---

*Symbols & definitions Table I

PRACTICAL TIMER CIRCUITS

A Simple Time Delay

The basic building block can be used without modification in simple time delay circuits. One such circuit is shown in Figure 3. The circuit operation is as follows:

The circuit values are determined by means of the equations developed previously. The value of the emitter resistor R_E is chosen by means of Equation (1) and (2) to meet the requirements.

$$R_{E(min)} < R_E < R_{E(max)}$$

When $R_E = 10\ \text{M}\Omega$, $C_E = 10\mu\text{F}$, and $\eta = 0.8$, the time required for one complete period can be found from Equation (7) to be:

$$T \approx R_E C_E \ \ln \frac{1}{1-\eta} = 10 \bullet 10^6 \times 10 \bullet 10^{-6} \times \ln \frac{1}{1-0.8}$$

$$T \approx 160 \text{ seconds}$$

R2 is selcted as 1 KΩ to provide maximum temperature compensation with the UJT used. The theory of temperature compensation is given in the appendix.

After the first cycle, the relay will normally be energized. When push-button S1, being normally closed, is activated the SCR turns off, the relay is de-energized, and power is applied to the relaxation oscillator and the load. After a time delay varying from less than a second to approximately 2.5 minutes, as determined by the setting of the 10 MΩ pot, the unijunction will fire and turn on the SCR. The relay will energize and power is removed from the oscillator and the load. The relay K1 will stay energized until the push button S1 is pushed again.

A variation of this same circuit is shown in Figure 4. Here the relay is replaced by an SCR which generally reduces circuit cost. After one cycle of operation, SCR #1 will be on, and a low value of voltage is applied to the UJT emitter circuit, thus interrupting the timing function. When push button S1 is pushed, or a positive going pulse is applied at point A, SCR #2 will turn on, and SCR #1 will be turned off by commutating capacitor C_C. With SCR #1 off, the supply voltage will be applied to R_E and the circuit will begin timing again. After a period of time determined by the setting of R_E, the UJT will fire and turn SCR #1 on and commutate SCR #2 off.

A LONG DURATION TIME DELAY

The time delay is, as previously shown, determined by the charge time of the capacitor. In order to achieve long time delays, R_E, C_E, or both will have to be large. For good accuracy and repeatability, the capacitor must have a leakage current that is much smaller than the charge current. A Mylar type capacitor has been found to be good for this purpose, but since this type of capacitor is fairly expensive for large values of capacitance, it is preferable to increase R_E in order to obtain long time delays. Large values of R_E, however, creates a problem due to the UJT peak point emitter current I_p. When the capacitor is charged almost to the peak point, only a small voltage will appear across R_E, and if R_E is very large, only a small current will be flowing. If the peak current of the UJT is appreciable, the device will never fire if the current through R_E is not sufficient to supply

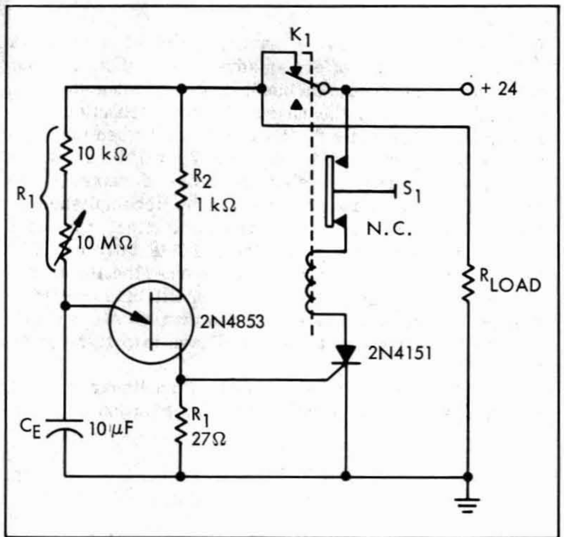
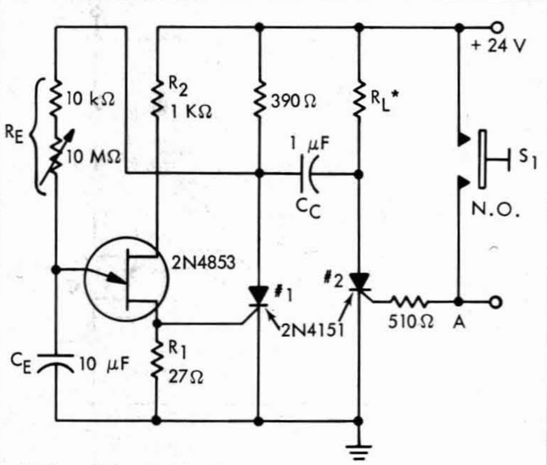


FIGURE 3 - A SIMPLE TIME DELAY CIRCUIT



*Value of R_L must be low enough to allow hold current to flow in the SCR.

FIGURE 4 - A SIMPLE TIME DELAY CIRCUIT USING TWO SCR'S

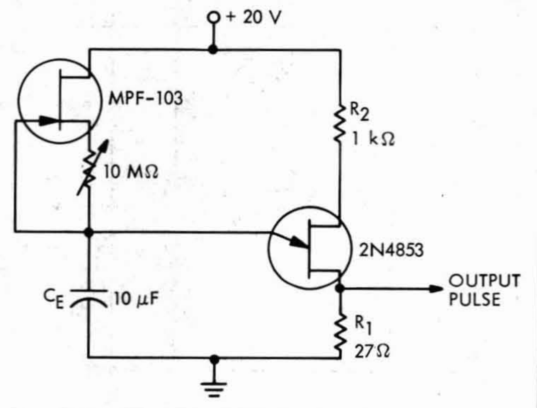


FIGURE 5 - A TIME DELAY CIRCUIT FEATURING CONSTANT CURRENT CHARGING

I_p. The annular device, having a typical I_p of 0.2µA @ V_{B2B1} = 25 Vdc, offers an advantage in this area and large values of R_E can be used. However, when charging through a resistor, the charge current will initially be relatively large while the charge current when the voltage on the capacitor is close to V_p will be small. It would, for this reason, be advantageous to charge with a constant small current. This can be accomplished by simply replacing R_E by a junction field effect transistor as shown in Figure 5. Since the JFET is fully on when there is no voltage from gate to source, the 10 MΩ resistor will determine the amount of off bias applied to the FET. A constant current of less than 1 µA can easily be obtained which results in time delays up to 10 minutes.

When the capacitor is charged with a linear current, the charge time can be found from the equation:

$$t_{\text{charge}} = \frac{(V_p - V_v) \cdot C_E}{I_{\text{charge}}} \tag{8}$$

When C_E is in microfarads and I_{charge} is in microamperes, t will be in seconds.

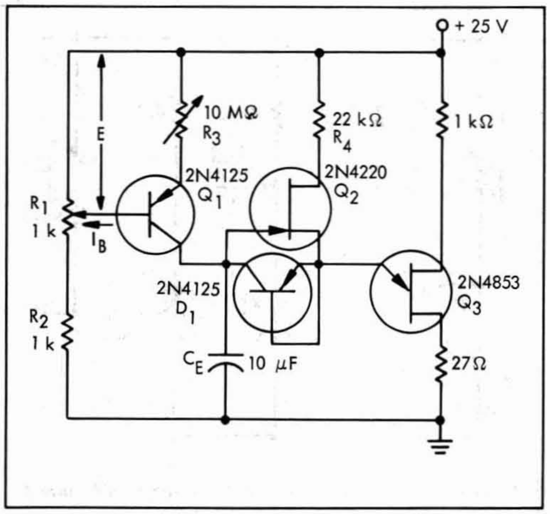


FIGURE 6 - LONG DURATION TIME DELAY

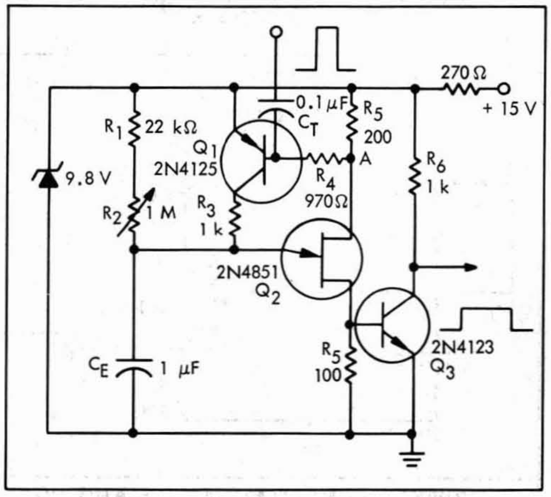


FIGURE 7 - A UJT MONOSTABLE CIRCUIT

However, even an emitter peak current as low as 0.2 µ A is objectionable if longer time delays are desired. In the circuit shown in Figure 6, the peak current is supplied separately from the charging current and extremely long time delays are possible. Transistor Q1 and resistors R1, R2, and R3 form a constant current source and the charge current might be adjusted to be as low as a few nanoamperes. This current would, of course, not be sufficient to fire the UJT where I = 0.2 µ A unless the peak current was supplied from another source. Field effect transistor Q2, acting as a source follower, supplies the current flowing into the emitter lead prior to firing and diode D1 prevents Q2 from supplying current to C_E. D1 must be selected to have a leakage much lower than the charge current.

The charge current to C_E is given by the formula:

$$I_{\text{charge}} = \frac{E - V_{BE}}{R3} - I_B \tag{9}$$

Since I_B is small, the delay time will vary linearly with R3. The voltage E, applied across R3 and the base emitter junction of Q1, is set by the variable resistor R1. Time delays up to 10 hours are possible with this circuit. Resistor R4 in series with the FET drain terminal must be large enough not to allow currents in excess of I_V to flow when the UJT is on, otherwise the UJT will not turn off and the circuit will latch up.

MONOSTABLE CIRCUITS (One Shots)

In the circuit shown in Figure 7 the UJT is normally on and the emitter saturation current is supplied by transistor Q1 which is also on. When a positive trigger pulse is applied to the base of Q1, this transistor is turned off and since the emitter current of Q2 becomes less than I_V, the UJT turns off also. This starts the timing cycle. The capacitor will start charging from the same voltage every time, namely the saturation voltage of the UJT. C_E charges through R1 and R2 and when the voltage on C_E equals V_p, the UJT fires. This will cause a drop in the voltage at point A and transistor Q1 will turn on and supply the emitter current required to keep the UJT on. Transistor Q3 serves as an output device and delivers the pulse shown in Figure 7. The starting pulse required at the base of Q1 could very well be generated by another UJT circuit. The circuit is sensitive to changes in voltage and a zener diode is used for voltage regulation.

Another monostable circuit is shown in Figure 8. In this circuit, the UJT is normally off. The circuit operation is as follows: When an input trigger pulse of positive polarity is applied to the base of Q1, this transistor will turn on and Q2 will turn off. A voltage is now applied to charge capacitor C_E and when the voltage on C_E reaches V_p, the UJT (Q3) will fire. The positive voltage developed across the 27Ω resistor is used as the output signal and also as a trigger signal to the base of Q2. The signal will trigger the flip-flop and Q2 will turn on. This leaves only a very small voltage applied to C_E until the start of the next cycle. The voltage on C_E will always be the same at the start of a cycle, no matter how long a time has elapsed since the last cycle was completed. This circuit is nearly insensitive to changes in the supply voltage and a change in V1 from 10 volts to 30 volts results in a variation of approximately 2% in timing. The output signal could also be taken from the flip-flop in which case the output would be a clean square wave.

The monostable circuits offer the following advantages over conventional transistor one shots: (1) The time delay available can generally be made longer. (2) The circuit can be triggered again immediately after the completion of one cycle. (3) The circuit of Figure 8 is relatively independent of changes in the bias voltage, contrary to the behavior of conventional one shots.

SEQUENTIAL UJT-SCR TIMER CIRCUIT

A sequential timer circuit using UJTs and SCRs is shown in Figure 9. Only three stages are shown, but as many additional stages as required can be added. The loads are in series with the anodes of SCR1, SCR2, and SCR3, while the function of SCR4 is to turn off SCR3. The circuit operation is as follows: When a trigger pulse is applied to the terminals marked start pulse, SCR1 turns on and power is applied to the load R_{L1}. The drop in voltage at the anode of SCR1 allows base current to flow in Q1, and this transistor, which supplies charge current to C_{E1}, is turned on. When the voltage on C_{E1} reaches V_p of Q2, the UJT will fire and trigger SCR2. This causes two things to happen: Transistor Q3 turns on and starts the charging cycle of Q4, and SCR1 is commutated off through the 1 μF capacitor. Next, Q4 will fire triggering SCR3 on, and so on. When SCR4 is turned on, it will remain on only long enough to discharge C3 since the current flowing in the 10 k anode is less than the holding current of the SCR. The duration that power is applied to the different loads can be adjusted individually, with the 5 MΩ variable resistors in series with C_{E1}, C_{E2}, and C_{E3}. The last stage of the circuit can be made to trigger the first stage if so desired, and the time pulses would then continue indefinitely after the sequence were initially started.

This circuit could be useful in washing machine controls, etc., where different cycles require different time durations.

UJT OSCILLATOR CIRCUITS

Most UJT oscillator circuits employ the basic relaxation oscillator circuit in some way or another. As mentioned previously, either the output at base-one, base-two, or the emitter can be utilized in order to fulfill a specified requirement.

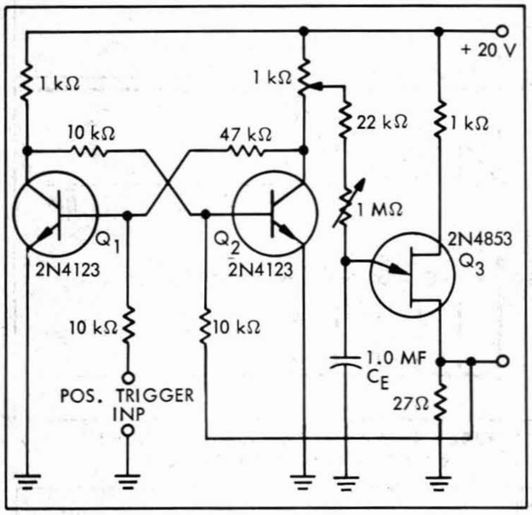
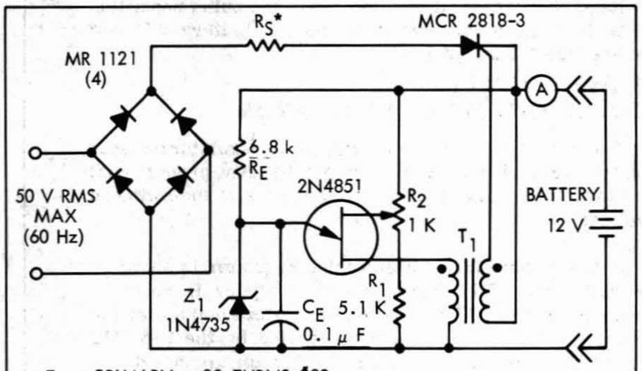
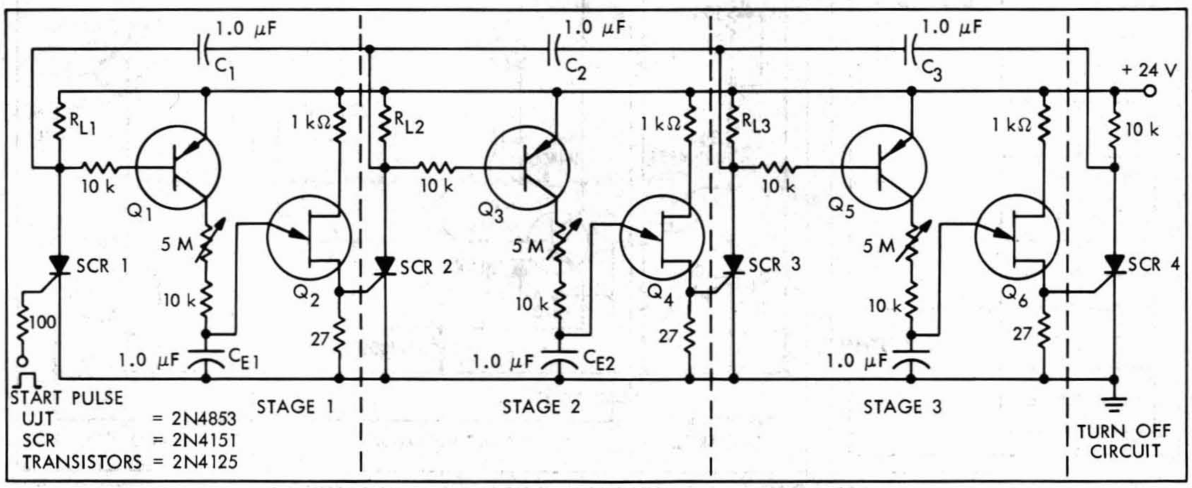

+ 20 V
1 kΩ
1 kΩ
10 kΩ
47 kΩ
22 kΩ
1 kΩ
1 MΩ
Q1
2N4123
Q2
2N4123
2N4853
Q3
10 kΩ
10 kΩ
1.0 MF
CE
27Ω
POS. TRIGGER
INP

FIGURE 8 - A UJT MONOSTABLE CIRCUIT INSENSITIVE TO CHANGE BIAS VOLTAGE


RS*
MCR 2818-3
MR 1121
(4)
A
50 V RMS
MAX
(60 Hz)
6.8 k
RE
2N4851
R2
1 K
BATTERY
12 V
T1
R1
Z1
1N4735
CE 5.1 K
0.1 μF

T1 - PRIMARY = 30 TURNS #22
SECONDARY = 45 TURNS #22
CORE = FERROXCUBE 203 F 181-3C3
* R_S - SERIES RESISTANCE TO LIMIT CURRENT THROUGH SCR.
MCR 2818-3 IS RATED AT 20 AMPS RMS.

FIGURE 10A - A 12 VOLT BATTERY CHARGER CONTROL (20 AMPS RMS MAX.)


1.0 μF
C1
1.0 μF
C2
1.0 μF
C3
+ 24 V
RL1
1 kΩ
RL2
1 kΩ
RL3
1 kΩ
10 k
10 k
10 k
10 k
Q1
Q3
Q5
5 M
5 M
5 M
SCR 1
SCR 2
SCR 3
SCR 4
Q2
Q4
Q6
10 k
10 k
10 k
100
27
27
27
1.0 μF
CE1
1.0 μF
CE2
1.0 μF
START PULSE
STAGE 1
STAGE 2
STAGE 3
TURN OFF
CIRCUIT

UJT = 2N4853
SCR = 2N4151
TRANSISTORS = 2N4125

FIGURE 9 - A SEQUENTIAL UJT TIMER CIRCUIT

BATTERY CHARGER

The battery charger circuit shown in Figure 10A is a very simple circuit utilizing the relaxation oscillator.

The circuit will not work unless the battery to be charged is connected with proper polarity. The battery voltage controls the charger and when the battery is fully charged, the charger will not supply current to the battery.

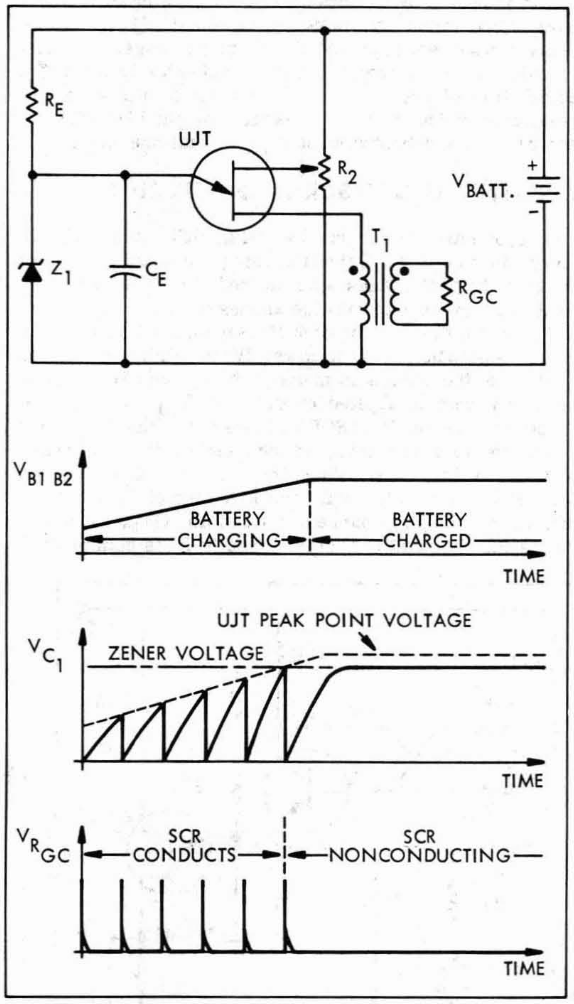
The circuit operation is as follows: The battery charging current is obtained through the SCR when it is triggered into the conducting state by the UJT relaxation oscillator. The oscillator is only activated when the battery voltage is low. V_{B2B1} of the UJT is derived from the voltage of the battery to be charged, and since $V_p = V_D + \eta V_{B2B1}$, the higher V_{B2B1}, the higher V_p. When V_p exceeds the breakdown voltage of the zener diode Z1, the UJT will cease to fire and the SCR will not conduct. This indicates that the battery has attained its desired charge as set by R2.

The relaxation oscillator itself and the waveforms associated with the operation is shown in Figure 10B. (The voltage increase will tend to change the pulse repetition rate, but this is not important, since the battery will tend to average the output.)

POWER SUPPLY SWITCHING MODE REGULATOR

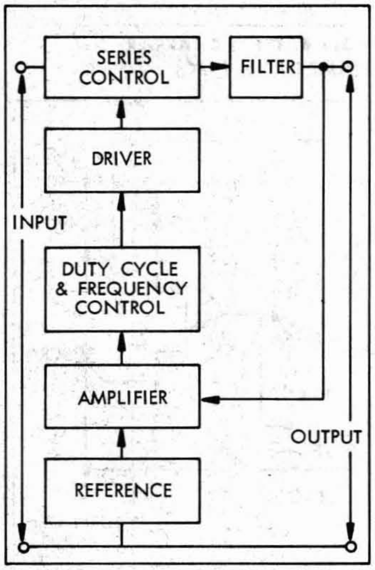
The operation of the switching mode regulator depends on the fact that the output voltage is directly proportional to the input voltage by the duty cycle of the switched voltage.

A block diagram of a switching regulator is shown in Figure 11A. The block called "duty cycle control" consists of two UJT relaxation oscillators and a bistable multivibrator. The pulses generated by the two UJT circuits trigger the bistable multivibrator to generate the variable duty cycle pulses. This part of the circuit is shown in Figure 11B. The oscillator circuit utilizing Q1 sets the basic operating frequency of the regulator at 5 kHz, while the Q4 oscillator controls the duty cycle.



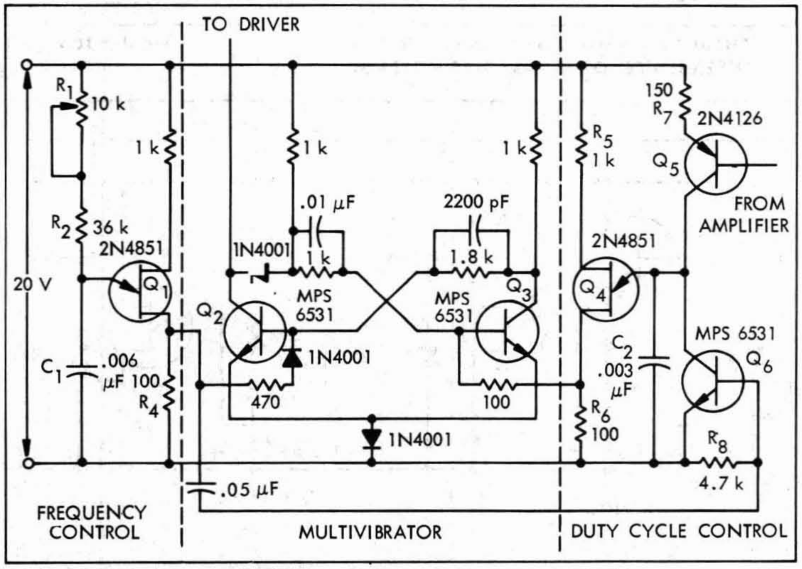
R_E
UJT
R_2
$V_{BATT.}$
+
−
T_1
Z_1
C_E
R_{GC}
$V_{B1\ B2}$
BATTERY CHARGING
BATTERY CHARGED
TIME
UJT PEAK POINT VOLTAGE
V_{C_1}
ZENER VOLTAGE
TIME
$V_{R_{GC}}$
SCR CONDUCTS
SCR NONCONDUCTING
TIME

FIGURE 10B - WAVEFORMS ASSOCIATED WITH BATTERY CHARGER OPERATION



SERIES CONTROL
FILTER
DRIVER
INPUT
DUTY CYCLE & FREQUENCY CONTROL
AMPLIFIER
OUTPUT
REFERENCE

FIGURE 11A - BLOCK DIAGRAM OF SWITCHING MODE REGULATOR



TO DRIVER
R_1
10 k
1 k
1 k
1 k
R_5
1 k
150
R_7
2N4126
Q_5
FROM AMPLIFIER
.01 μF
2200 pF
R_2
36 k
2N4851
1N4001
1 k
1.8 k
2N4851
20 V
Q_1
MPS 6531
MPS 6531
Q_3
Q_4
Q_2
MPS 6531
C_1
.006 μF
100
R_4
1N4001
C_2
.003 μF
Q_6
470
100
R_6
100
1N4001
R_8
4.7 k
.05 μF
FREQUENCY CONTROL
MULTIVIBRATOR
DUTY CYCLE CONTROL

FIGURE 11B - DUTY CYCLE AND FREQUENCY CONTROL OF THE SWITCHING REGULATOR

To obtain an understanding of the operation of the switching mode regulator, the generation of one cycle of voltage into the filter circuit will be established with the aid of Figures 12A through E. The pulses in Figure 12A are the trigger pulses generated by the 5 kHz relaxation oscillator Q1. These pulses trigger one side of the bistable multivibrator on and the collector current of the "on" transistor (Q2) is shown in Figure 12B. The 5kHz trigger pulse also discharges capacitor C2 via transistor Q6 so that C2 will begin charging from zero each time Q2 is turned on. The charging current for C2 is provided by a current source comprised of Q5 and R7. The waveforms are shown in Figure 12C. When the voltage on the capacitor reaches the firing voltage of Q4, the capacitor is discharged through R6 and generates the pulse in Figure 12D. This pulse triggers the opposite side of the multivibrator, and collector current ceases to flow in Q2. This completes one cycle of the duty cycle control circuit. The voltage that is applied to the filter circuit is shown in Figure 12E. This voltage is averaged by the filter to give a constant dc output.

The charging current provided by transistor Q5 is controlled by the amplifier (see Figure 11A). The amplifier senses a portion of the output of the regulator and compares this voltage to the reference. The voltage difference is amplified by the amplifier and applied as a current to the base of Q5 to control the charging of C2.

A SPACE-MARK GENERATOR WITH VOLTAGE-CONTROLLED DUTY CYCLE

Both the frequency and the duty cycle of the output pulse of the circuit in Figure 13 are variable. The frequency may be varied by means of resistor R_E in the source of Q1, while the duty cycle varies linearly with the reference voltage applied to the base of Q5.

The circuit operation is as follows: Field effect transistor Q1 acts as a constant current source charging C_E, and the rate of current flow is adjusted by R_E. A linear ramp is generated at the emitter of Q2, and this

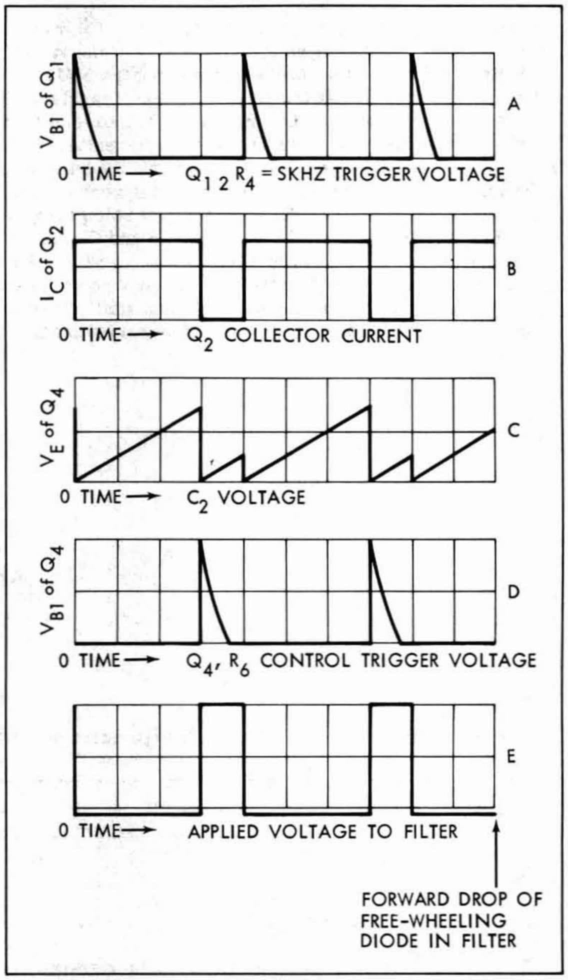
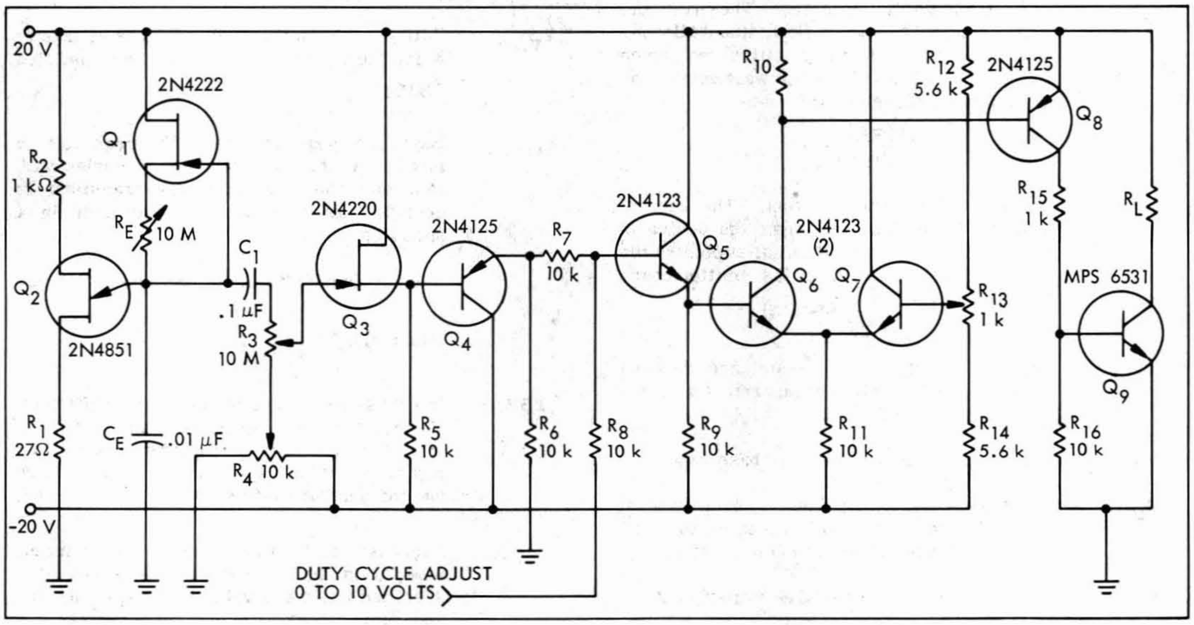


FIGURE 12 - CIRCUIT WAVESHAPES



20 V
2N4222
Q1
R2 1 kΩ
RE 10 M
C1 .1 µF
R3 10 M
Q2
2N4851
R1 27Ω
CE .01 µF
R4 10 k
-20 V
2N4220
Q3
2N4125
Q4
R7 10 k
R5 10 k
R6 10 k
R8 10 k
2N4123
Q5
R9 10 k
R10
2N4123 (2)
Q6
Q7
R11 10 k
R12 5.6 k
R13 1 k
R14 5.6 k
2N4125
Q8
R15 1 k
RL
MPS 6531
Q9
R16 10 k
DUTY CYCLE ADJUST 0 TO 10 VOLTS

FIGURE 13 - SPACE MARK GENERATOR WITH VOLTAGE CONTROLLED DUTY CYCLE

ramp is applied to the gate of FET Q3. The ramp is shifted up or down in voltage by means of the variable resistors R3 and R4 until a ramp going from -10 volts to zero is observed at the emitter of Q4. Transistor Q6 and Q7 form a differential amplifier. The base of Q7 is biased such that the other half of the differential amplifier Q6 will fire when the voltage at the base of Q5 crosses zero. The time at which the zero crossing occurs depends on the duty cycle adjust voltage applied to resistor R8. When Q6 turns on, Q8 and Q9 are also turned on, and power is applied to the load R_L. When the voltage on C_E reaches the emitter peak point voltage of the UJT Q2, it will fire and Q9 turns off. Then the cycle repeats. The duty cycle can be varied from 0 to 100%.

CONCLUSION

The application of the unijunction transistor in a variety of practical timer and oscillator circuits has been shown.

A UJT timer circuit employing relatively few parts offers timing capabilities ranging from milliseconds to several hours. The UJT is compatible with other solid state devices and works particularly well with SCRs.

Oscillators and pulse generators with variable frequency and/or pulse width can be constructed using the UJT and amazingly few extra components.

The annular UJT offers improved characteristics important in timer and oscillator design, such as low I_p, low I_{EO}, and low I_v.

APPENDIX

TABLE I

Unijunction Transistor Nomenclature

Symbol	Definition
I_E	Emitter current
I_{EO}	Emitter reverse current.
(I_{EBZO})	Measured between emitter and base-two at a specified voltage, and base-one open-circuit.
I_p	Peak point emitter current. The maximum emitter current that can flow without allowing the UJT to go into the negative resistance region. (Peak point is the lowest current on the emitter characteristic where: $\frac{dV_{EB1}}{dI_E} = 0.$)
I_V	Valley point emitter current. The current flowing in the emitter when the device is biased to the valley point. (Valley point is the second lowest current on the emitter characteristic where $\frac{dVE_{B1}}{dI_E} = 0.$)
r_{BB}	Interbase resistance. Resistance between base-two and base-one measured at a specified interbase voltage.
$V_{B2\ B1}$	Voltage between base-two and base-one.
V_p	Peak point emitter voltage. The maximum voltage seen at the emitter before the UJT goes into the negative resistance region.
V_D	Forward voltage drop of the emitter junction. Also called $V_{F(EB1)}$ or V_F.
V_{EB1}	Emitter to base-one voltage.
$V_{EB1(sat)}$	Emitter saturation voltage. Forward voltage drop from emitter to base-one at a specified emitter current larger than I_V and specified interbase voltage.
V_v	Valley point emitter voltage. The voltage at which the valley point occurs with a specified V_{B2B1}.
V_{OB1}	Base-one peak voltage. The peak voltage measured across a resistor in series with base-one when the unijunction transistor is operated as a relaxation oscillator in a specified circuit.
η	Intrinsic standoff ratio. Defined by the relationship: $\eta = \frac{V_p - V_D}{V_{B2B1}}$
α_{rBB}	Interbase resistance temperature coefficient. Variation of resistance between B2 and B1 over the specified temperature range and measured at the specific interbase voltage and temperature with emitter open-circuited.
$I_{B2\ (mod)}$	Interbase modulation current. B2 current modulation due to firing. Measured at a specified interbase voltage, emitter current and temperature.

TEMPERATURE STABILIZATION OF THE PEAK POINT VOLTAGE

It has been shown in AN293 how practically all UJT characteristics are temperature dependent. The interbase resistance r_{BB} and emitter reverse current I_{EO} increase, while the peak and valley voltage and current, the intrinsic standoff ratio η and the junction diode drop decrease with increasing temperature.

The peak point voltage is given by the equation:

$$V_p = V_D + \eta V_{B2B1} \qquad (10)$$

Since both V_D and η decrease with temperature, V_p will also decrease. This is, of course, a very undesirable condition in many applications, and particularly in timers and oscillator circuits. It has been found, however, that the change in V_p can be compensated for by adding a resistor R2 in series with the base two terminal.

If this resistor is selected properly, V_p can be made to vary less than 1% over a 50°C temperature variation. An equivalent circuit for the UJT in the cutoff region, including the external resistor R2, is shown in Figure 1. The peak point voltage is now given by:

$$V_p = V_D + \frac{\eta V_1 r_{BB}}{(r_{BB} + R2)} \qquad (11)$$

When temperature is increased, V_D decreases, and for V_p to remain unchanged, the second term in Equation (6), representing the voltage at point A, must increase. Since r_{BB} will increase and R2 will remain unchanged, the second term in the equation will indeed increase.

It would seem like a relatively simple task to calculate R2 from Equation (11) by taking the derivative of V_p with respect to temperature, setting $\frac{dV_p}{dt}$ equal to zero, and solve for R2. This procedure would result in the following equation for R2.

$$R2 = 1/2 \left[-(2 r_{BB} + V_1 \eta \frac{K_2}{K_1} + V_1 r_{BB} \frac{K_3}{K_1}) \pm \right.$$

$$\left. (2 r_{BB} + V_1 \eta \frac{K_2}{K_1} + V_1 r_{BB} \frac{K_3}{K_1} - 4 r_{BB} (1 + V1 \frac{K_3}{K_1}) \right] \qquad (12)$$

where $K_1 = \frac{dV_D}{dT} = -2.7 \text{ mV/}^{\circ}\text{C}$

$$K_2 = \frac{d\, r_{BB}}{dt} = \frac{r_{BBN} \cdot 0.77}{100} \ /^{\circ}\text{C}$$

$$K_3 = \frac{d\eta}{dT} = \frac{\eta_N \cdot 0.06}{100} \ /^{\circ}\text{C}$$

and the subscript N denotes the value at 25°C.

When solving this equation, it would also have to be taken into account that r_{BB} is voltage dependent and when V_{B2B1} is increased by one volt, r_{BB} increases 1.2% (based on the value of r_{BB} at V_{B2B1} = 3 V). Furthermore, the temperature dependency of r_{BB} affects not only terms containing K2 but also terms containing r_{BB} itself.

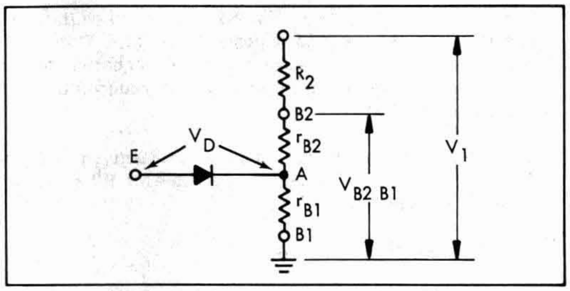


FIGURE I - ELECTRICAL EQUIVALENT CIRCUIT FOR THE UJT WITH THE EXTERNAL COMPENSATING RESISTOR R2. THE EQUIVALENT CIRCUIT IS VALID IN THE CUTOFF REGION ONLY

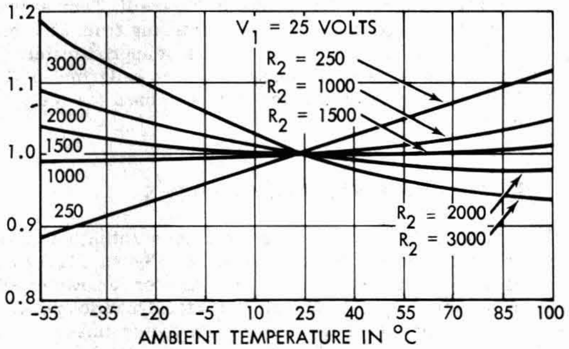


FIGURE II - FREQUENCY VERSUS TEMPERATURE FOR A UJT RELAXATION OSCILLATOR CIRCUIT. (FREQUENCY IS NORMALIZED TO 25°C AND R2 IS A VARIABLE PARAMETER)

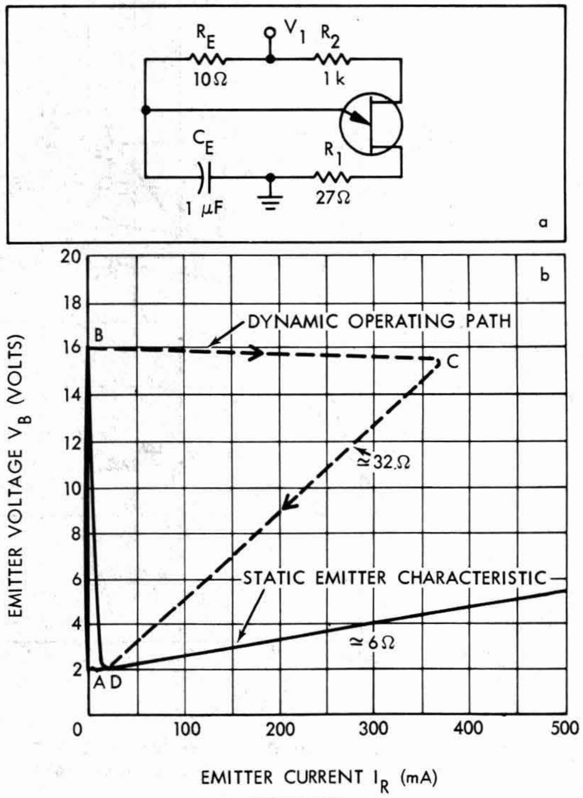


FIGURE III

In equation (12), r_{BB}, K1, K2, and η are voltage dependent and $V_{B2\ B1}$ is dependent on R2. This interdependency results in a very complex equation that is difficult to solve which in turn greatly reduces the usefulness of Equation (12).

An empirically derived formula for R2 given in Equation (13) will generally result in a value for R2 relatively close to the optimum value.

$$R2 = 0.015 \bullet V_1 \bullet r_{BB} \bullet \eta \tag{13}$$

If a high degree of accuracy is required, however, a final adjustment of R2 should be made in the actual operating circuit.

Frequency variation as a function of temperature for a typical annular UJT is shown in Figure II. Temperature curves for several values of R2 ranging from 250 ohms to 3 kohms are shown, and an R2 of approximately 1.5 kohms can be seen to compensate very well from -5°C to +85°C. A smaller resistor should be used for operation below -5°C.

DYNAMIC OPERATING PATHS

In order to determine the dynamic operating path of the relaxation oscillator, the circuit in Figure IIIa can be used. Figure IIIb shows the emitter characteristic curve for V_{B2B1} = 20 volts with the dynamic operating path of the oscillator shown with dotted lines. (V_1 in Figure IIIa is adjusted for V_{B2B1} = 20 volts.)

At the beginning of a cycle, C_E will start to charge from point A on the characteristic curve. At point B, where the voltage of C_E equals V_p, the UJT will fire and the characteristic curve goes into the negative resistance region. The voltage on the capacitor cannot change instantaneously, however, and the dynamic operating path will move from point B to point C. The time required to move from B to C is approximately 1 μsec. From point C, the operating path follows an essentially straight line to point D, which is approximately equal to the valley point. This straight line has a slope of approximately 32 volts/ampere or 32 ohms, and is composed of R1 and the UJT emitter base one saturation resistance. There is not enough emitter current available to sustain operation at point D, and the operating path tries to follow the characteristic curve to the point where it is intersected by the load line determined by R_E (similar to load line 3 in Figure 2). If the emitter circuit of the UJT were purely resistive (i.e. capacitor C_E), this intersection point would be a stable operating point. To reach this point, however, the emitter voltage must increase. The resistance from emitter to base-one will also increase, and the emitter current will decrease somewhat. When the emitter voltage increases, however, current starts to flow into the capacitor and the emitter current is reduced more than that required by the characteristic curve. So, with a capacitor C_E in the emitter circuit, there are no stable operating points in the negative resistance region, and from point D, therefore, the operating path goes to point A again and the cycle repeats. It takes about 180 μsec to traverse the path from point C to point A in the circuit shown.

The shape of the dynamic operating path is determined by the capacitor C_E, the bias voltage, and the resistor R1. Figure IVa shows operating paths for different values of C_E while Figure IVb shows operating paths for fixed C_E but varying interbase voltage.

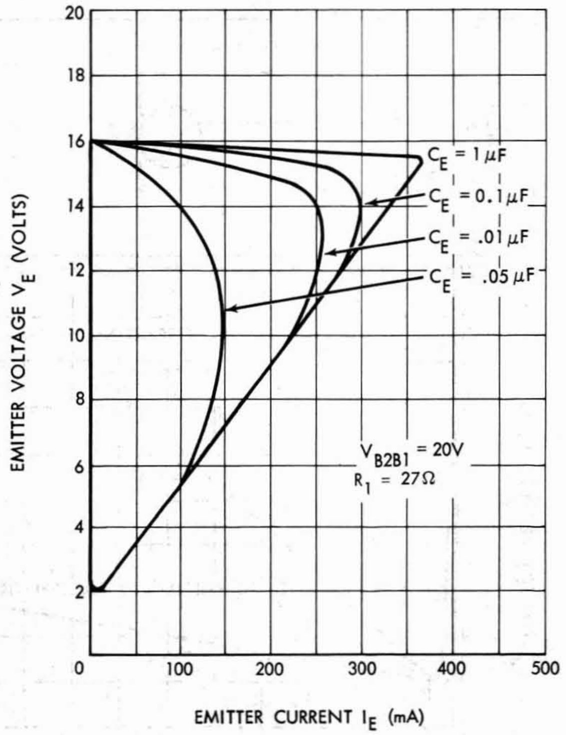


FIGURE IVa - DYNAMIC OPERATING PATH VERSUS EMITTER CAPACITANCE (CIRCUIT - FIGURE IIIA)

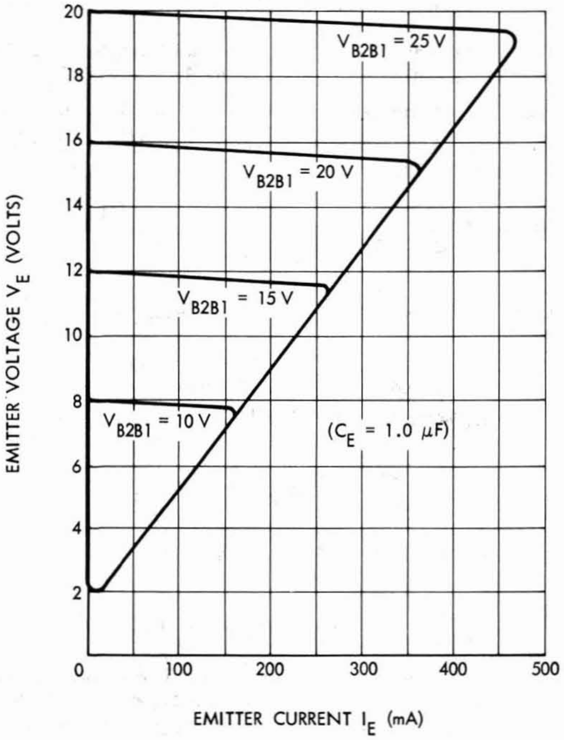


FIGURE IVb - DYNAMIC OPERATION PATH VERSUS INTERBASE VOLTAGE (CIRCUIT - FIGURE IIIA)

When an inductive load, like a relay coil, for example, is substituted for R1, the dynamic operating path will be somewhat different. Figure Va shows a relaxation oscillator having a pulse transformer instead of R1, and Figure Vb shows the resulting dynamic operating path. An important difference here is that the emitter no longer ceases to conduct when valley voltage is reached but goes down to less than 0.5 volts before turning off. Figure Vc shows how the turn-off voltage is dependent on the bias voltage.

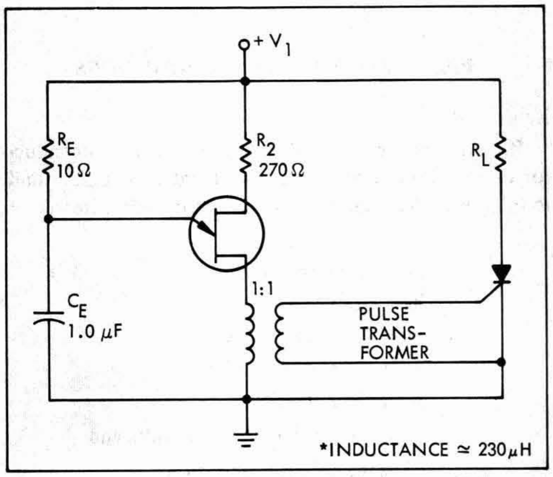

+V1
RE
10 Ω
R2
270 Ω
RL
CE
1.0 μF
1:1
PULSE
TRANS-
FORMER
*INDUCTANCE ≃ 230μH

FIGURE Va - A RELAXATION OSCILLATOR WITH INDUCTIVE* LOAD

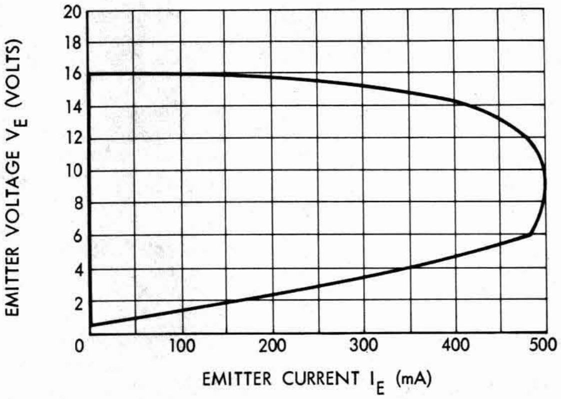


FIGURE Vb

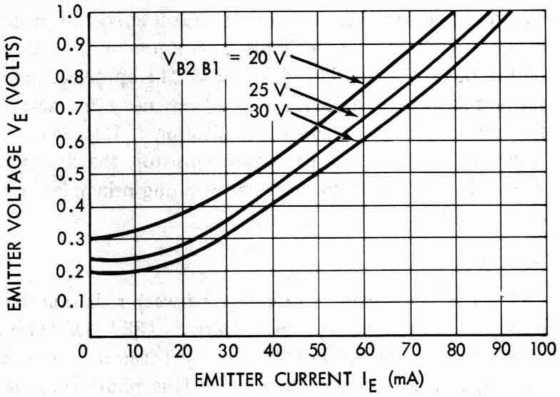


FIGURE Vc

THEORY AND CHARACTERISTICS OF PHOTOTRANSISTORS

INTRODUCTION

Phototransistor operation is based on the sensitivity of a pn junction to radiant energy. If radiant energy of proper wave-length is made to impinge on a junction, the current through that junction will increase. This optoelectronic phenomenon has provided the circuit designer with a device for use in a wide variety of applications. However, to make optimum use of the phototransistor, the designer should have a sound grasp of its operating principles and characteristics.

HISTORY

The first significant relationships between radiation and electricity were noted by Gustav Hertz in 1887. Hertz observed that under the influence of light, certain surfaces were found to liberate electrons. This photo-emissive effect was put into theory by Max Planck in 1900. He proposed that light of a frequency f contained energy bundles or packets, which he called photons. Furthermore, the energy content of each photon was directly proportional to the light frequency:

$$E = hf, \qquad (1)$$

where E is the photon energy,
h is Planck's constant, and
f is the light frequency.

Planck theorized that a metal had associated with it a work function, or binding energy for free electrons. If a photon could transfer its energy to a free electron, and that energy exceeded the work function, the electron could be liberated from the surface. The presence of an electric field could enhance this by effectively reducing the work function. Einstein extended Planck's findings by showing that the velocity, and hence the momentum of an emitted electron, depended on the work function and the light frequency.

PHOTO EFFECT IN SEMICONDUCTORS

Bulk Crystal

If light of proper wavelength impinges on a semiconductor crystal, the concentration of charge carriers is found to increase. Thus, the crystal conductivity will increase:

$$\sigma = q\,(\mu_e\, n + \mu_h\, p), \qquad (2)$$

where σ is the conductivity,
q is the electron charge,
μ_e is the electron mobility,
μ_h is the hole mobility,
n is the electron concentration, and
p is the hole concentration.

The process by which charge-carrier concentration is increased is shown in Figure 1. The band structure of the semiconductor is shown, with an energy gap, or forbidden region, of Eg electron volts. Radiation from two light sources is shown striking the crystal. Light frequency f_1 is sufficiently high that its photon energy, hf_1, is slightly greater than the energy gap. This energy is transferred to a bound electron at site one in the valence band, and the electron is excited to a higher energy level, site one in the conduction band, where it is free to serve as a current carrier. The hole left behind at site one in the valence band is also free to serve as a current carrier.

The photon energy of the lower-frequency light, hf_2, is less than the band gap, and an electron freed from site two in the valence band will rise to a level in the forbidden region, only to release this energy and fall back into the valence band and recombine with a hole at site three.

The above discussion implies that the energy gap, Eg, represents a threshold of response to light. This is true, however, it is not an abrupt threshold. Throughout the photo-excitation process, the law of conservation of mo-

Circuit diagrams external to Motorola products are included as a means of illustrating typical semiconductor applications; consequently, complete information sufficient for construction purposes is not necessarily given. The information in this Application Note has been carefully checked and is believed to be entirely reliable. However, no responsibility is assumed for inaccuracies. Furthermore, such information does not convey to the purchaser of the semiconductor devices described any license under the patent rights of Motorola Inc. or others.

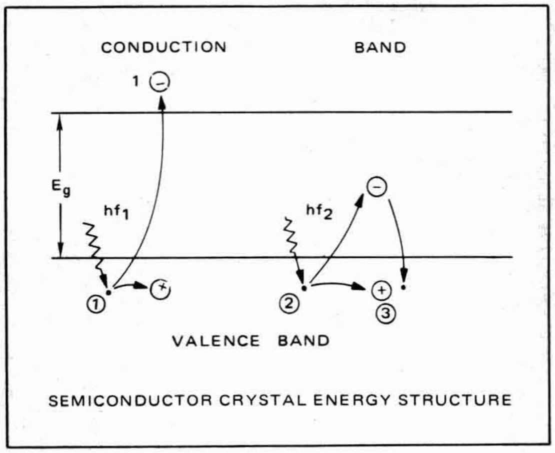


FIGURE 1 – Photoeffect in a Semiconductor

mentum applies. The momentum and density of hole-electron sites are highest at the center of both the valence and conduction bands, and fall to zero at the upper and lower ends of the bands. Therefore, the probability of an excited valence-band electron finding a site of like momentum in the conduction band is greatest at the center of the bands and lowest at the ends of the bands. Consequently, the response of the crystal to the impinging light is found to rise from zero at a photon energy of Eg electron volts, to a peak at some greater energy level, and then to fall to zero again at an energy corresponding to the difference between the bottom of the valence band and the top of the conduction band.

The response is a function of energy, and therefore of frequency, and is often given as a function of reciprocal frequency, or, more precisely, of wave length. An example is shown in Figure 2 for a crystal of cadmium-selenide. On the basis of the information given so far, it would seem reasonable to expect symmetry in such a curve; however, trapping centers and other absorption phenomena affect the shape of the curve[1].

The optical response of a bulk semiconductor can be modified by the addition of impurities. Addition of an acceptor impurity, which will cause the bulk material to become p-type in nature, results in impurity levels which lie somewhat above the top of the valence band. Photo-excitation can occur from these impurity levels to the conduction band, generally resulting in a shifting and reshaping of the spectral response curve. A similar modification of response can be attributed to the donor impurity levels in n-type material.

PN Junctions

If a pn junction is exposed to light of proper frequency, the current flow across the junction will tend to increase. If the junction is forward-biased, the net increase will be relatively insignificant. However, if the junction is reverse-biased, the change will be quite appreciable. Figure 3 shows the photo effect in the junction for a frequency well within the response curve for the device.

Photons create hole-electron pairs in the crystal on both sides of the junction. The transferred energy promotes the electrons into the conduction band, leaving the holes in the valence band. The applied external bias provides an electric field, $\mathcal{E}$, as shown in the figure. Thus the photo-induced electrons in the p-side conduction band will flow down the potential hill at the junction into the n-side and from there to the external circuit. Likewise, holes in the valence band of the n-side will flow across the junction into the p-side where they will add to the external current.

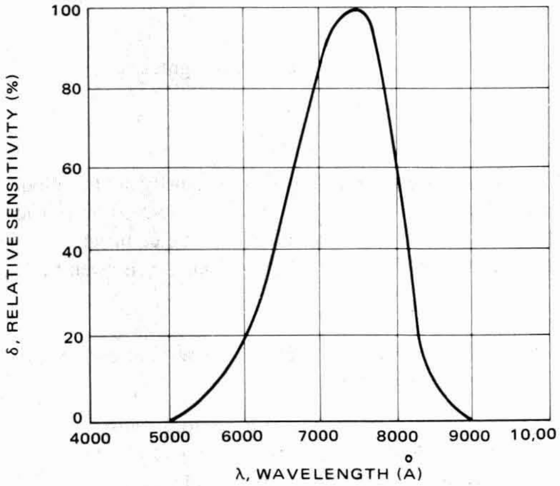


FIGURE 2 – Spectral Response of Cadmium Selenide

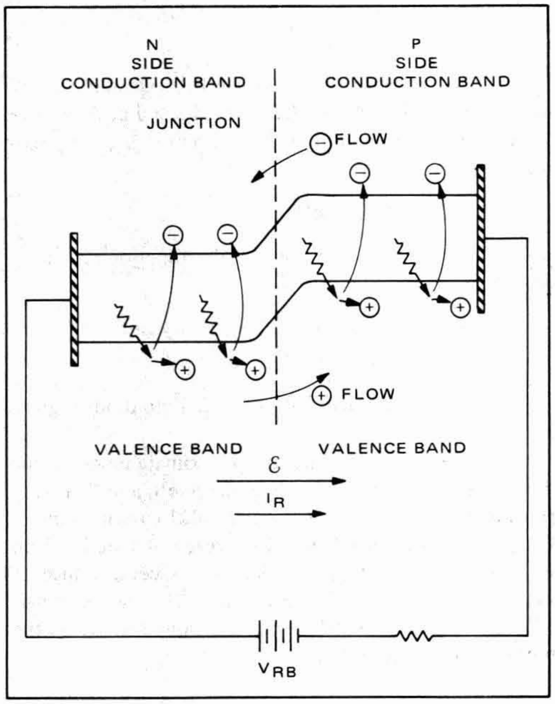


FIGURE 3 – Photo Effect in a Reverse-Biased PN Junction

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[1] See references for a detailed discussion of these.

Under dark conditions, the current flow through the reverse-biased diode is the reverse saturation current, I_o. This current is relatively independent of the applied voltage (below breakdown) and is basically a result of the thermal generation of hole-electron pairs.

When the junction is illuminated, the energy transferred from photons creates additional hole-electron pairs. The number of hole-electron pairs created is a function of the light intensity.

For example, incident monochromatic radiation of H (watts/cm^2) will provide P photons to the diode:

$$P = \frac{\lambda H}{hc}, \qquad (3)$$

where λ is the wavelength of incident light,

h is Planck's constant, and

c is the velocity of light.

The increase in minority carrier density in the diode will depend on P, the conservation of momentum restriction, and the reflectance and transmittance properties of the crystal. Therefore, the photo current, I_λ, is given by

$$I_\lambda = \eta F q A, \qquad (4)$$

where η is the quantum efficiency or ratio of current carriers to incident photons,

F is the fraction of incident photons transmitted by the crystal,

q is the charge of an electron, and

A is the diode active area.

Thus, under illuminated conditions, the total current flow is

$$I = I_o + I_\lambda. \qquad (5)$$

If I_λ is sufficiently large, I_o can be neglected, and by using the spectral response characteristics and peak spectral sensitivity of the diode, the total current is given approximately by

$$I \approx \delta S_R H, \qquad (6)$$

where δ is the relative response and a function of radiant wavelength,

S_R is the peak spectral sensitivity, and

H is the incident radiation.

The spectral response for a silicon photo-diode is given in Figure 4.

Using the above relations, an approximate model of the diode is given in Figure 5. Here, the photo and thermally generated currents are shown as parallel current sources. C represents the capacitance of the reverse-biased junction while G represents the equivalent shunt conductance of the diode and is generally quite small. This model applies only for reverse bias, which, as mentioned above, is the normal mode of operation.

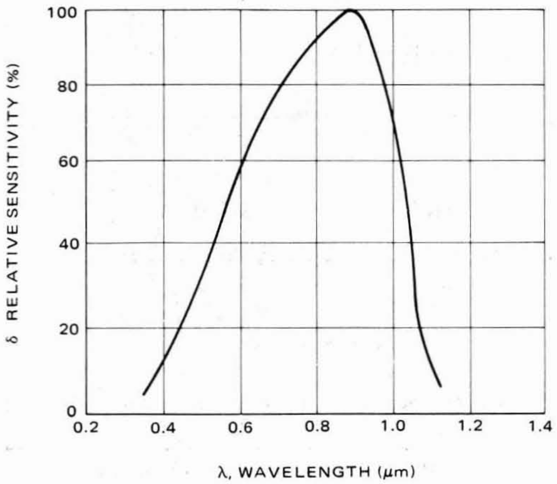


FIGURE 4 – Spectral Response of Silicon Photodiode

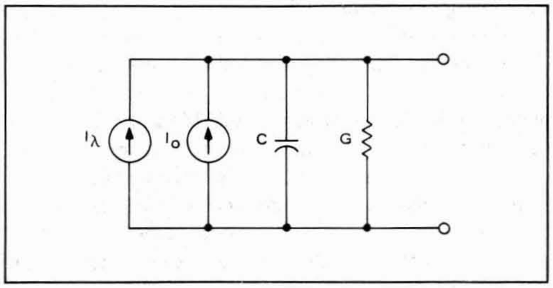


FIGURE 5 – Approximate Model of Photodiode

Photo Transistor

If the pn junction discussed above is made the collector-base diode of a bipolar transistor, the photo-induced current is the transistor base current. The current gain of the transistor will thus result in a collector-emitter current of

$$I_C = (h_{fe} + 1)\, I_\lambda, \qquad (7)$$

where I_C is the collector current,

h_{fe} is the forward current gain, and

I_λ is the photo induced base current.

The base terminal can be left floating, or can be biased up to a desired quiescent level. In either case, the collector-base junction is reverse biased and the diode current is the reverse leakage current. Thus, photo-stimulation will result in a significant increase in diode, or base current, and with current gain will result in a significant increase in collector current.

The energy-band diagram for the photo transistor is shown in Figure 6. The photo-induced base current is returned to the collector through the emitter and the external circuitry. In so doing, electrons are supplied to the base region by the emitter where they are pulled into the collector by the electric field $\mathcal{E}$.

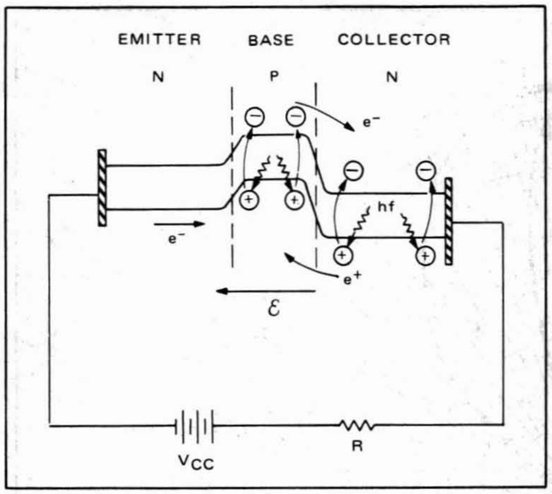


FIGURE 6 – Photoeffect in a Transistor

The model of the photo diode in Figure 5 might also be applied to the phototransistor, however, this would be severely limited in conveying the true characteristics of the transistor. A more useful and accurate model can be obtained by using the hybrid-pi model of the transistor and adding the photo-current generator between collector and base. This model appears in Figure 7.

Assuming a temperature of 25°C, and a radiation source at the wave length of peak response (i.e., $\delta = 1$), the following relations apply:

$$I_\lambda \approx S_{RCBO} \cdot H, \tag{8a}$$

$$gm = 40\, i_c, \text{ and} \tag{8b}$$

$$r_{be} = h_{fe}/g_m, \tag{8c}$$

where S_{RCBO} is the collector-base diode radiation sensitivity with open emitter,

g_m is the forward transconductance,

i_c is the collector current, and

r_{be} is the effective base-emitter resistance.

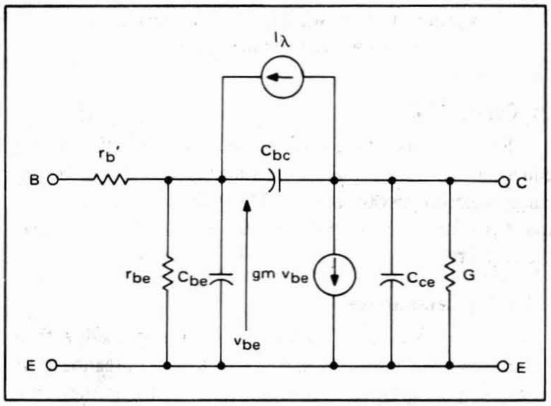


FIGURE 7 – Hybrid-pi Model of Phototransistor

In most cases $r'_b \ll r_{be}$, and can be neglected. The open-base operation is represented in Figure 8. Using this model, a feel for the high-frequency response of the device may be obtained by using the relationship

$$f_t \approx \frac{g_m}{2\pi C_{BE}}, \tag{9}$$

where f_t is the device current-gain-bandwidth product.

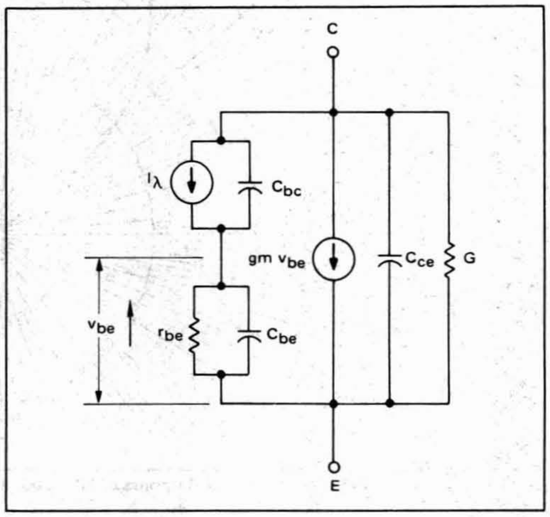


FIGURE 8 – Floating Base Approximate Model of Phototransistor

STATIC ELECTRICAL CHARACTERISTICS OF PHOTOTRANSISTORS

Spectral Response

As mentioned previously, the spectral response curve provides an indication of a device's ability to respond to radiation of different wave lengths. Figure 9 shows the spectral response for constant energy radiation for the Motorola MRD300 phototransistor series. As the figure indicates, peak response is obtained at about 8000 Å (Angstroms), or 0.8 μm.

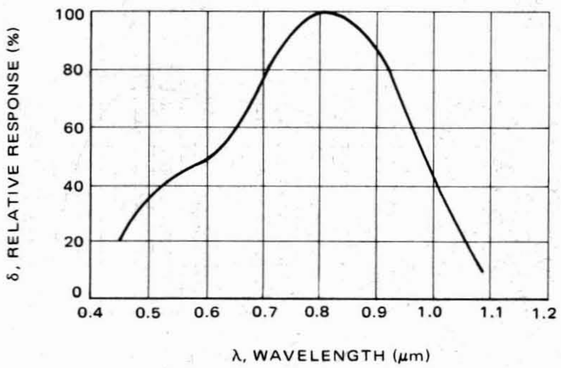


FIGURE 9 – Constant Energy Spectral Response for MRD300

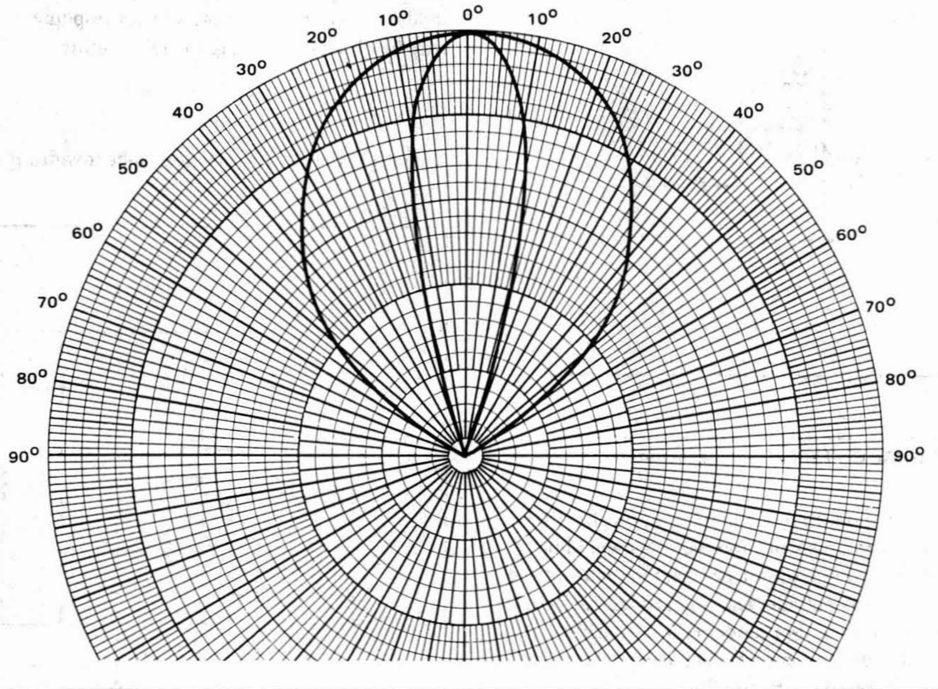


FIGURE 10 – Polar Response of MRD300. Inner Curve with Lens, Outer Curve with Flat Glass.

Angular Alignment

Lambert's law of illumination states that the illumination of a surface is proportional to the cosine of the angle between the normal to the surface and the direction of the radiation. Thus, the angular alignment of a phototransistor and radiation source is quite significant. The cosine proportionately represents an ideal angular response. The presence of an optical lens and the limit of window size further affect the response. This information is best conveyed by a polar plot of the device response. Such a plot in Figure 10 gives the polar response for the MRD300 series.

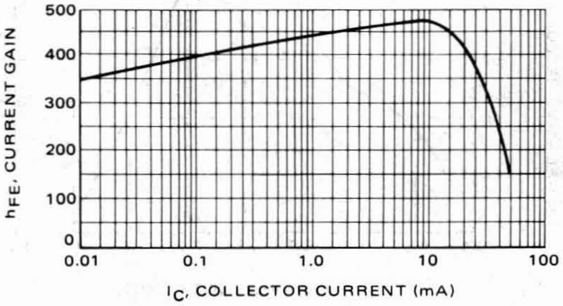


FIGURE 11 – DC Current Gain versus Collector Current

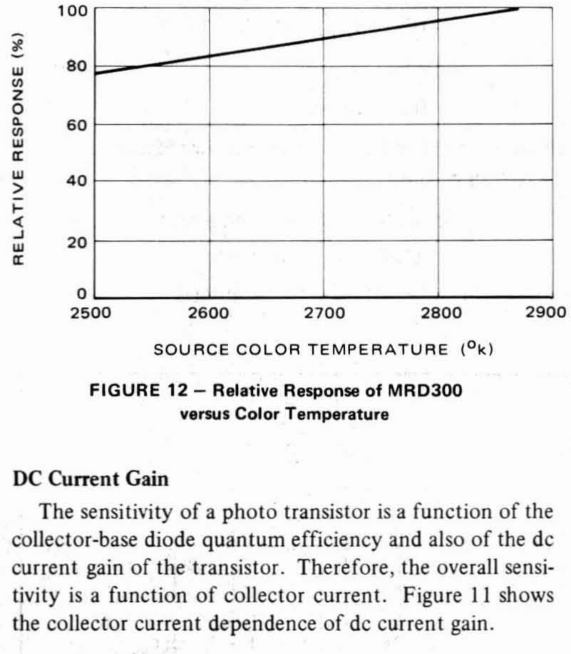


FIGURE 12 – Relative Response of MRD300 versus Color Temperature

DC Current Gain

The sensitivity of a photo transistor is a function of the collector-base diode quantum efficiency and also of the dc current gain of the transistor. Therefore, the overall sensitivity is a function of collector current. Figure 11 shows the collector current dependence of dc current gain.

Color Temperature Response

In many instances, a photo transistor is used with a broad band source of radiation, such as an incandescent lamp. The response of the photo transistor is therefore dependent on the source color temperature. Incandescent sources are normally operated at a color temperature of 2870°K, but, lower-color-temperature operation is not uncommon. It therefore becomes desirable to know the result of a color temperature difference on the photo sensitivity. Figure 12 shows the relative response of the MRD300 series as a function of color temperature.

Temperature Coefficient of Ip

A number of applications call for the use of phototransistors in temperature environments other than normal room temperature. The variation in photo current with temperature changes is approximately linear with a positive slope of about 0.667%/°C.

The magnitude of this temperature coefficient is primarily a result of the increase in h_{FE} versus temperature, since the collector-base photo current temperature coefficient is only about 0.1%/°C.

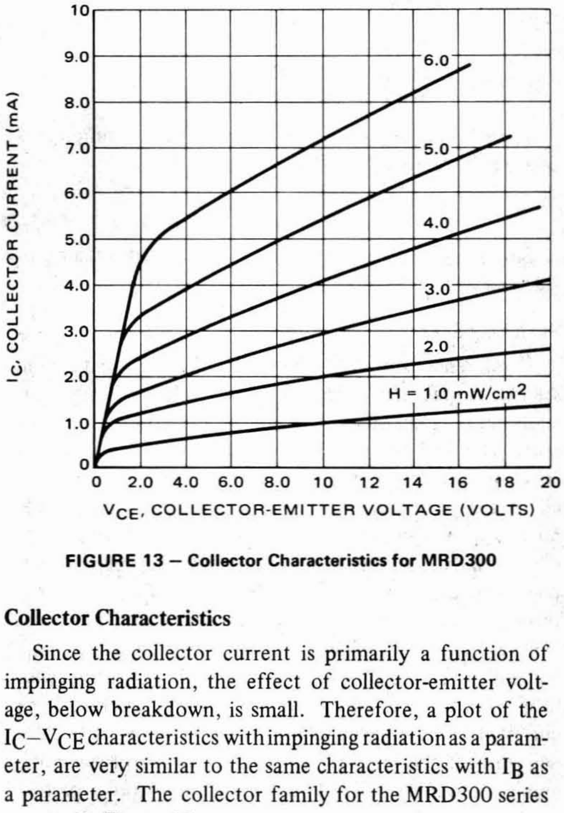


FIGURE 13 — Collector Characteristics for MRD300

Collector Characteristics

Since the collector current is primarily a function of impinging radiation, the effect of collector-emitter voltage, below breakdown, is small. Therefore, a plot of the I_C-V_{CE} characteristics with impinging radiation as a parameter, are very similar to the same characteristics with I_B as a parameter. The collector family for the MRD300 series appears in Figure 13.

Radiation Sensitivity

The capability of a given phototransistor to serve in a given application is quite often dependent on the radiation sensitivity of the device. The open-base radiation sensitivity for the MRD300 series is given in Figure 14. This indicates that the sensitivity is approximately linear with respect to impinging radiation. The additional capability of the MRD300 to be pre-biased gives rise to interest in the sensitivity as a function of equivalent base resistance. Figure 15 gives this relationship.

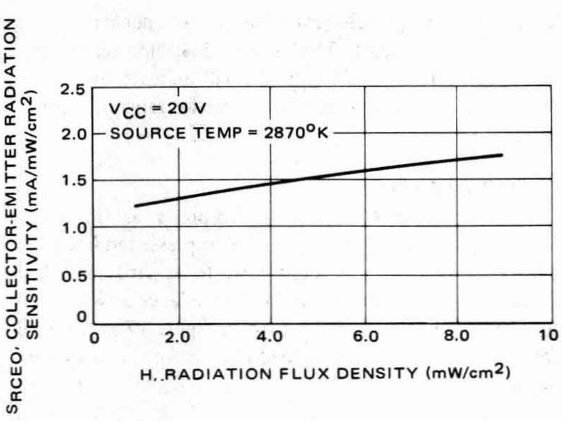


FIGURE 14 — Open Base Sensitivity versus Radiation for MRD300

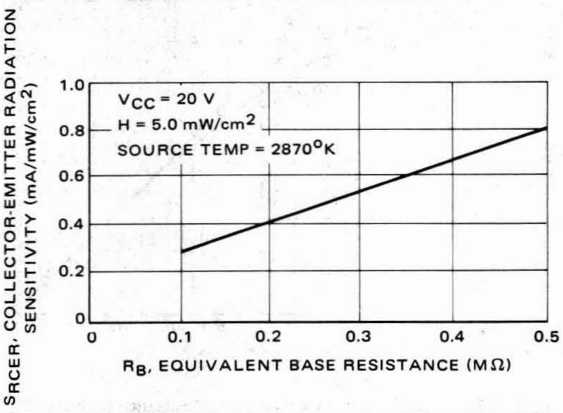


FIGURE 15 — Effect of Base Resistance on Sensitivity of MRD300

Capacitance

Junction capacitance is the significant parameter in determining the high frequency capability and switching speed of a transistor. The junction capacitances of the MRD300 as a function of junction voltages are given in Figure 16.

DYNAMIC CHARACTERISTICS OF PHOTOTRANSISTORS

Linearity

The variation of h_{FE} with respect to collector current results in a non-linear response of the photo transistor over

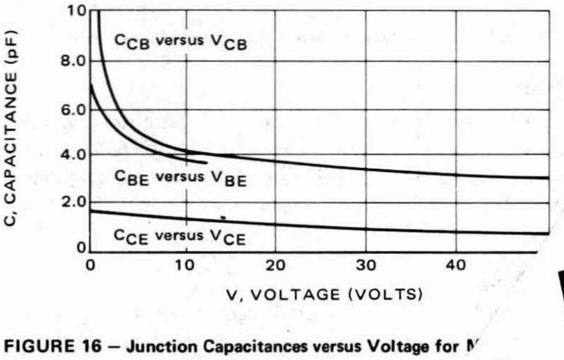


FIGURE 16 — Junction Capacitances versus Voltage for M

large signal swings. However, the small-signal response is approximately linear. The use of a load line on the collector characteristic of Figure 13 will indicate the degree of linearity to be expected for a specific range of optical drive.

Frequency Response

The phototransistor frequency response, as referred to in the discussion of Figures 7 and 8, is presented in Figure 17. The device response is flat down to dc with the rolloff frequency dependent on the load impedance as well as on the device. The response is given in Figure 17 as the 3-dB frequency as a function of load impedance for two values of collector current.

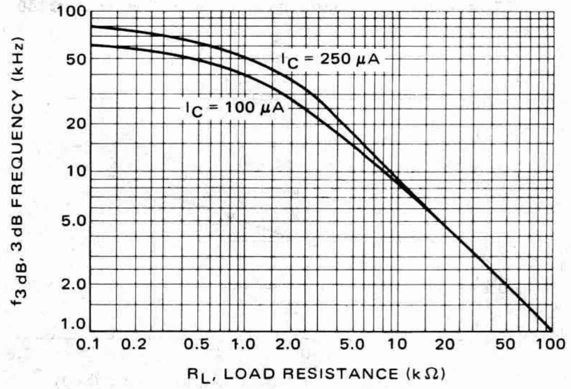


FIGURE 17 – 3 dB Frequency versus Load Resistance for MRD300

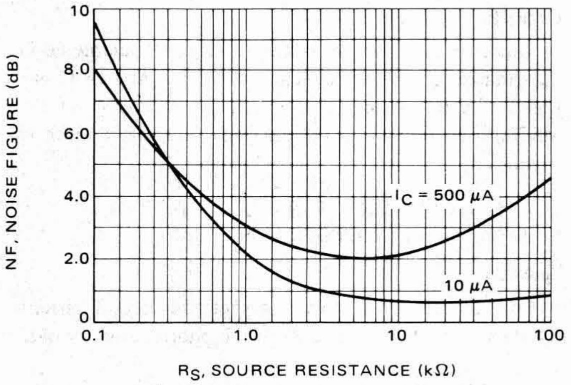


FIGURE 18 – MRD300 Noise Figure versus Source Resistance

Noise Figure

Although the usual operation of the phototransistor is in the floating base mode, a good qualitative feel for the device's noise characteristic can be obtained by measuring noise figure under standard conditions. The 1 kHz noise figure for the MRD300 is shown in Figure 18.

Small Signal h Parameters

As with noise figure, the small-signal h-parameters, measured under standard conditions, give a qualitative feel for the device behavior. These are given as functions of collector current in Figure 19. With this information, the device can be analyzed in the standard hybrid model of Figure 20(a); by use of the conversions of Table I, the equivalent r-parameter model of Figure 20(b) can be used.

TABLE I – Parameter Conversions

$$h_{fb} = \frac{h_{fe}}{1 + h_{fe}}$$

$$r_c = \frac{h_{fe} + 1}{h_{oe}}$$

$$r_e = \frac{h_{re}}{h_{oe}}$$

$$r_b = h_{ie} - \frac{h_{re}(1 + h_{fe})}{h_{oe}}$$

SWITCHING CHARACTERISTICS OF PHOTOTRANSISTORS

In switching applications, two important requirements of a transistor are:

(1) speed
(2) ON voltage

Since some optical drives for phototransistors can provide fast light pulses, the same two considerations apply.

Switching Speed

If reference is made to the model of Figure 8, it can be seen that a fast rise in the current I_λ will not result in an equivalent instantaneous increase in collector-emitter current. The initial flow of I_λ must supply charging current to C_{CB} and C_{BE}. Once these capacitances have been charged, I_λ will flow through r_{be}. Then the current generator, $g_m \cdot v_{be}$, will begin to supply current. During turn-off, a similar situation occurs. Although I_λ may instantaneously drop to zero, the discharge of C_{CB} and C_{BE} through r_{be} will maintain a current flow through the collector. When the capacitances have been discharged, V_{be} will fall to zero and the current, $g_m \cdot V_{be}$, will likewise drop to zero. (This discussion assumes negligible leakage currents). These capacitances therefore result in turn-on and turn-off delays, and in rise and fall times for switching applications just as found in conventional bipolar switching transistors. And, just as with conventional switching, the times are a function of drive. Figure 21 shows the collector current (or drive) dependence of the turn-on delay and rise times. As indicated the delay time is dependent on the device only; whereas the rise-time is dependent on both the device and the load.

If a high-intensity source, such as a xenon flash lamp, is used for the optical drive, the device becomes optically saturated unless large optical attenuation is placed between source and detector. This can result in a significant storage time during the turn off, especially in the floating-base mode since stored charge has no direct path out of the

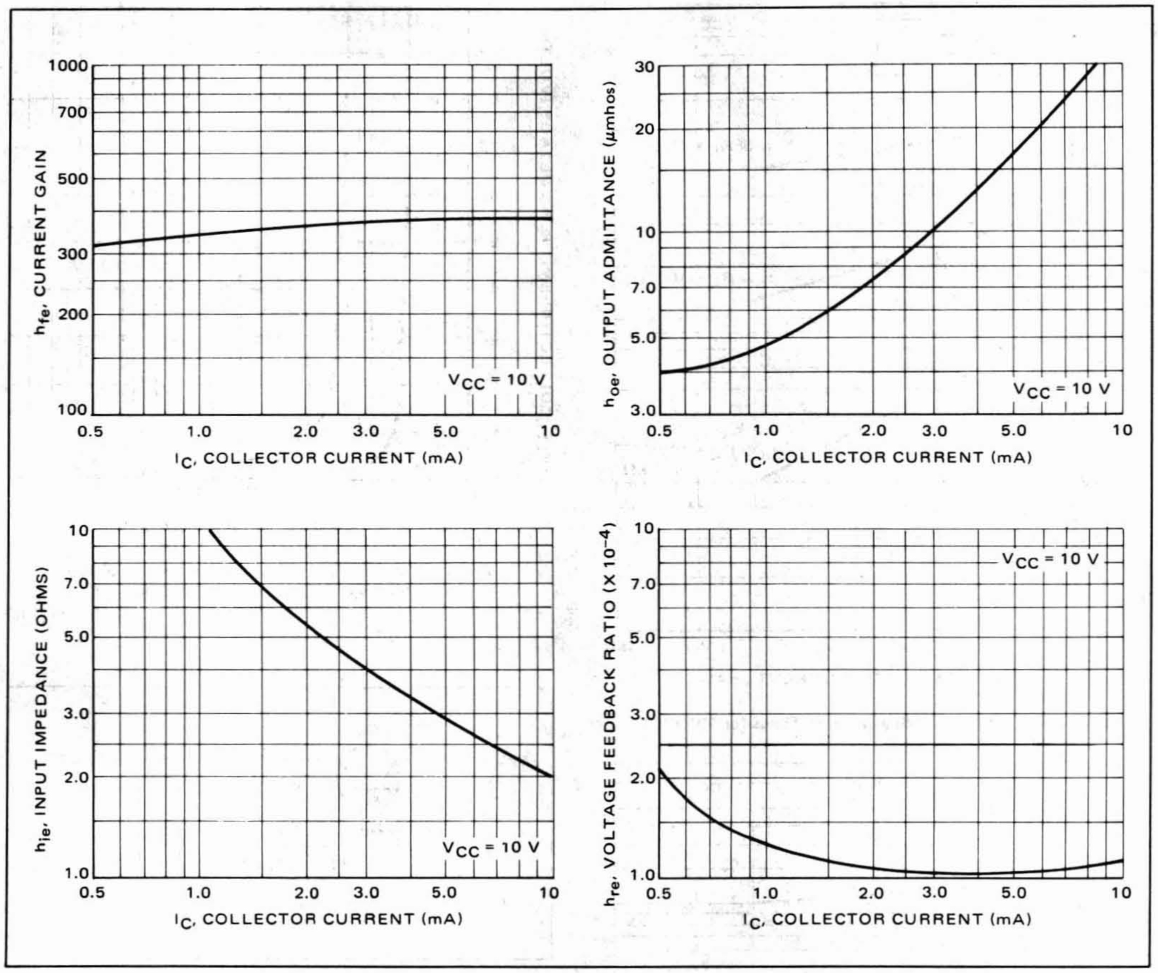
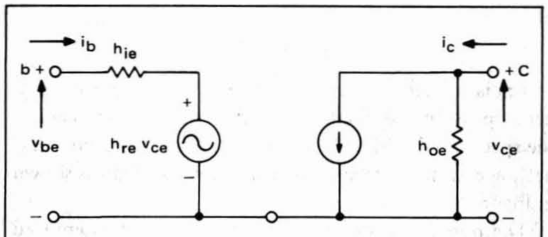
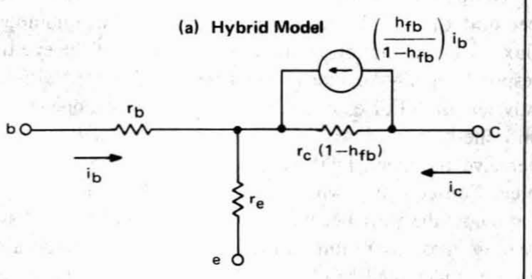


FIGURE 19 — 1 kHz h-Parameters versus Collector Current for MRD300



(a) Hybrid Model



(b) r-Parameter Model

FIGURE 20 — Low Frequency Analytical Models of Phototransistor Without Photo Current Generator

base region. However, if a non-saturating source, such as a GaAs diode, is used for switching drive, the storage, or turn-off delay time is quite low as shown in Figure 22.

Saturation Voltage

An ideal switch has zero ON impedance, or an ON voltage drop of zero. The ON saturation voltage of the MRD300 is relatively low, approximately 0.2 volts. For a given collector current, the ON voltage is a function of drive, and is shown in Figure 23.

APPLICATIONS OF PHOTOTRANSISTORS

As mentioned previously, the phototransistor can be used in a wide variety of applications. Figure 24 shows two phototransistors in a series-shunt chopper circuit. As Q_1 is switched ON, Q_2 is OFF, and when Q_1 is switched OFF, Q_2 is driven ON.

Logic circuitry featuring the high input/output electrical isolation of photo transistors is shown in Figure 25.

Figure 26 shows a linear application of the phototransistor. As mentioned previously, the linearity is obtained for small-signal swings.

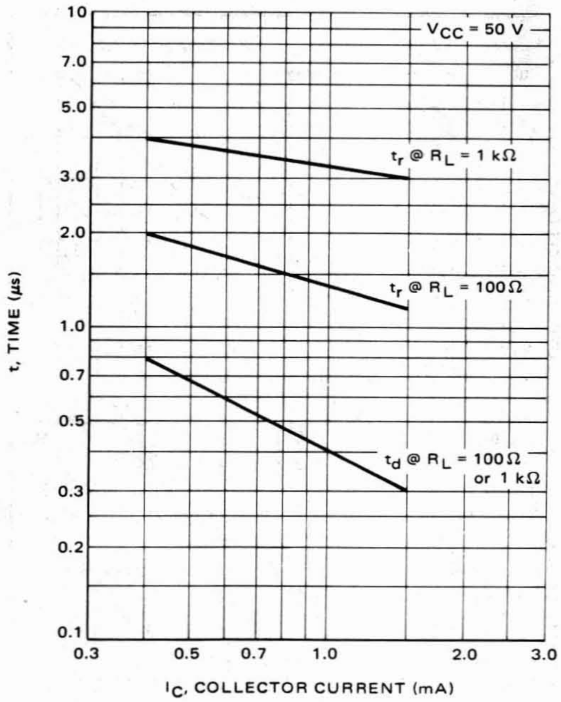


FIGURE 21 – Switching Delay and Rise Times for MRD300

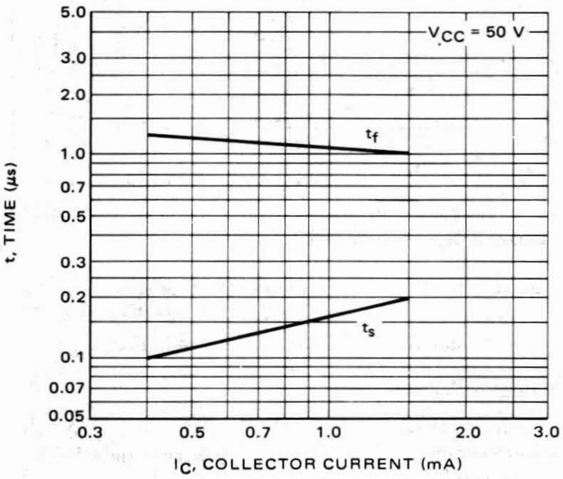


FIGURE 22 – Switching Storage and Fall Times for MRD300

A double-pole, single-throw relay is shown in Figure 27.

In general, the phototransistor can be used in counting circuitry, level indications, alarm circuits, tachometers, and various process controls.

Conclusion

The phototransistor is a light-sensitive active device of moderately high sensitivity and relatively high speed. Its response is both a function of light intensity and wavelength, and behaves basically like a standard bipolar transistor with an externally controlled collector-base leakage current.

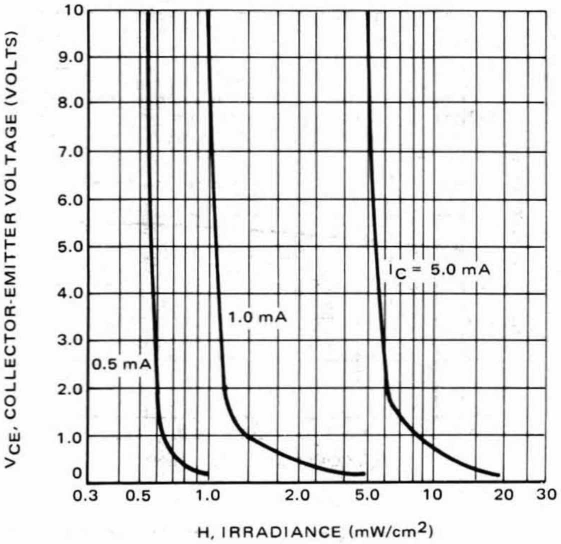


FIGURE 23 – Collector Emitter Saturation Voltage as a Function of Irradiance for MRD300

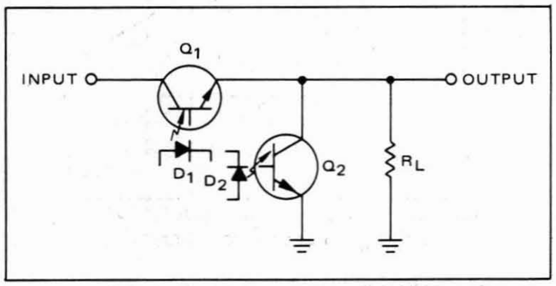


FIGURE 24 – Series-Shunt Chopper Circuit Using MRD300 Phototransistors and GaAs Light Emitting Diodes (LEDs)

APPENDIX I

Radiant energy covers a broad band of the electromagnetic spectrum. A relatively small segment of the band is the spectrum of visible light. A portion of the electromagnetic spectrum including the range of visible light is shown in Figure I-1.

The portion of radiant flux, or radiant energy emitted per unit time, which is visible is referred to as luminous flux. This distinction is due to the inability of the eye to respond equally to like power levels of different visible wavelengths. For example, if two light sources, one green and one blue are both emitting like wattage, the eye will perceive the green light as being much brighter than the blue. Consequently, when speaking of visible light of varying color, the watt becomes a poor measure of brightness. A more meaningful unit is the lumen. In order to obtain a clear understanding of the lumen, two other definitions are required.

The first of these is the standard source (Fig. I-2). The standard source, adopted by international agreement, con-

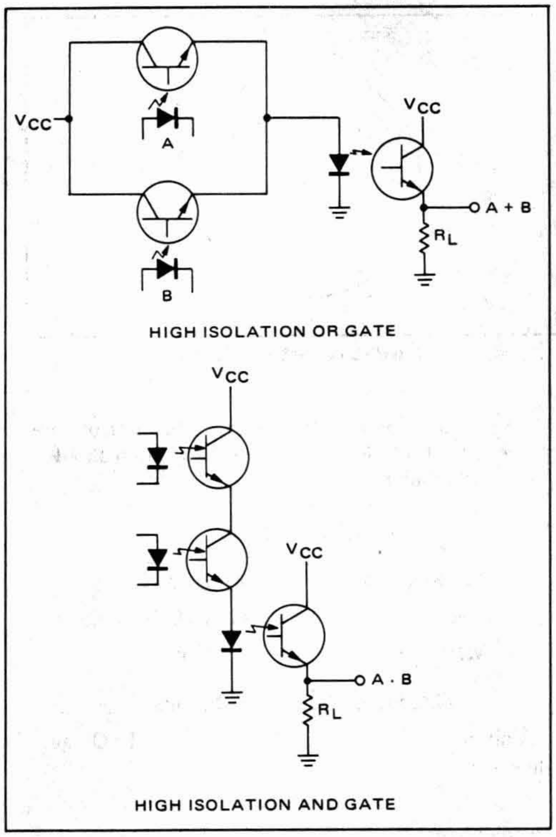

VCC
A
VCC
A + B
RL
B
HIGH ISOLATION OR GATE
VCC
VCC
A · B
RL
HIGH ISOLATION AND GATE

FIGURE 25 – Logic Circuits Using the MRD300 and LEDs

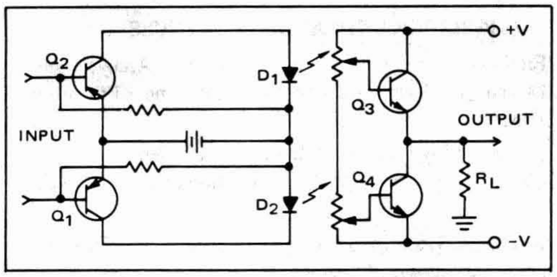

+V
Q2
D1
Q3
INPUT
OUTPUT
Q4
RL
D2
Q1
-V

FIGURE 26 – Small Signal Linear Amplifier Using MRD300 and LEDs

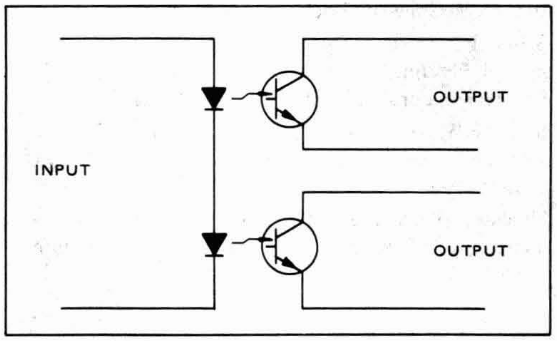

OUTPUT
INPUT
OUTPUT

FIGURE 27 – DPST Relay Using MRD300s and LEDs

sists of a segment of fused thoria immersed in a chamber of platinum. When the platinum is at its melting point, the light emitted from the chamber approximates the radiation of a black body. The luminous flux emitted by the source is dependent on the aperture and cone of radiation. The cone of radiation is measured in terms of the solid angle.

The concept of a solid angle comes from spherical geometry. If a point is enclosed by a spherical surface and a set of radial lines define an area on the surface, the radial lines also subtend a solid angle. This angle, ω, is shown in Figure I-3, and is defined as

$$\omega = \frac{A}{r^2}, \qquad \text{(I-1)}$$

where A is the described area and r is the spherical radius.

If the area A is equal to r^2, then the solid angle subtended is one unit solid angle or one steradian, which is nothing more than the three-dimensional equivalent of a radian.

With the standard source and unit solid angle established, the lumen can be defined.

A lumen is the luminous flux emitted from a standard source and included within one steradian.

Using the concept of the lumen, it is now possible to define other terms of illumination.

Illuminance

If a differential amount of luminous flux, dF, is impinging on a differential area, dA, the illuminance, E, is given by

$$E = \frac{dF}{dA}. \qquad \text{(I-2)}$$

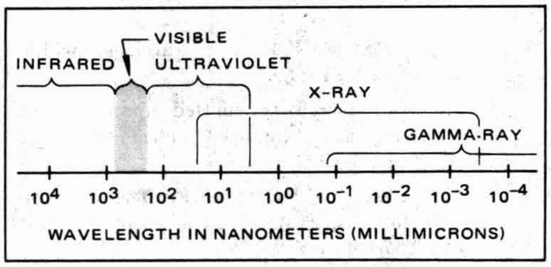

VISIBLE
INFRARED
ULTRAVIOLET
X-RAY
GAMMA-RAY
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4
WAVELENGTH IN NANOMETERS (MILLIMICRONS)

FIGURE I–1 – Portion of Electromagnetic Spectrum

Illuminance is most often expressed in lumens per square foot, or foot-candles. If the illuminance is constant over the area, (I-2) becomes

$$E = F/A. \qquad \text{(I-3)}$$

Luminous Intensity

When the differential flux, dF, is emitted through a differential solid angle, $d\omega$, the luminous intensity, I, is given by

$$I = \frac{dF}{d\omega}. \qquad \text{(I-4)}$$

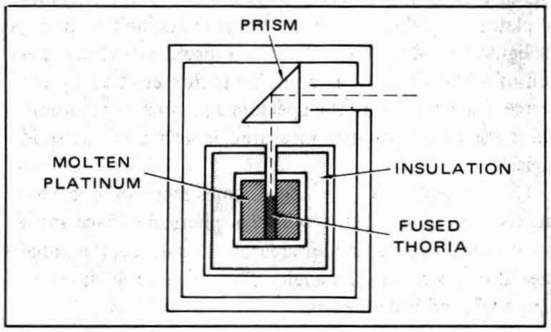


FIGURE I–2 – International Standard Source

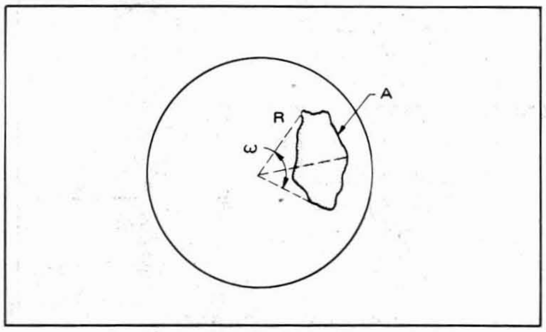


FIGURE I–3 – Solid Angle, ω

Luminous intensity is most often expressed in lumens per steradian or candela. If the luminous intensity is constant with respect to the angle of emission, (I-4) becomes:

$$I = \frac{F}{\omega}. \qquad \text{(I-5)}$$

If the wavelength of visible radiation is varied, but the illumination is held constant, the radiative power in watts will be found to vary. This again illustrates the poor quality of the watt as a measure of illumination. A relation between illumination and radiative power must then be specified at a particular frequency. The point of specification has been taken to be at a wavelength of 0.555 μm, which is the peak of spectral response of the human eye. At this wavelength, 1 watt of radiative power is equivalent to 680 lumens.

APPENDIX II
OPTOELECTRONIC DEFINITIONS

F, Luminous Flux: Radiant flux of wavelength within the band of visible light.

Lumen: The luminous flux emitted from a standard source and included within one steradian (solid angle equivalent of a radian).

H, Radiation Flux Density (Irradiance): The total incident radiation energy measured in power per unit area (e.g., mW/cm^2).

E, Luminous Flux Density (Illuminance): Radiation flux density of wavelength within the band of visible light. Measured in lumens/ft^2 or foot candles. At the wavelength of peak response of the human eye. 0.555 μm (0.555 X 10^{-6}m), 1 watt of radiative power is equivalent to 680 lumens.

S_R, Radiation Sensitivity: The ratio of photo-induced current to incident radiant energy, the latter measured at the plane of the lens of the photo device.

S_I, Illumination Sensitivity: The ratio of photo-induced current to incident luminous energy, the latter measured at the plane of the lens of the photo device.

Spectral Response: Sensitivity as a function of wavelength of incident energy. Usually normalized to peak sensitivity.

Constants

Planck's constant: $h = 4.13 \times 10^{-15}$ eV-s.
electron charge: $q = 1.60 \times 10^{-19}$ coulomb.
velocity of light: $c = 3 \times 10^{8}$ m/s.

Illumination Conversion Factors

Multiply	By	To Obtain
lumens/ft^2	1	ft. candles
lumens/ft^2*	1.58 X 10^{-3}	mW/cm^2
candlepower	4π	lumens

*At 0.555 μm.

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